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Arkansas Animal Science Department Report 2000

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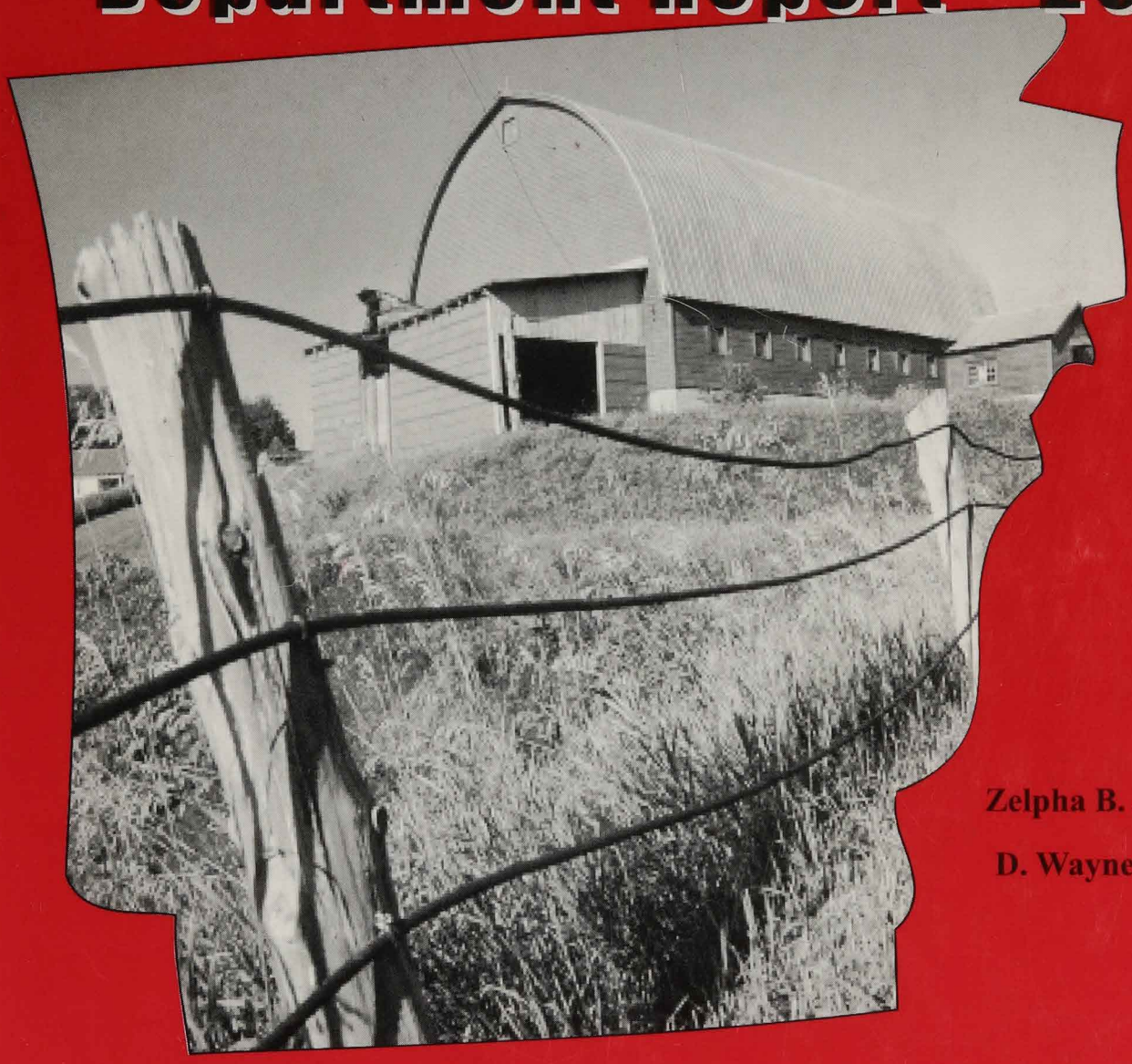
Arkansas

Animal Science

Department Report • 2000



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Editors

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ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT 2000

Edited by

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INTRODUCTION

The faculty and staff of the Animal Science Program are pleased to present the third edition of Arkansas Animal Science. We hope you will find the reports of the research, teaching, and extension programs useful.

The Dorothy E. King Equine Pavilion was dedicated on May 9, 2000. This facility, which features a lighted outdoor arena and pastures, was funded through a $440,000 grant from the Carl B. and Dorothy E. King Foundation of Dallas, Texas. This signaled the long-awaited beginning of an equine program at the University of Arkansas. We were pleased that Dr. Nancy Jack (BS, Tarleton State, MS and Ph.D., New Mexico State) joined the faculty to direct the new King Equine Program. The announcement of the $239,000 endowment to fund the Florence E. King Scholarships in Equine Studies capped a very good first year for the equine program. The new complex is located adjacent to the Pauline Whitaker Animal Science Center. A new white fence frames the entire set of facilities and extends the length of the property along Garland Avenue.

Other good news for the program included the announcement by Governor Mike Huckabee that $600,000 had been released for construction of a new swine research and teaching center. We are also pleased to announce the anticipated construction of an off-site grower-finishing barn donated by industry. These new facilities add substantial research and teaching capacity to the department's swine program.

Finally, the Animal Science Building has undergone a thorough renovation. The addition of an atrium provides a formal entrance and a very nice setting for functions in the building. The Department of Animal Science is grateful for the outstanding support it has received from higher administration in the College and Division of Agriculture, from the state government, and from private sources.

While facilities are an absolute requirement for a productive program, it is in the end what the faculty does with them that determines the quality of the program. We are proud of the work recorded in this 2000 report. We are also proud of the students in the department. Particularly, we are proud that the department had the outstanding senior for the Bumpers College at the spring 2000 graduation and that three of the nine Magna cum Laude graduates were from Animal Science.

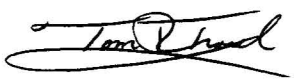
Animal Science is very much devoted to youth education and development. During the past year, over 20,000 youth were involved in 4-H livestock projects. Two very successful activities that took place last year were the Mid-American Grassland Evaluation Contest and Livestock Judging Camps. The Grassland Contest is designed to teach students about grassland resource management for livestock and wildlife uses. The contest was held in Cape Girardeau, Missouri. First-place honors in the 4-H division went to White County, and second place honors went to Van Buren County. Two Livestock Judging Camps (Fayetteville and Hope) were conducted this past year. A total of 120 youth participated to learn the fundamentals of livestock judging, oral communications through reason, and industry standards for selection of beef, sheep and swine.

Extension programs in Animal Science continue to grow and receive national attention. Arkansas Grazing Schools, the Arkansas Beef Improvement Program, beef quality assurance, dairy management programs, equine training and management, forage demonstrations, and the Arkansas Feedout Program are just a few such programs. Reports of these programs can be found within this publication.

With a totally combined Animal Science Program (teaching, research, and extension), the University of Arkansas is working to meet the needs of the livestock industry.

Sincerely,

Keith Lusby
Department Head
Fayetteville



Tom Troxel
Section Leader
Little Rock

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

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/feet
g = gram(s)
gal = gallon(s)
h = hour(s)
in = inch(es)
IU = international units
kcal = kilocalorie(s)
kg = kilogram(s)
L = liters(s)
lb = pound(s)
LH = lutenizing hormone
m = meters
mg = milligram(s)
mcg = microgram(s)
mEq = millequivalent(s)
min = minutes(s)
mm = millimeter(s)
mo = month(s)
N = nitrogen
ng = nanogram(s)
NS = not significant
ppb = parts per billion
ppm = parts per million
r = correlation coefficient
r^2 = simple coefficient of determination
R^2 = multiple coefficient of determination
RNA = ribonucleic acid
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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Building on Quality Undergraduate Programs in Animal Science

C. Rosenkrans, Jr.[1]

Story in Brief

Growth of an academic department is essential if that entity plans to graduate students who will shape an industry and positively impact society. Departmental growth can be assessed by the number of students majoring in the degree program, the number of students enrolled in courses offered by the department, and finally, by the breadth of programs offered by the department. Our department is in the midst of growth in all three of these areas.

Mission

As outlined in our strategic plan, the teaching mission of our department is to *provide an outstanding teaching program ensuring that students can obtain the best possible training to prepare them for productive careers in the Animal Sciences and related fields*. This mission comes out of our overall mission to be a demand-driven program focused on the needs of the state of Arkansas. Therefore, our quest is to envision programs and prepare students for the future needs of animal scientists.

Number of Animal Science Majors

What is the desired number of animal science students? That question is hard to answer, but one hopes to graduate as many students as there are job openings. However, quality and breadth of education affects the number of jobs that are available for graduates. Currently, the Department of Animal Science has approximately 110 students, which is about 16% of the agricultural students in Bumpers College. Based on projected increased student enrollment at the University of Arkansas and Bumpers College, we had anticipated having 200 undergraduate students by 2005. That number was based on a number of factors, but primarily on recruitment efforts and increased retention and graduation rates. The University of Arkansas is implementing more rigorous entrance requirements that initially restrict the pool of prospective students. This, coupled with a restricted number of out-of-state tuition waivers, may make our projected numbers somewhat optimistic in the short run. However, increasing entrance standards has led to an increase in retention and graduation rates at other universities around the country. Placing nearly twice as many graduates in traditional animal science jobs could be problematic. Therefore, we are developing programs that broaden our base and create opportunities for our students.

Undergraduate Programs

Last year we offered three new courses aimed at students interested in companion animals, primarily dogs, cats, and other pets. This year, we are proud to offer an expanded equine science program. New courses include Introduction to the Equine Industry and Selection, Merchandising Livestock and Horses, Principles of Equine Behavior and Training, and Topics in Equine Law. These courses supplement the traditional capstone course in Horse Production. As we have developed these new courses, there has been considerable discussion, both within the department and within the animal science community at large, as to where animal science curricula and programs are going. Does the inclusion of a greater number of species under the animal science umbrella mean that we are trying to move away from our traditional base? No! What it does mean is that the animal science faculty are the most qualified to teach our disciplines to any student interested in animals. As we look to the future, it appears that the number of people employed in the traditional livestock positions are limited to about the current number of graduates; however, those students interested in companion animals and the biomedical and allied industries have many opportunities.

Maintaining Quality

As we transition into the future, how do we maintain quality in our graduates? Our department has established a career fair and training opportunities for our students. We are advising students to be active in leadership programs and to take the opportunity to do an internship or two. In addition, all prospective graduates are required to take a species examination with the American Registry of Professional Animal Scientists. Those tests satisfy the requirement of the state legislature that all Arkansas colleges provide evidence, beyond granting a degree, that students have gained critical skills. To their credit, our graduating seniors who have taken the ARPAS tests have all passed their examinations. We believe that broadening our teaching program expands the opportunities for all of our animal science majors, giving us the opportunity to impact our industries and society as a whole.

[1] Department of Animal Science, Fayetteville.

Arkansas Steer Feedout Program, 1998-1999

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 postweaning 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 (67% vs. 31%). Hot carcass weight, quality grade, days on feed, feed cost per pound of gain, yield grade, medicine cost, and fat thickness 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 Steer Feedout Program allows producers to learn more about the characteristics of their calf crop and the factors that influence value beyond the weaned-calf phase. It 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 whether changes in genetics or management factors are warranted.

Experimental Procedures

On November 5, 1998, 210 steers from 26 Arkansas producers representing 15 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). Steers were sorted into two feeding groups on the basis of weight, frame, and condition. Management factors such as processing, medical treatments, and diets were the same as those for 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. Steers were slaughtered in two groups (April 22 and May 26, 1999). 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. Breed type of each steer enrolled in the program was used to group calves according to whether they fit the following criteria: ≥ 50 % English, ≤ 50% Continental, and ≤ 25% Brahman. 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.

Steers were also grouped according to whether 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 using SAS were computed and reported.

Factors affecting return over specified cost for all steers, the top 25% (based on return over specified costs) steers, and the bottom 25% steers were determined using the Stepwise method of PROC REG. Independent variables included in weight, percentage Brahman, percentage English, percentage Continental breeding, ADG, yield grade, quality grade, feed cost per pound of gain, hot carcass weight, days on feed, medicine cost, ribeye area, ribeye area/hot carcass cwt., and dressing percentage.

Results and Discussion

The financial report is summarized in Table 1. Average gross income per head was $746.18 with a range from $347 to $961. Expenses in Table 1 are those related to the feedlot phase of production. Return over specified cost reported in

[1] All authors are associated with the Animal Science Section, Cooperative Extension Service, Little Rock.

Table 1 does not include the value of the calves at the start of the feeding period. To determine the true profitability of feeding these calves and selling them on a quality-yield grade system, this value would have to be included.

The producers did an excellent job of weaning calves early and administering vaccines prior to shipment. Only 15 calves (7.1%) were treated for sickness. Average medicine cost per sick calf was $21.49. Medicine costs for the entire group averaged $1.43 per head. The health status of cattle in the feedyard usually has a major impact on performance and profit. Healthy steers had higher returns over specified costs ($470.34) than steers that became sick ($420.73; $P < 0.01$). In addition, healthy steers had a higher dressing percentage (63.9%) than those that became sick (61.6%; $P < 0.1$). No differences were detected between healthy steers and steers that became sick, for arrival weight, ADG, feed cost of gain, carcass value/cwt., ribeye area/cwt, carcass weight, ribeye area, and percent grading Choice ($P > 0.10$). This is probably due to the fact that so few steers became sick.

The average off-the-truck arrival weight was 636 lb (range = 380 to 920). The ADG, average days on feed, feed cost per pound of gain, and total cost per pound of gain were 2.93 lb (1.33 to 4.48), 181 d (166 to 200), $0.47 ($0.19 to $1.12), and $0.55 ($0.24 to $1.28), respectively.

The average carcass weight, ribeye area, dressing percentage, yield grade, and fat thickness were 743 lb (510 to 982), 12.4 in^2 (8.2 to 18.1), 63.8% (58.2% to 68.8%), 2.70 (0.94 to 4.88), and 0.37 in (0.12 to 1.00), respectively. Fifty-two percent of the carcasses graded Choice, whereas 37%, 10%, and 0.5% graded Select, Standard, and dark cutter, respectively. A few carcasses graded Prime (0.5%). Carcass value was $1.03 per cwt for Choice-Yield Grade 2 carcasses for both slaughter dates. The discount, however, for Select graded carcasses was greater for calves sold on May 26, 1999 ($8) than for calves sold on April 22, 1999 ($3).

The percentage English, Continental, and/or Brahman breeding were determined for each calf. 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 2). Calves that fit the breed-type criteria graded 67% Choice compared with the calves that did not fit the breed-type criteria graded 31% Choice. A review of the data suggests there is 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 seven significant factors that affected the return over specified costs in the 1998-99 Steer Feedout Program. Factors are listed from the most important to the least important.

Factors Affecting Returns Over Specified Cost

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

1. Hot Carcass Weight—The relationship between hot carcass weight and feedlot returns over specified costs 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 3 shows the relationship between hot carcass weight, total cost of gain, ADG, and feedlot returns over specified costs.

Hot carcass weight discounts were observed for carcasses weighing less than 550 lb and greater than 950 lb. Carcasses less than 550 lb were discounted an average of $25 per cwt and carcasses greater than 950 lb were discounted $18 per cwt.

2. Quality Grade—Cattle that graded Choice, Select, and Standard had returns over specified cost of $498, $431, $393, respectively. 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 EPDs 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.

3. Days on Feed—Cattle were sold on April 22 or May 26, 1999. There was a negative relationship between days on feed and returns over specified cost. This means that on the average, the steers that were sold in April had a higher feedlot return over specified costs than those sold in May ($503 vs. $471).

A factor that affected the relationship between days on feed and feedlot return over specified costs was the price difference between Choice and Select quality grades on the two slaughter days. There was a $3 per cwt discount between Choice and Select carcasses on April 22 and an $8 per cwt discount between Choice and Select carcasses on May 26.

4. Feed Cost of Gain—Feed cost of gain had a negative relationship to feedlot return over specified costs. As feed cost of gain decreased, return over specified costs increased. Based upon returns over specified costs, the average feed cost of gain for the steers in the bottom 25% was $0.54/lb compared to $0.45/lb for the steers in the top 25%. The average feed cost per gain for all the steers was $0.47.

5. Yield Grade—Yield grades 1 to 3 have a positive impact on feedlot returns over specified costs ($451, $462, and $499 for yield grades 1, 2, and 3, respectively), but a negative impact for yield grades greater than 4 ($377).

6. Medicine Cost—Healthy calves had higher dressing percentage (63.9% vs. 61.6%) and higher feedlot returns over specified costs ($470 vs. $420) than calves that were treated for illness.

7. Fat Thickness—Fat thickness is the number one factor that determines yield grade. Cattle that are short and have 0.8 in or more fat thickness at slaughter will be discounted as yield grade 4s. Therefore, calves less than 42 in tall (at the hip) at 7 mo of age are too small.

Table 4 summarizes the performance and carcass data from the steers that were in the bottom 25% and top 25%

(based on returns over specified costs) and the average of all the steers. The five main factors that predicted net returns of steers in the bottom 25% were feed cost of gain, quality grade, medicine cost, dressing percentage, and fat thickness. In summary, the calves in the bottom 25% had high feed and medicine cost and low dressing percent, and failed to grade Choice. The cattle that performed the best were medium to large framed and 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 ≤ 3.5, and hot carcass weight between 550 and 950 lb. This year, 50% of the Arkansas calves fit all those requirements. Steers that met the industry standards had higher ADG (3.0 vs. 2.8 lb) and averaged $77 more per head than those that did not fit the industry standards ($P < 0.01$). They had higher carcass values ($1.04 vs. $0.97) because they graded Choice, they 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.

Acknowledgment

The Arkansas Steer Feedout Program would like to thank the Arkansas Cattlemen's Association for sponsoring the Steer Feedout Tour.

Table 1. 1998-99 Arkansas steer feedout summary—financial results.

Item	Average	Range
Gross income	$746.18	$347 to $961
Expenses		
Feed	$240.06	$170 to $309
Medicine	1.25	0 to 47.11
Processing	11.46	11.42 to 11.49
Yardage	12.23	11.31 to 13.35
Fees	1.00	1.00
Interest	5.36	4.61 to 6.14
Freight	8.17	6.13 to 10.24
Total	$279.53	$207 to $349
Return over specified costs	$466.65	$32 to $669

Table 2. Performance and carcass data of Arkansas steers that did or did not fit the breed-type criteria.[1]

	Fit breed-type criteria	Did not fit breed-type criteria	Significance
Percent grading Choice	67%	31%	P < 0.01
Yield grade Ribeye area, in^2	2.0	1.7	P < 0.01
Ribeye area/100 lb carcass weight	11.9	13.2	P < 0.01
Average daily gain, lb	3.12	3.00	NS[2]
Dressing percentage	63.2%	64.2%	P < 0.01
Hot carcass weight, lb	750	775	NS
Carcass value	$1.02	$0.99	P = 0.02
Feed cost per pound of gain	$0.42	$0.48	P = 0.03
Return over specified costs	$493	$481	NS
Percentage that met industry standards	67%	27%	P < 0.01

[1] At least 50% English, no more than 50% Continental, and less than 25% Brahman.

[2] NS = not significant.

Table 3. Summary of hot carcass weight, total cost of gain, ADG, and feedlot returns over specified cost.

Hot carcass weight, lb	Total cost of gain/lb	ADG, lb	Feedlot returns over specified cost
<600	$0.70	2.1	$238
600-699	$0.59	2.5	$263
700-799	$0.54	3.0	$347
800-899	$0.52	3.3	$544

Table 4. Performance of the bottom 25%, average, and top 25% steers based on return over specified costs.

	Bottom 25%	Average	Top 25%
No. steers	52	206[1]	52
In weight, lb	591	636	691
Muscle score	1.2	1.2	1.1
Frame score			
Large	31%	56%	67%
Medium	69%	44%	33%
Final weight, lb	1065	1165	1290
ADG, lb	2.47[a]	2.93	3.30[b]
Gross income	$638	$746	$860
Carcass value/lb	$0.95[a]	$1.00	$1.03[b]
Hot carcass weight, lb	673	743	825
Dressing percentage	63.2%	63.8%	64.4%
Interest	$5.80	$5.36	$4.93
Medicine	$2.11[a]	$1.25	$0.86[b]
Total feed cost per head	$246	$240	$249
Total expense	$287	$280	$287
Return over specified costs	$351[a]	$467	$573[b]
Days on feed	192[a]	181	170[b]
Feed cost/lb of gain	$0.54[a]	$0.47	$0.45[b]
Total cost/lb of gain	$0.63[a]	$0.55	$0.53[b]
Ribeye area, in^2	11.6[a]	12.4	13.2[b]
Fat thickness, in	0.38	0.37	0.37
Quality grade			
Prime	0%	0.5%	2%
Choice	20%[a]	52%	75%[b]
Select	56%[a]	37%	23%[b]
Standard	21%	10%	0%
Dark Cutter	2%	0.5%	0%
Yield grade	1.9	2.7	2.7

Values within rows with unlike superscripts are significantly different ($P < 0.01$).

[1] Four calves were not used in this data set. One calf died, one was railed, and two were returned to their owners.

Current and Subsequent Season Effects of Parasite Control in Arkansas Stocker Calves

M. Fincher,[1] D. Hubbell,[2] C. Tucker,[1] T.A. Yazwinski,[1] L.B. Daniels,[1] and Z. Johnson[1]

Story in Brief

Four nematocidal regimens were evaluated for parasite control in stocker calves during mid- and late-season grazing on contaminated pasture. Six naturally infected, 6-mo-old calves were randomly allocated to each of 10 equivalent and adjoining 4-acre pastures. All animals on two randomly designated pastures received one of the five treatments: (1) control; (2) ivermectin (IVOMEC Merial Ltd) on day 0 as a subcutaneous injection at the rate of 0.2 mg/kg BW; (3) ivermectin (as described above) on days 0 and 56; (4) fenbendazole (SAFEGUARD Intervet) as a drench at the rate of 10 mg/kg BW on day 0 and 5 mg/kg BW on day 56; and (5) ivermectin sustained-release bolus (IVOMEC SR Bolus Merial Ltd). Body weights and fecal parasite egg counts were obtained at approximately 4-wk intervals until trial termination at day 133 (November 17, 1998), at which time all cattle were removed from the pastures. On March 1, 1999, and continuing until March 31, 1999, two parasite-free tracer calves were placed on each of the control and bolus treatment group pastures, and subsequently sacrificed for nematode quantifications after 30 d in confinement. For the performance portion of the study, fecal parasite egg counts were highest for the control groups, lowest for the bolus groups, and intermediate for the fenbendazole and injectable ivermectin groups. In general, weight gains were inversely proportional to egg counts, with ADG greatest for the bolus-treated cattle (1.23 lb/head/d), lowest for the controls (0.55 lb/head/d), and intermediate for the fenbendazole and injectable ivermectin groups (0.93 to 0.95 lb/head/d). Benefits of parasite control beyond the short-term effects of enhanced performance of treated cattle were illustrated by the tracer calf nematode counts. Average total burdens in tracer calves from control pastures were 3.8 times greater than those recovered from tracers removed from the bolus treatment group pastures.

Introduction

Stocker cattle production in Arkansas is an intensive process with high stocking rates, short duration, and great production demands occurring simultaneously with each group of calves. These types of operations are extremely susceptible to the detriment of a vast number of pathogens, with nematodiasis being of premier incidence and concern. The following study was designed to assess several nematocidal strategies that are common in our state and to measure the degree to which parasitisms acquired by future stocker calves are influenced by current parasite control measures.

Experimental Procedures

In May and early June of 1998, a group of stocker calves was assembled from local sale barns and producers. All animals were male castrates and approximately 6 mo of age at acquisition. On June 11, 1998 (trial day –26), the animals were fecal sampled for parasite egg counts per 0.5 g of feces. The animals were subsequently ranked in accordance with the above egg counts and bracketed into six groups of 10 animals per group. Within each bracket, the animals were randomly allocated for eventual placement onto one of the 10 study pastures. Pastures were then randomly assigned one of five treatment group designations (two pastures/treatment group). All pastures were adjoining and identical in size (4 acres), prior contamination (2 yr of grazing by naturally infected cattle) and herbage type (fescue).

Four different nematocidal regimes, plus a control, were investigated. The five treatment group designations were:

1. Control—no treatment.
2. Fenbendazole—Given as SAFEGUARD as an oral drench at the rate of 10 mg/kg BW on day 0 (anticipating arrested *Ostertagia*) and 5 mg/kg BW on day 56.
3. Ivermectin on day 0—Given as IVOMEC as a subcutaneous injection at the dosage rate of 0.2 mg/kg BW.
4. Ivermectin on day 0 and 56—Given each time as IVOMEC as a subcutaneous injection at the dosage rate of 0.2 mg/kg BW.

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5. Ivermectin Sustained-Release Bolus (ISRB)—Given on day 0 at the rate of one bolus per animal.

The actual trial was started on July 7, 1998 (trial day 0), with each animal being weighed, treated according to allocation, fecal sampled for parasite egg counts, and placed on its designated pasture. Subsequently, all animals were weighed and fecal sampled at approximately 28-d intervals until November 17, 1998 (trial day 133).

During the study, control animals, as a group, shed the most parasite eggs and ISRB-treated animals shed the least. Therefore, in order to determine the extent to which pasture infectivities at the start of the subsequent grazing season might be influenced by previous degree of parasite control, two parasite-free tracer calves were placed on each of the control and ISRB pastures the following spring for a 30-d grazing period (March 1 to March 31, 1999). After grazing, the tracers were placed on concrete for 21 d prior to necropsy for parasite recovery. No cattle grazed on the experimental pastures between the time of study-calf removal and the placement of tracer calves.

All parasite egg counts, coprocultures, and infective larva identifications were performed according to standard techniques (Thienport et al., 1979). Nematode counts in tracer calves were also conducted according to standardized procedures (Yazwinski et al., 1997). The data were analyzed for variance with general linear models (SAS Inst. Inc., Cary, NC). Prior to analysis, all egg and nematode counts were transformed to the log 10 $(x + 1)$.

Results and Discussion

Strongyle egg counts for the production phase of the study are presented in Table 1. Counts for the treatment groups were equivalent on day 0. For all remaining sample dates, ISRB-treated cattle were negative for parasite eggs (with the exception of one calf on trial day 105), with counts lower than control calf levels at every post-treatment date ($P \leq 0.05$). Egg counts for calves receiving repeated fenbendazole treatments were lower ($P < 0.05$) than control calf levels until the final sample date. Calves treated with ivermectin, either on day 0 only or on days 0 and 56, had egg counts significantly lower than control calf levels on every post-treatment sampling date with the exception of day 105.

Average daily gains are given in Table 2. Rates of gain for the first 56 d of the study were not significantly influenced by treatment. For the remainder of the grazing study (days 56 to 133) and for the total 133-d grazing period, control animal gains were significantly lower than gains made by any of the treated animal groups ($P < 0.05$).

Nematode counts obtained from the tracer calves placed on control and ISRB calf pastures are summarized in Table 3. Prior grazing by ISRB-treated calves lowered the availability of all infective nematodes combined ($P < 0.05$) with the greatest decrease seen with *Trichostrongylus axei* (99.5% reduction; $P \leq 0.01$).

These data clearly illustrate that pasture contamination and animal performance are directly influenced by parasite control measures. It is especially noteworthy that fall grazing by ISRB-treated calves significantly reduced challenge to subsequent, spring-placed tracers by 76.7% (8,946 vs. 2,324 total nematodes). Parasitisms encountered by calves during an entire grazing period are to a great degree the result of initial pasture challenge. As illustrated in this study, timely use of "complete" (ISRB) nematocidal control greatly depresses subsequent parasitisms.

For the most part, nematode egg counts and weight gains for calves reflected trends which were to be expected. An exception to this was seen with the calves that were given injectable ivermectin on days 0 and 56. Egg counts for both pasture groups were significantly ($P \leq 0.05$) lower on day 28 than on day 0, indicating treatment effectiveness at the onset of the study. Egg counts on day 84, however, were significantly decreased from day 56 levels for only one of the two pastured groups. The pasture group which did not have significant egg count reductions also displayed the lower ADGs for the treatment group.

Implications

A decrease in ivermectin effectiveness, similar to what is documented above, has been sporadically encountered by farmers in Arkansas for several years. Research is currently ongoing at the University of Arkansas to further define this infrequent condition as well as develop managerial means to maintain improvements in animal well-being that result from effective parasite control.

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Table 1. Arithmetic means of strongyle EP 1/2G counts by treatment group and trial day.

	Treatment group				
Trial day	Control	FBZ on days 0 and 56	IVM on day 0	IVM on days 0 and 56	ISRB
0	112.4	97.7	84.2	79.3	90.7
28	70.3[a]	0.1[b]	1.3[b]	4.1[b]	0.0[b]
56	246.3[a]	12.7[c]	37.4[b]	48.1[b]	0.0[d]
84	268.9[a]	0.2[d]	80.2[b]	19.8[c]	0.0[d]
105	139.5[a]	10.3[b]	46.7[a,b]	63.0[a,b]	0.3[c]
133	97.1[a]	80.3[a]	38.3[b]	29.3[b]	0.0[c]

Means on the same line with unlike superscripts are significantly different ($P \leq 0.05$), for data transformed to the log 10 [$x + 1$].

FBZ = fenbendazole; IVM = ivermectin; ISRB = ivermectin sustained-release bolus.

Table 2. ADGs (lb) by treatment group and study period.

	Days of study		
Treatment group	0–56	56–133	0–133
Control	0.62	0.44[c]	0.53[c]
FBZ on days 0 and 56	0.71	1.12[a,b]	0.95[a,b]
IVM on day 0	0.97	0.93[b]	0.93[a,b]
IVM on days 0 and 56	0.71	1.06[b]	0.93[b]
ISRB	0.88	1.48[a]	1.23[a]

Means in the same column with unlike superscripts are significantly different ($P \leq 0.05$).

FBZ = fenbendazole; IVM = ivermectin; ISRB = ivermectin sustained-release bolus.

Table 3. Nematode count arithmetic means for tracer calves placed on ISRB and control pastures (two tracer calves per pasture, two pastures per treatment).

	Tracer calves from:	
Nematode	Control pasture	ISRB pasture
Ostertagia spp. as:		
Adult	5,579	1,466
Developing fourth-stage larvae	188	132
Inhibited (early fourth-stage) larvae	1,071[a]	246[b]
Trichostrongylus axei	196[c]	1[d]
Nematodirus helvetianus	16	37
Cooperia spp.	1,896	442
All nematodes	8,946[a]	2,324[b]

Means on the same line are significantly different for data transformed to the log 10 [$x + 1$], at the 5% ([a,b]) and 1% ([c,d]) levels of probability.

ISRB = ivermectin sustained-release bolus.

Flunixin Meglumine as Adjunct Therapy for Bovine Respiratory Disease in Stocker Cattle

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Story in Brief

There is increasing pressure from consumers to reduce the amounts of antibiotics used in food animals, primarily because of concerns about the development of antibiotic-resistant bacteria. The objectives of this study were to examine the use of nonsteroidal anti-inflammatory drugs to enhance bovine respiratory disease therapy. Ninety-six stocker calves were purchased from several salebarns in Central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility at Savoy. The calves were blocked by weight (bulls were stratified through the treatment groups) and randomly assigned to one of 16 grass lots (1.1 acres) with six calves per lot. Calves with clinical signs of bovine respiratory disease (BRD) from group 1 were treated with flunixin meglumine (Benamine, Schering-Plough Animal Health Corp., Union, NJ) at 2.2 mg/kg BW intravenously (IV) and tilmicosin phosphate (Micotil, Elanco Animal Health, Indianapolis, IN) at 10 mg/kg subcutaneously (SC). Calves with clinical signs of BRD from group 2 were treated with tilmicosin phosphate at 10 mg/kg SC. The percentage of treatment successes was higher in group 1 than in group 2 (88% vs. 61%, P = 0.06). The combined percentage of treatment failures and BRD relapses was less in group 1 than in group 2 (5% vs. 38%, P = 0.02). The total medication cost per head for group 1 was less than the cost for group 2 ($14.66 vs. $18.10, P = 0.10). The ADG (lb per head/d) over the 35-d backgrounding period was not different between groups (2.2 vs. 2.4, P = 0.51). The flunixin meglumine/tilmicosin phosphate therapy was more successful for treating BRD than using tilmicosin phosphate alone.

Introduction

Bovine respiratory disease (BRD) is a complex syndrome caused by several viruses complicated by secondary bacterial infections. The economic consequences of this syndrome are considerable, in terms of loss from death, decreased growth performance, increased medication costs, and labor. There is a wide variety of therapeutic options, most of which involve the use of antibiotics.

There is increasing pressure from consumers to reduce the use of antibiotics in food animals, primarily because of concerns about the development of antibiotic-resistant bacteria. In addition, the trade barriers with regards to antibiotics in food animals established by the European Union will have significant economic impact on U.S. producers. It will become important for industry and producers to seek therapies that will reduce the use of antibiotics in production animal medicine.

Nonsteroidal anti-inflammatory drugs (NSAIDs) have been widely used in veterinary medicine to reduce the effects of inflammatory mediators produced during bacterial infection (Higgins et al., 1986, Balmer et al., 1997, Bottoms et al., 1981, Selman et al., 1986, and Vernimb et al., 1977). Their mode of action involves the inhibition of cyclo-oxygenase, as well as prostaglandins and thromboxane B_2 (Anderson et al., 1990) These products of inflammation are presumed to be responsible for much of the lung damage seen with BRD (Mosier, 1997). Flunixin meglumine is a NSAID that has been approved for use in beef cattle. The purpose of this study was to examine flunixin meglumine as adjunct therapy for BRD in stressed stocker cattle.

Experimental Procedures

Ninety-six stocker calves (bulls and steers, 396 to 526 lb) were purchased from several salebarns in central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility at Savoy. Initial processing was done within 24 h of arrival. This included vaccination with a modified-live viral vaccine (Infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza – 3, bovine respiratory syncytial virus), a killed multivalent clostridial vaccine and

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a killed *Pasteurella* spp. vaccine. The cattle were treated for external and internal parasites with a pour-on endectocide. The calves were revaccinated with the same products 2 wk after arrival. In addition, bulls were castrated using a banding method, given a vaccination for tetanus and horns were tipped.

The calves were blocked by weight (bulls were stratified through treatment groups) and randomly assigned to one of 16 grass lots (1.1 acres), with six calves per lot. The calves were offered 2 lb per head/d 16% protein supplement. This was gradually increased to 4 lb per head/d for the remainder of the study (35 d). Grass hay was supplemented as necessary.

Calves with clinical signs of BRD (Table 1) were removed from their home lots and treated according to one of two treatment protocols. Group 1 calves were treated with flunixin meglumine at 2.2 mg/kg BW IV and tilmicosin phosphate at 10 mg/kg SC. Group 2 calves were treated with tilmicosin phosphate at 10 mg/kg SC. Calves were examined 48 h after treatment to assess treatment success. Treatment success was characterized by an abatement of clinical signs accompanied by reduction in body temperature ≤103°F. No improvement in clinical signs and no reduction in body temperature within 48 h post-treatment were considered to be a treatment failure. An animal that had been initially treated, successfully, was sent home, and began showing signs of BRD again was considered to have relapsed. Personnel evaluating animals for clinical signs of BRD were blinded to treatment group assignment.

The parameters recorded were proportion of treatment successes and treatment failures, proportion of BRD relapses, average medication costs, ADG (lb per head/d), and cost of gain per pound (includes cost of feed, medication, processing, and chute charges). The parametric data were analyzed using analysis of variance for medication costs, ADG, and cost of gain per pound. Analysis of nonparametric outcomes (treatment successes, treatment failures, and percent of BRD relapses) was done with the Goodness of Fit Test using the chi-squared distribution.

Results and Discussion

The number of calves noted with clinical signs of BRD was the same for each treatment group (Table 2). The number of treatment successes was greater for group 1 (antibiotic plus NSAID) than for group 2 (antibiotic alone) (88% vs. 61%, $P = 0.06$).

The combined number of treatment failures and BRD relapses was less for group 1 than for group 2 (5% vs. 38%, $P < 0.05$). Total medication cost per head for group 1 was less than for group 2 ($14.66 vs. $18.10, $P = 0.10$). Average daily gain over the 35-d feeding period was not different between groups (2.2 vs. 2.4 lb per head/d, $P = 0.51$). Cost of gain per pound was the same for both groups ($0.37). There was no reduction in cost of gain with the use of flunixin meglumine. This reflects the similar ADG between treatment groups.

Implications

Flunixin meglumine in conjunction with tilmicosin phosphate for the treatment of BRD resulted in a reduced percentage of treatment failures and BRD relapses. This represents an advantage in terms of reduced labor for treating these animals and reduced medication costs. In addition, antibiotic use would be reduced if the animals had fewer relapses. Although we did not see an advantage in ADG and cost of gain in this 35-d trial, one might expect a long-term advantage in growth performance from quicker recoveries from BRD.

Acknowledgments

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Table 1. Criteria for evaluation of bovine respiratory disease.

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

Table 2. Percentage of treatment success, failure, and relapse, medication cost, ADG and cost per pound of gain in calves treated for bovine respiratory disease (BRD).

	Treatment		
Item	Tilmicosin + flunixin meglumine	Tilmicosin alone	P value
Treatment success, %	88 (23/26)	61 (16/26)	0.06
Treatment failure and BRD relapses, %	11 (3/26)	38 (10/26)	< 0.05
Average medication cost per head, $	14.66	18.10	0.10
ADG, lb per head/d	2.2	2.4	0.51
Cost per pound of gain, $	0.37	0.37	NS

Serum Acute-Phase Inflammation Proteins as a Means of Assessing Effectiveness of Flunixin Meglumine Therapy for Bovine Respiratory Disease

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Story in Brief

Serum acute-phase protein levels in cattle treated for bovine respiratory disease (BRD) were used to assess the effectiveness of treatment with antibiotics and flunixin meglumine. Ninety-six stocker calves were purchased from several sale barns in Central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility in Savoy. Processing was done within 24 h of arrival, blood was collected, and serum harvested for baseline determination of α-glycoprotein (AGP) and haptoglobin (HPT). The calves were blocked by weight and sex, then randomly assigned to one of 16 1.1–acre lots with six calves per lot. Calves from group 1 with clinical signs of BRD were treated with flunixin meglumine at 2.2 mg/kg BW intravenously and tilmicosin phosphate at 10 mg/kg subcutaneously. Calves with clinical signs of BRD from group 2 were treated with tilmicosin phosphate at 10 mg/kg BW subcutaneously. Blood was collected each time an animal was treated for BRD, as well as 48 h after treatment. Serum AGP and HPT were determined using commercially available agar gel immunodiffusion (AGID) assay kits. There was large variation in the AGID results. Neither serum AGP nor HPT levels were correlated with response to BRD therapy as measured by reduction in body temperature and abatement of clinical signs.

Introduction

The economic consequences of bovine respiratory disease (BRD) in weaned calves and stocker cattle are considerable in terms of loss from death, decreased growth performance, increased medication costs, and labor. It is a complex disease involving both viruses and bacteria. The inflammation that accompanies BRD can result in permanent lung damage. The goals of therapeutic treatment for BRD are to reduce or resolve the lung damage. It is often difficult to determine whether this has actually been accomplished. Treatment success is often evaluated by the abatement of clinical signs and reduction in body temperature. In some cases, subclinical inflammation may persist, resulting in permanent lung damage.

Acute-phase proteins, such as α-glycoprotein (AGP) and haptoglobin (HPT), are elevated during acute or chronic periods of inflammation associated with infectious disease. The plasma concentration of these proteins can change up to 1,000-fold during disease episodes (Eckersall and Conner, 1988). Alsemgeest et al. (1994) reported on the value of measuring serum AGP and HPT in cattle to distinguish between acute, subacute and chronic inflammatory disease. They found that these values could be used to distinguish healthy animals from those with inflammation.

Flunixin meglumine (Banamine, Schering-Plough Animal Health Corp., Union, NJ) is a nonsteroidal anti-inflammatory drug (NSAID) that has been widely used as a therapeutic agent in horses (Bottoms et al., 1981). It has recently been approved for use in conjunction with antibiotics for the treatment of BRD. Its primary mode of action is to inhibit inflammatory mediators such as cyclo-oxygenase and prostaglandins (Anderson et al., 1990). The effect of flunixin meglumine on serum AGP and HPT has not been reported.

The purpose of this study was to determine the potential value of serum AGP and HPT levels to assess the therapeutic effectiveness of treating BRD with antibiotics and flunixin meglumine.

Experimental Procedures

Ninety-six stocker calves (steers and bulls, 396 to 26 lb BW) were purchased from several sale barns in central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility at Savoy. Initial processing was done within 24 h of arrival. This included vaccination with a modified-live viral vaccine (Infectious bovine rhinotracheitis virus, bovine viral diarrhea virus, parainfluenza – 3 virus, bovine respiratory syncytial virus), a killed multivalent clostridial vaccine and a killed *Pasteurella spp.* vaccine. The cattle were re-vaccinated 2 wk post-arrival with the same vaccines given initially. In addition,

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bulls were castrated using a banding method and given a vaccination for tetanus, and their horns were tipped.

The calves were blocked by weight (bulls were stratified through treatment groups) and randomly assigned to one of 16 grass lots (1.1 acres), with six calves per lot. The calves were offered 2 lb per head/d of a 16% protein supplement. This was gradually increased to 4 lb/head/d for the remainder of the 35-d study. Grass hay was supplemented as necessary.

Calves with clinical signs of BRD (Table 1) were removed from their home lots and treated according to one of two treatment protocols. Group 1 calves were treated with flunixin meglumine at 2.2 mg/kg BW intravenously and tilmicosin phosphate (Micotil, Elanco Animal Health, Indianapolis, IN) at 10 mg/kg BW subcutaneously (SC). Group 2 calves were treated with tilmicosin phosphate at 10 mg/kg BW SC. Calves were examined 48 h after treatment to assess treatment success. Blood was collected from the jugular vein each time an animal was treated for BRD, as well as 48 h after treatment. Serum was harvested to be used in commercially available agar gel immunodiffussion (AGID) tests for AGP and HPT (bovine serum haptoglobin and α_1–acid glycoprotein measurement kits, Cardiotech Services, Inc., Louisville, KY). Treatment success was characterized by an abatement of clinical signs accompanied by body temperature reduction to ≤ 103°F. Treatment failure was defined as no improvement in clinical signs and no body temperature reduction within 48 h post-treatment. Animals that had been initially treated successfully, were sent home, and began showing signs of BRD again were considered to have relapsed. Personnel evaluating animals for clinical signs of BRD and those running the serum AGID tests were blinded to treatment group assignment.

Results and Discussion

Neither serum AGP nor HPT levels were correlated with response to BRD therapy as measured by reduction in body temperature and abatement of clinical signs (Table 1). Serum HPT and AGP were variable within treatment groups, having both increased and decreased 48 h after treatment for BRD. Furthermore, serum AGP and HPT levels remained elevated in some of the animals that had recovered clinically. Patterns of serum AGP and HPT change were not correlated with clinical recovery or body temperature reduction. In addition, there were no differences between treatment groups with regard to changes in AGP and HPT 48 h after treatment (Table 2). Similar variability was reported by Young et al. (1996) with regard to using serum HPT levels as a diagnostic tool for clinical respiratory tract disease in feedlot cattle. In the present study, there was no predictable effect on AGP or HPT associated with flunixin meglumine or antibiotic treatment (Table 1). Forty-eight hours may not have been enough time for detectable changes in serum AGP and HPT levels after treatment for BRD. It is also possible that flunixin meglumine or antibiotic treatment does not have an effect on the two acute-phase proteins examined.

Implications

Current methods of evaluating treatment success for BRD, with the exception of rectal temperature, are mostly subjective. Experienced producers and feedlot personnel are forced to rely on subjective criteria for disease detection, since no reliable, objective predictors of BRD are available. Results of this study imply that variability of serum acute-phase proteins within a population may preclude their value as predictors of BRD or treatment response. Further investigations are required to determine whether optimum timing of sample collection would enhance usefulness of these tests under field conditions.

Acknowledgments

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Table 1. Criteria for evaluation of bovine respiratory disease.

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

Table 2. Serum α-glycoprotein (AGP) and haptoglobin (HPT) (mg/ml) at time of treatment for bovine respiratory disease and 48 h after treatment.

	Treatment		
Item	Tilmicosin + flunixin meglumine	Tilmicosin alone	P value
HPT at treatment	784	950	0.35
HPT 48 h post-treatment	638	743	0.48
Change in HPT from treatment to 48 h	–208	–147	0.74
AGP at treatment	853	868	0.95
AGP 48 h post-treatment	1055	1142	0.75
Change in AGP from treatment to 48 h	187	290	0.72

Growth Performance and Serum Prolactin Concentrations of Stocker Steers Implanted with Trenbolone Acetate While Grazing Endophyte-Infected Fescue in the Spring

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Story in Brief

A 64-d grazing study was conducted to evaluate the impact of implant treatment on growth performance, hair score, and serum prolactin level of steers grazing high- (HE) or low- (LE) endophyte-infected tall fescue pastures. Mixed-breed steers (n = 130; 542 ± 7.7 lb) were allocated randomly to one of three 10-acre HE or one of four 10-acre LE pastures beginning April 13. Within each replication, half of the steers were implanted with trenbolone acetate (40 mg) and estradiol (8 mg), and half were not implanted. No implant treatment by endophyte level interactions were detected ($P > 0.10$). Overall BW gains were greater ($P < 0.05$) in the implanted groups than in the nonimplanted groups, but serum prolactin concentrations and hair scores did not differ ($P > 0.10$) between groups on either day 36 or 64. Steers grazing HE pastures had lower ($P < 0.01$) total BW gain, inferior ($P < 0.05$) hair scores, and lower ($P < 0.01$) serum prolactin concentrations on day 64 than those grazing LE pastures. Across forage and implant treatments, overall animal BW gains were negatively correlated with hair scores measured on day 64 ($r = -0.28$; $P < 0.01$), and positively correlated with serum prolactin levels measured on days 36 and 64 ($r = 0.33$ and 0.43, respectively; $P < 0.01$). Therefore, fescue toxicity symptoms were manifested in HE steers, and implanting with trenbolone acetate and estradiol improved grazing BW gain, but implanting steers with trenbolone acetate and estradiol did not offset the toxic effects of grazing infected fescue.

Introduction

Reductions in animal BW gain due to the presence of infection of tall fescue with *Neotyphodium coenophialum* are well documented (Coffey et al., 1990; Hoveland et al., 1980; 1983; Fribourg et al., 1991; McMurphy et al., 1990). Many products or compounds have been tried in an attempt to reduce the impact of tall fescue toxicity, but most have been unsuccessful or impractical. However, in a fall-grazing study, steers implanted with zeranol (Ralgro, 36 mg) gained 36% faster than nonimplanted steers when grazing high-endophyte (HE) tall fescue, but they gained only 12% faster than nonimplanted steers when grazing low-endophyte (LE) tall fescue (Brazle and Coffey, 1991). Therefore, zeranol actually offset some of the toxic effects of infected fescue in grazing steers. Other estrogenic implants have not shown similar benefits when steers grazed HE fescue (Coffey et al., 1992; Davenport et al., 1993; Beconi et al., 1995). The benefits of implanting steers grazing HE fescue with a combination of an androgenic (trenbolone acetate) and an estrogenic (estradiol) implant have not been determined. The objective of this study was to compare the effects of an androgenic-estrogenic implant combination on growth performance of steers grazing LE- or HE-infected fescue in the spring.

Experimental Procedures

A total of 130 mixed-breed steers (542 ± 7.7 lb) were weighed without prior removal from pasture and water on April 13 and allocated randomly into one of seven groups that were then allocated randomly to either one of four LE-infected or one of three HE-infected fescue pastures. Pastures varied slightly in their acreage and were stocked at two steers per acre. Within each pasture group, half of the cattle were implanted with a combination of 40 mg trenbolone acetate and 8 mg estradiol (Revalor G; Hoescht-Roussel Agri-Vet., Co., Overland Park, KS) and half were not implanted. Calves had ad libitum access to a commercial mineral supplement and were fed no other supplemental feed.

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Calves were weighed on May 19 (day 36) and June 16 (day 64) without prior removal from pasture or water to determine an intermediate and final weight. Groups of calves were comingled prior to weighing and were weighed in random order. A hair score based on a five-point scale (Table 1) was assigned to the calves on day 36 and day 64. Blood samples were collected via jugular venipuncture on those days, and serum prolactin levels were determined.

Pastures were fertilized with 50 lb nitrogen/acre on February 19, and phosphorus and potassium fertilization was applied in the fall. Hand-plucked pasture samples were gathered from multiple random locations within each pasture for ergovaline analysis on day 36. These samples were immediately stored on ice in plastic bags, transported to an ultra-low freezer (–75°C), and then freeze-dried. Available forage was appraised visually at the beginning of the experiment and on days 36 and 64. Height of leaf canopy and a visual appraisal of forage density were used to estimate available forage on June 16.

Data were analyzed using SAS (SAS Inst., Inc., Cary, NC) procedures for a 2 x 2 factorial arrangement of a split-plot design experiment using initial weight as a covariate. The model included effects of endophyte level, replicate (endophyte level), implant, and the implant x endophyte level interaction. Animal was considered the experimental unit for the implant treatment, and group of animals was considered the experimental unit for endophyte level.

Results and Discussion

The implant treatment x endophyte level interaction was not significant ($P > 0.10$) for any of the measurements evaluated in this experiment. Overall gain by steers grazing LE-infected pastures averaged 34.5 lb (0.54 lb/d) greater ($P < 0.01$) than that by calves grazing HE-infected pastures (Table 2). The majority (64%) of this weight differential occurred between days 36 and 64. During the period from day 0 until day 36, steers grazing LE-infected pastures gained 0.35 lb/d more than those grazing HE-infected pastures, whereas from day 36 until day 64, steers grazing LE-infected pastures gained 0.79 lb/d more than those grazing HE-infected pastures. Others (Crawford et al, 1989; Chestnut et al., 1991; Thompson et al., 1993) have reported seasonal differences in response to the endophytic toxins.

Hair scores did not differ between steers grazing LE- and HE-infected pastures on day 36. However, by day 64, calves grazing LE pastures had lower ($P < 0.05$) hair scores than those grazing HE pastures. Although hair-score data were not analyzed across dates, the apparent difference in scores came from a decrease in those from calves grazing LE pastures. Those calves had almost one full hair score change during the 28-d period between May 19 and June 16, whereas calves grazing HE pastures did not demonstrate a change in hair score during that same period.

Implanted calves gained 0.2 lb/d more ($P < 0.05$) during the 64-d study than nonimplanted calves. Much of this gain differential was accounted for during the first 36-d period; implanted calves gained 0.25 lb/d more ($P < 0.01$) than nonimplanted calves during this period, but gained only 0.13 lb/d more ($P = 0.29$) than nonimplanted calves during the last 28 d. Hair scores did not differ ($P > 0.10$) between implant treatments.

Implant treatment had no effect on serum prolactin concentration. Calves grazing HE-infected pastures had lower serum prolactin levels than those grazing LE-infected pastures.

Implications

Many products have been tried in an attempt to offset the effects of consuming tall fescue toxins; most have met with limited success. Other implants have shown promise in directly reducing some of these toxic effects in the fall, but the combination of trenbolone acetate and estradiol apparently does not offset these toxic effects in the spring. However, in order to improve performance by calves consuming infected fescue, a combination of growth-promoting products will probably have to be used, even though these products do not directly affect the toxic effects of tall fescue. Therefore, in a grazing program with stocker cattle, implanting calves with trenbolone acetate and estradiol could be used to improve weight gains.

Acknowledgments

Appreciation is expressed to Hoescht-Roussel Agri-Vet. Co. for donation of implants.

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Table 1. Hair score scale.

1	Smooth, short (<1/4 in) hair over entire body.
2	Rough hair over 25% of body.
3	Rough hair over 50% of body.
4	Rough hair over 75% of body.
5	Rough hair over entire body.

Table 2. Gain, hair score, and serum prolactin levels of steers grazing high- and low-endophyte tall fescue and implanted with a combination of trenbolone acetate and estradiol.

	Implant effects				Endophyte effects			
	I	NI	SE	P value	HE	LE	SE	P value
Weight day 36,lb	605	596	3.1	0.01	594	607	3.9	0.04
Weight day 64, lb	642	629	4.4	0.01	618	652	6.3	0.01
Gain day 0–36, lb	63	54	3.1	0.01	52	65	3.9	0.04
Gain day 37–64, lb	36	33	3.1	0.29	24	46	6.6	0.04
ADG day 0–36, lb	1.75	1.50	0.085	0.01	1.45	1.80	0.109	0.04
ADG day 37–64, lb	1.30	1.17	0.112	0.30	0.84	1.63	0.234	0.04
Total gain, lb	99	87	4.4	0.01	76	110	6.3	0.01
Daily gain, lb	1.55	1.35	0.068	0.01	1.18	1.72	0.098	0.01
Hair score day 36	3.6	3.4	0.16	0.25	3.3	3.7	0.26	0.24
Hair score day 64	3.2	3.0	0.15	0.36	3.4	2.8	0.16	0.02
Hair change	0.4	0.3	0.14	0.74	–0.1	0.9	0.16	0.01
Prolactin day 36, ng/ml	76	70	13.2	0.70	14	132	13.8	0.01
Prolactin day 64, ng/ml	205	208	36.2	0.95	9	404	37.0	0.01

Means presented are least-squares means.

See Table 1 for description of hair score.

HE = high-endophyte-infected pastures; I = implanted with trenbolone acetate (40 mg) and estradiol (8 mg); LE = low-endophyte-infected pastures; NI = not implanted.

Effect of Dietary Chromium-L-Methionine on Glucose Metabolism of Beef Calves

E.B. Kegley,[1] D.L. Galloway,[1] and T.M. Fakler[2]

Story in Brief

Thirty-six crossbred steers (635 ± 8.2 lb initial BW) were used to determine the effect of chromium (Cr), as chromium-L-methionine, on glucose tolerance and insulin sensitivity in beef calves. Calves were fed a control diet (55% corn, 38% cottonseed hulls, 5% soybean meal) or the control diet supplemented with 400 or 800 ppb Cr as chromium-L-methionine. On days 21, 22, and 23, four calves per dietary treatment were fitted with an indwelling jugular catheter. Approximately 24 h after catheterization, an intravenous glucose tolerance test (500 mg glucose/kg BW) followed 5 h later by an intravenous insulin challenge test (0.1 IU insulin/kg BW) was conducted. There was no effect ($P > 0.10$) of dietary treatment on ADG or feed intake. During the glucose tolerance test, serum insulin concentrations were increased by supplemental chromium-L-methionine (linear effect of Cr, $P < 0.05$). Supplemental chromium-L-methionine increased the glucose clearance rate from 0 to 10 min after the insulin challenge test (linear effect of Cr, $P < 0.05$). Glucose half-life from 0 to 15 min after the insulin infusion was also decreased by supplemental chromium-L-methionine (linear effect of Cr, $P < 0.03$). These data indicate that supplemental Cr as chromium-L-methionine increased the glucose clearance rate after an insulin infusion and increased the insulin response to an intravenous glucose challenge in growing calves.

Introduction

Chromium (Cr) was first shown to be an essential nutrient for normal glucose metabolism in 1959 in the rat. Chromium is a component of a glucose tolerance factor that potentiates the action of insulin. The bioavailability of Cr sources has been determined on the basis of their ability to alter glucose metabolism. Limited research has investigated the effect of supplemental Cr in cattle diets on glucose metabolism. Supplemental Cr, as chromium picolinate, increased glucose clearance rate and decreased glucose half-life and area under the curve in calves fed corn-cottonseed hull-based diets. In calves fed milk replacer, supplemental Cr, as a chromium-nicotinic acid complex, slowed the return to the basal glucose concentration after an insulin infusion (NRC, 1997). The objective of this experiment was to assess the effect of 400 or 800 ppb supplemental Cr, as chromium-L-methionine, on glucose tolerance and insulin sensitivity of beef calves.

Materials and Methods

Thirty-six crossbred steers initially weighing 635 ± 8 lb were blocked by weight (two blocks) and randomly assigned to pens (three pens per block, six steers per pen). Pens within a block were randomly assigned to a treatment. Steers were kept in drylots and had ad libitum access to water. Twice daily, at 0730 and 1430, calves were moved to a feeding barn containing 36 locking feeding gates, where they were individually offered feed.

Three dietary treatments included either a control diet or the control diet supplemented with 400 or 800 ppb Cr as chromium-L-methionine (Zinpro Corp., Eden Prairie, MN). The diets were formulated to meet or exceed, NRC (1996) recommendations (Table 1). Calves were offered an amount of feed greater than most had consumed on the previous day.

Calves were fed their respective diets for 22, 23, or 24 d. On days 21, 22, and 23, four calves per dietary treatment were fitted with an indwelling jugular catheter. Calves were weighed before the morning feeding on day 21, 22, or 23. The next day, 2 h after being offered the morning feeding, steers were infused intravenously with 0.5 g glucose/kg BW (IVGTT). Five hours later, steers were infused intravenously with 0.1 IU insulin/kg BW (IVICT). Blood samples were obtained immediately before (−10 and 0) and 5, 10, 15, 30, 45, 60, 90, 120, and 150 min after each infusion.

The plasma glucose and serum insulin concentrations after each infusion were analyzed using the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). A spatial structure was used as the covariance structure. The model

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included dietary treatment, block, time, and the time by dietary treatment interaction. The glucose and insulin kinetic data and the growth performance data were analyzed using the GLM procedure of SAS. The model included block and dietary treatment. Individual animal was used as the experimental unit. Least-squares means were reported.

Results and Discussion

There was no effect ($P > 0.10$) of Cr supple-mentation on ADG, DM intake, or feed-to-gain ratio during the 21- to 23-d feeding period (Table 2). Supplemental Cr has increased ADG of calves in some studies; however, in other experiments, it has not affected ADG (NRC, 1997). These variable results may reflect differences in Cr status of the calves, the amount of stress to which the calves had been exposed, the amount and bioavailablity of Cr in the basal diet, or the bioavailablity of the supplemental Cr source.

Intravenous Glucose Tolerance Test. There was a significant time by dietary treatment interaction ($P < 0.05$) on plasma glucose concentrations after the glucose infusion (Figure 1). Plasma glucose concentrations of calves fed 800 ppb supplemental Cr were greater than controls immediately after the glucose infusion, but by 30 min after infusion, those calves had plasma glucose concentrations that were lower than calves fed the control diet. Glucose clearance rates and glucose half-lives after the intravenous glucose tolerance test (Table 2) were not affected ($P > 0.10$) by dietary treatment.

There was a linear effect ($P < 0.05$) of supplemental chromium-L-methionine on serum insulin concentrations after the glucose infusion (Figure 2). Calves fed increasing concentrations of chromium-L-methionine had greater insulin responses than control calves after the glucose infusion. Area under the insulin curve between 0 and 60 min after IVGTT was greater ($P < 0.05$; linear effect of Cr supplementation) for calves supplemented with chromium-L-methionine (Table 2).

Intravenous Insulin Challenge Test. There was a linear effect of supplemental dietary chromium-L-methionine on glucose clearance rates (Table 2) when measured between 0 to 10 min ($P < 0.05$), 5 to 10 min ($P < 0.02$), and 0 to 15 min ($P < 0.07$) after infusion. Steers fed 800 ppb Cr had the greatest glucose clearance rates, whereas steers fed 400 ppb Cr had intermediate rates of glucose clearance. Glucose half-lives were decreased in a linear manner by supplemental Cr from 0 to 10 min ($P < 0.03$), 5 to 10 min ($P < 0.08$), 0 to 15 min ($P < 0.04$), and 0 to 30 min ($P < 0.06$) after infusion.

There was not a time x treatment interaction ($P > 0.10$) on plasma glucose concentrations after the IVICT. There was, however, a linear effect of supplemental chromium-L-methionine ($P < 0.05$) on plasma glucose concentrations after the insulin challenge test (Figure 3). Calves fed increasing concentrations of chromium-L-methionine had reduced concentrations of plasma glucose after the insulin infusion.

There was a time x dietary treatment interaction ($P < 0.01$) on serum insulin concentrations after the insulin infusion (Figure 4). There were also overall linear ($P < 0.04$) and quadratic ($P < 0.04$) effects of supplemental chromium-L-methionine on insulin concentrations after the insulin infusion. Steers fed 800 ppb Cr as chromium-L-methionine had the greatest serum insulin concentrations after the insulin infusion.

Implications

Currently, chromium is not approved for addition to cattle diets. Chromium-L-methionine was a bioavailable source of chromium, altering glucose and insulin metabolism in growing beef calves. More research must be done to determine the impact of this supplemental chromium source on immune function, body composition, and growth performance.

Acknowledgments

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The authors express their appreciation to Pete Hornsby, Gordon Carte, and John Silgar of the Stocker-Receiving Facility in Savoy for the management and care of the experimental animals. Gratitude is extended to J.W. Spears, North Carolina State University, for chromium analysis of the basal diet; to M.T. Socha, Zinpro Corp. for assistance with diet formulation; and to Zelpha Johnson, University of Arkansas, for her assistance with statistical analysis of the data.

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

Ingredient	%
Cottonseed hulls	38.3
Corn, cracked	54.8
Soybean meal	5.2
Limestone	0.92
Salt, white	0.17
Urea	0.81
Vitamin premix[b]	+
Trace mineral premix[c]	+

[a] Diet analyzed 88.9% DM, and 11.8% CP, 45.9% neutral detergent fiber, 31.1% acid detergent fiber, 3% ash, and 0.2 ppm chronium (DM basis).

[b] Vitamin premix supplied 1,136 IU of vitamin A, 227 IU of vitamin D, and 0.14 IU of vitamin E/lb of diet.

[c] Trace mineral premix supplied 5 ppm copper as copper sulfate, 20 ppm zinc as zinc sulfate, 0.1 ppm cobalt as cobalt carbonate, 0.5 ppm iodine as calcium iodate, and 0.1 ppm selenium as sodium selenite.

Table 2. Effects of dietary chromium-L-methionine on growth performance, and glucose and insulin kinetics.

	Supplemental chronium, ppb			
	0	400	800	SE
Growth performance				
Initial wt, lb	635	635	635	8.2
Final wt, lb	688	688	686	10.8
ADG, lb	2.38	2.38	2.31	0.324
DM intake, lb/d	14.02	14.22	13.85	0.300
After the intravenous glucose tolerance test				
Glucose clearance rate, %/min				
15 to 30 min	1.53	1.57	1.70	0.125
Area under the insulin curve, μIU of serum insulin/(mL • min)				
0 to 60 min[a]	3571	5205	6604	1000
After the intravenous insulin infusion				
Glucose clearance rate, %/min				
0 to 10 min[a]	1.31	1.64	1.66	0.120
5 to 10 min[a]	2.18	2.73	2.82	0.181
0 to 15 min[b]	1.64	1.99	1.96	0.120
Glucose half-life, min				
0 to 10 min[a]	64.4	43.8	45.1	5.95
5 to 10 min[b]	36.8	26.2	27.0	3.89
0 to 15 min[a]	50.0	35.5	36.9	4.22
0 to 30 min[b]	42.4	33.5	33.0	3.41

[a] Linear effect of Cr supplementation ($P < 0.05$).

[b] Linear effect of Cr supplementation ($P < 0.10$).

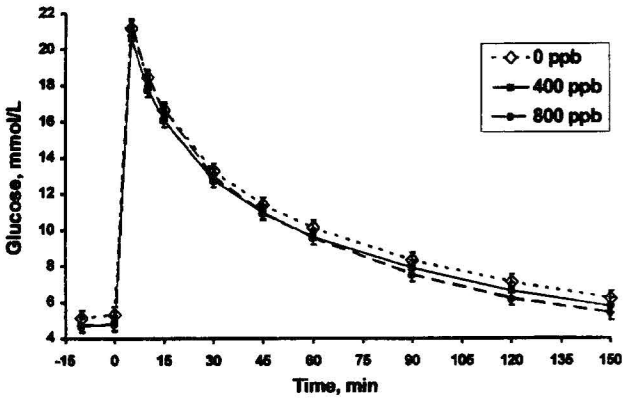

Figure 1. Effect of chromium-L-methionine on plasma glucose concentrations after an intravenous glucose tolerance test. Significant time x dietary treatment interaction ($P < 0.05$).

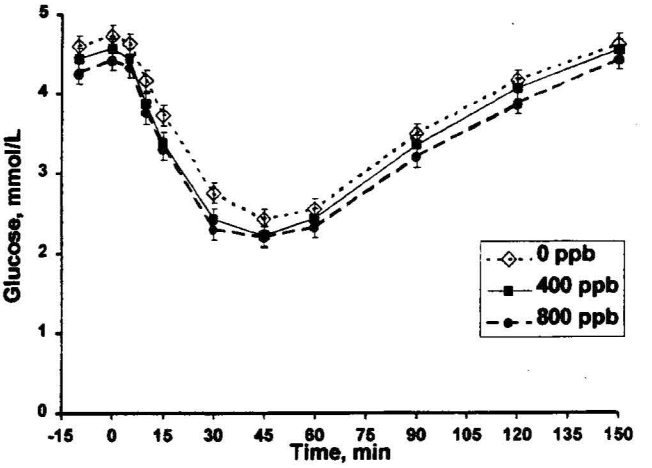

Figure 3. Effect of chromium-L-methionine on plasma glucose concentrations after an intravenous insulin infusion. Linear effect ($P < 0.05$) of supplemental chromium-L-methionine.

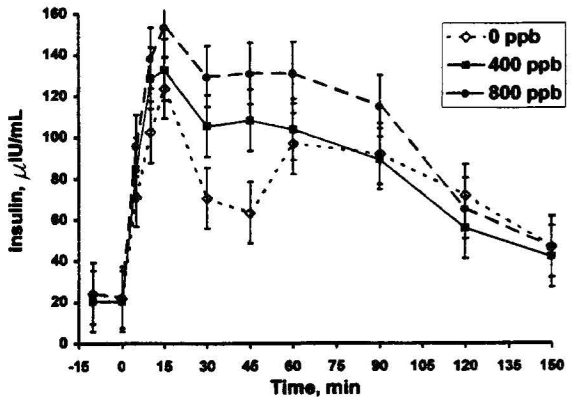

Figure 2. Effect of chromium-L-methionine on serum insulin concentrations after an intravenous glucose tolerance test. Linear effect ($P < 0.05$) of supplemental chromium-L-methionine.

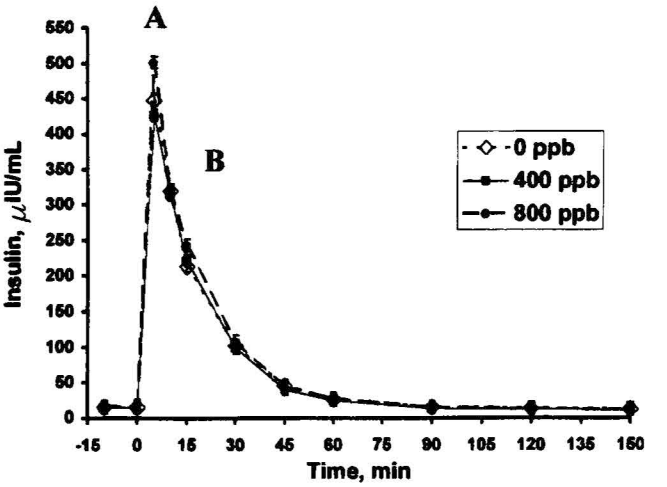

Figure 4. Effect of chromium-L-methionine on serum insulin concentrations after an intravenous infusion. Significant time x dietary treatment interaction ($P < 0.01$). A = 800 ppb greater ($P < 0.01$) than 0 and 400 ppb. B = 800 ppb greater ($P < 0.05$) than 0 ppb.

Interaction of Amprolium and Supplemental Dietary Thiamin on Thiamin Status and Growth Performance of Stressed Calves

S.A. Silzell, E.B. Kegley, K.P. Coffey, and L.B. Daniels[1]

Story in Brief

Ninety-six mixed-breed steers were used for a 35-d trial to determine the effects of amprolium (a coccidiostat) and supplemental thiamin (vitamin B_1) on thiamin status and growth performance of stressed calves. Treatments were 1) no supplemental thiamin and no amprolium, 2) amprolium, 3) supplemental thiamin (147 ppm), and 4) supplemental thiamin (147 ppm) plus amprolium. Amprolium was top-dressed at a rate of 2.3 mg/lb BW for the first 21 d of the study. Calves fed amprolium had increased ($P < 0.01$) ADG from day 0 to 7. Supplemental thiamin tended to increase ADG from day 0 to 21 ($P < 0.10$). Blood thiamin monophosphate concentrations (TMP; day x thiamin interaction) were increased ($P < 0.001$) by supplemental thiamin on every sampling date; however, the magnitude of increase was not as great on day 35 ($P = 0.08$). A day by amprolium interaction was detected on blood TMP ($P < 0.05$) and blood thiamin pyrophosphate (TPP; $P < 0.05$) concentrations. Blood TMP and TPP concentrations were decreased on days 14, 21, and 28 ($P < 0.05$) in the calves fed amprolium, but amprolium did not affect TMP and TPP concentrations on days 7 and 35. Thiamin supplementation had no effect on the number of coccidial oocysts in feces, but calves fed amprolium had reduced numbers of oocysts ($P < 0.05$). Supplemental thiamin and amprolium did not improve overall ADG, ADFI, or feed/gain for the 35-d trial.

Introduction

Loss of body condition, poor gains, and mortality are effects of acute coccidiosis in cattle. The cost of coccidiosis to the cattle producer was estimated to be $54.25 per animal (Fox, 1983). Amprolium is an effective anticoccidial that may be fed to cattle. Amprolium kills coccidia by preventing thiamin uptake and utilization by the protozoa (Coombs et al., 1997). High concentrations of amprolium have also been used to experimentally induce animals to become thiamin deficient (Rammel and Hill, 1986). Therefore, when administering amprolium at a therapeutic level, there is the possibility for alteration of thiamin status in stressed calves. The purpose of this study was to determine the effects of amprolium and supplemental thiamin on thiamin status, growth performance, and coccidial oocyst numbers in stressed calves.

Materials and Methods

Forty-five steers and 51 bulls (465 ± 3.3 lb initial BW) were purchased at sale barns and delivered to the Stocker 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 rhinotracheitis virus, bovine viral diarrhea, 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 and Vision CD-T, Bayer Corp.). All bulls were castrated by banding (Callicrate Bander, St. Francis, KS). Calves were weighed upon arrival, blocked by weight, stratified by castration and horn tipping, and assigned randomly to pens within a block (four pens/block). Calves were housed in 16 drylot pens with six calves/pen and were given ad libitum access to water. Calves were fed a complete ration (Table 1) once a day. Daily feed intake and any refusals were recorded. Calves were offered a small amount of long hay in addition to the complete ration for the first 5 d of the study. Treatments were 1) no supplemental thiamin and no amprolium, 2) amprolium, 3) supplemental thiamin, and 4) supplemental thiamin plus amprolium. Supplemental thiamin was provided as thiamin mononitrate (Nutra Blend Corp., Neosho, MO) at a rate of 147 ppm. The amprolium (Amprolium 1.25% Cattle Pellets, Nutra Blend Corp.) was top-dressed at a rate of 2.3 mg/lb initial BW for 21 d. Calves were observed daily for signs of morbidity. Any calves observed to be depressed were pulled and rectal temperature was measured. Calves with a rectal temperature greater than 104°F were treated with antibiotics according to a preplanned antibiotic regimen.

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Two consecutive weights were measured at the beginning and end of the study, and interim body weights were obtained on days 7, 14, 21, and 28. Fecal samples were obtained on days 1, 7, 14, 21, 28, and 35 for coccidia oocyst counts. Blood samples were obtained via jugular venipuncture on days 1, 7, 14, 21, 28, and 35 for blood thiamin monophosphate (TMP) and thiamin pyrophosphate (TPP) concentrations.

Weights, ADG, ADFI, feed/gain, initial concentrations of blood TMP and TPP, incidence of morbidity, medication costs, and number of antibiotic treatments were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Blood TMP and TPP concentrations were analyzed using the MIXED procedure of SAS with day 0 as a covariant. The model included block, thiamin, amprolium, the thiamin x amprolium interaction, day, the day x thiamin interaction, the day x amprolium interaction, the day x thiamin by amprolium interaction and initial concentration as a covariant. The natural log of the coccidia oocyst counts were analyzed using the MIXED procedure of SAS.

Results and Discussion

Average daily gain for the 35-d study (Table 2) was not affected ($P > 0.10$) by dietary supplementation of thiamin or amprolium. Gains during the period from day 0 to 14 were greater in thiamin supplemented calves ($P < 0.05$) compared with those fed no supplemental thiamin. Calves fed amprolium had increased ADG from day 0 to 7 ($P < 0.01$). There was no ($P > 0.10$) thiamin x amprolium interaction on ADG.

The ADFI (Table 2) for day 0 to 35 was not different ($P > 0.10$) among treatments. Average daily feed intake from day 0 to 28 had a tendency for a thiamin by amprolium interaction ($P = 0.10$). Amprolium decreased ($P < 0.05$) ADFI among calves fed no supplemental thiamin, but ADFI did not differ among other treatment combinations. The feed/gain from day 0 to 21 tended to improve as a result of thiamin supplementation ($P = 0.08$). There were no differences in the feed/gain over the entire 35-d study because of supplemental thiamin or amprolium.

Zinn et al. (1987) reported that feeding two levels of supplemental thiamin (20 or 200 mg thiamin/d) to stressed calves reduced morbidity the first 10 d of a 56-d study. In the present study, there were no differences ($P > 0.10$) due to supplemental thiamin or amprolium on morbidity rates, or medication costs (data not shown).

There was a day x thiamin interaction on TMP concentrations ($P < 0.001$; Figure 1). Thiamin monophosphate concentrations were increased by supplemental thiamin ($P < 0.001$) on days 7, 14, 21, and 28; however, the magnitude of increase was not as great on day 35 ($P = 0.08$). A thiamin x day interaction ($P < 0.01$) was detected on TPP concentrations, with an increase in TPP concentrations on days 7, 14, and 21 ($P < 0.001$) due to thiamin supplementation. A day x amprolium interaction was detected on TMP ($P < 0.05$) and TPP ($P < 0.05$) concentrations. Thiamin monophosphate and TPP concentrations were decreased on days 14, 21, and 28 ($P < 0.05$) in the calves fed amprolium, but were not different on day 7 and 35.

Coccidial oocyst counts (Table 2) decreased ($P < 0.05$) when amprolium was fed. There was also an effect of day on number of oocysts present ($P < 0.001$), with the greatest numbers observed on day 1 ($P < 0.001$). Numbers of oocysts and incidence of oocyst presence were greater on days 28 and 35 than on day 14 ($P < 0.05$). Cattle fed amprolium also had lower incidence of coccidial oocyst presence ($P < 0.05$). There was no thiamin x amprolium interaction detected on fecal oocyst numbers or the incidence of oocyst presence. Supplementation of thiamin did not interfere with the efficacy of the amprolium.

Implications

Amprolium reduced thiamin status compared to controls in stressed receiving cattle; however, there were no clinical incidences of thiamin deficiency (polioencepholomacia), and no detrimental effects on growth performance as a result of using amprolium for 21 d as a coccidiostat. Dietary thiamin supplementation did increase thiamin concentrations in blood and did not interfere with the efficacy of amprolium.

Acknowledgment

The authors acknowledge T.A. Yazwinski and C. Tucker for their expertise and assistance with the Coccidia data collection; K. Beers for HPLC analysis; Z. B. Johnson for assistance with statistical analysis; and J.A. Hornsby, G. Carte, and J. Silgar for the management and care of the experimental animals.

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Table 1. Ingredient and chemical composition of basal diets, DM basis.[a]

Ingredient	%
Corn, cracked	52.25
Cottonseed hulls	30.05
Fat	1.13
Soybean meal	11.23
Molasses, mixture of cane and beet	3.41
Dicalcium phosphate	0.44
Limestone	1.31
Salt, white	0.16
Vitamin A, D, E premix[b]	0.01
Trace mineral premix[c]	0.01

[a] Diets contained 0 or 147 ppm of thiamin as thiamin mononitrate. Diets analyzed to contain 87% DM, 12% CP, 24.4% acid detergent fiber, 39.5% neutral detergent fiber, and 4.65% ash.

[b] Vitamin A, D, E premix added to provide 2,000 IU vitamin A, 400 IU vitamin D, and 5.3 IU vitamin E/lb diet.

[c] Trace minerals added to provide 26 ppm zinc as zinc sulfate, and 0.1 ppm selenium as sodium selenite.

Table 2. Effect of amprolium and supplemental thiamin on growth performance, number of oocysts, and incidence of coccidial oocyst presence of stressed calves.

	Control		Thiamin[a]			
	No amprolium[b]	Amprolium	No amprolium	Amprolium	SE	Significance
ADG, lb						
Day 0 to 7	1.8	2.9	2.4	3.3	0.26	T†, A**
Day 0 to 14	1.2	1.4	1.9	2.2	0.32	T*
Day 0 to 21	2.0	1.8	2.4	2.4	0.27	T†
Day 0 to 28	2.8	2.4	2.9	2.7	0.21	
Day 0 to 35	2.3	2.3	2.6	2.6	0.24	
Day 21 to 35	2.9	3.0	3.0	2.8	0.38	
ADFI, lb						
Day 0 to 7	8.1	8.0	8.1	8.7	0.25	
Day 0 to 14	$9.4^{x,y}$	8.4^{y}	$9.0^{x,y}$	9.7^{x}	0.37	T x A†
Day 0 to 21	$10.6^{x,y}$	9.2^{y}	$10.4^{x,y}$	10.7^{x}	0.46	T x A†
Day 0 to 28	$11.9^{x,y}$	10.3^{z}	11.7^{y}	11.8^{y}	0.45	T x A†
Day 0 to 35	12.7	11.3	12.7	12.7	0.42	
Day 21 to 35	15.9	14.6	16.2	15.7	0.50	A†
Feed/gain						
Day 0 to 7	5.6	2.9	9.4	2.7	3.12	
Day 0 to 14	9.7	8.3	5.0	4.7	1.56	T*
Day 0 to 21	5.7	5.3	4.3	4.5	0.48	T†
Day 0 to 28	4.3	4.2	4.0	4.4	0.22	
Day 0 to 35	5.7	5.0	4.9	5.0	0.41	
Day 21 to 35	6.2	4.8	5.7	5.9	0.84	
Oocysts, No./g of feces (geometric mean)[c]						A*, D***
Day 0	52.9	46.5	53.6	53.3	0.31	
Day 7	4.3	0.3	1.6	0.6	0.31	
Day 14	0.6	0.4	0.7	0.01	0.31	
Day 21	1.3	0.2	1.3	1.2	0.31	
Day 28	1.7	0.1	4.2	1.5	0.31	
Day 35	0.5	0.8	4.4	2.2	0.31	
Incidence of oocyst presence, %						A*, D***
Day 0	96	92	92	96	7.4	
Day 7	49	25	33	29	7.4	
Day 14	25	21	29	4	7.4	
Day 21	29	17	33	25	7.4	
Day 28	42	12	46	38	7.4	
Day 35	25	33	42	38	7.4	

Means within the same row lacking common superscripts differ ($P < 0.05$).

A = effect of amprolium; T = effect of supplemental thiamin; T x A = thiamin by amprolium interaction; D = effect of day.

[a] Thiamin supplemented to provide 147 ppm thiamin.

[b] With or without amprolium (2.3 mg/lb initial BW) from day 1 to 21.

[c] Counts were log-transformed for statistical analysis and geometric means are shown.

† $P < 0.10$. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

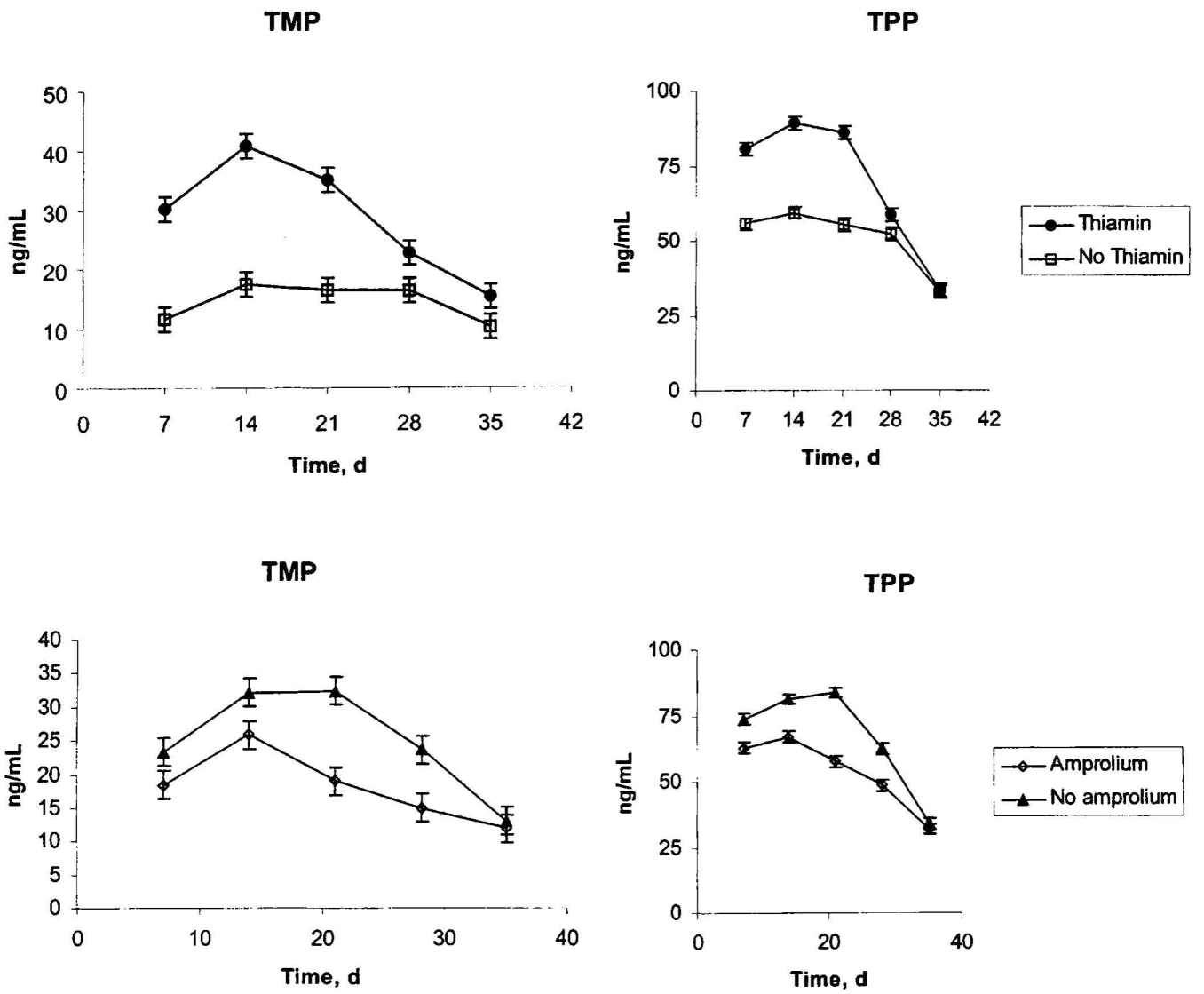

Figure 1. Main effects of supplemental thiamin and amprolium on blood thiamin monophosphate (TMP) and thiamin pyrophosphate (TPP) concentrations.

Prediction of Mature Weight and Maturing Rate From Body Measurements Taken on Angus and Charolais Calves at Birth

Z.B. Johnson, A.H. Brown, Jr., C.F. Rosenkrans, Jr., and J.A. Hornsby[1]

Story in Brief

The objective of this study was to use body measurements taken at birth to predict mature weight and maturing rate of mature cows. Body measurements for length of rear leg from hook to dewclaw (LL), circumference of forearm (FA), heart girth circumference (HG), body length from point of shoulder to pin bone (BL), width at loin (WL), width at hip (WH), and depth at chest (DC) were taken within 24 h of birth on 131 purebred Angus and 39 Charolais female calves in 1992, 1993, and 1994. Fifty-four Angus and 20 Charolais remained in the herd long enough to obtain estimates of mature weight (A) and maturing rate (k) using Brody's model. Stepwise regression procedures were used to determine which traits would be predictors of A and k. Stepwise regression including the seven body measurements gave the following equation for A: A = –507.32 + 126.20 (LL) + 91.70 (FA) + 6.25 (BL) + 171.41 (WL) – 121.27 (DC). The R^2 value was 0.46. For k the equation was 0.10018 – 0.00096 (BL) with an R^2 value of 0.29. Including early weights and gains in models for A did not give higher R^2 values. Including early gains in the model for k gave the equation: k = 0.08135 – 0.00091 (BL) + 0.01510 (ADG from 240 to 360 d) with an R^2 of 0.32. Results of this study indicate that body measurements taken at birth may be useful in predicting mature weight and maturing rate of cows. Higher R^2 values were obtained for A than for k; however, more traits were retained in the model.

Introduction

Growth curves generated from weight-age data have been used by many workers to describe growth and development of cattle. Two parameters of these curves have biological meaning: a size parameter, usually evaluated as weight at maturity (A), and growth rate relative to body size, commonly referred to as maturing rate (k). Fitzhugh and Taylor (1971) suggested that individual differences in rate of maturing are likely to be associated with differences in production efficiency. Also rate of maturing and mature weight have been found to be related to lifetime production characters of the cow.

The parameters A and k can be obtained only in retrospect from mature animals, after growth is completed. They need to be predictable early in the life of the animal to be useful in selection programs. It has been suggested by some researchers (Beltran et al., 1992) that the inclusion of some measurement of skeletal size could improve the accuracy of equations for estimating mature weight and maturing rate. The objective of this study was to examine the feasibility of using body measurements taken at birth to predict growth curve parameters of mature cows.

Materials and Methods

Animals used were female Angus and Charolais calves born in the respective University of Arkansas purebred herds in 1992, 1993, and 1994. Body measurements for length of rear leg from hook to dewclaw (LL), circumference of forearm (FA), heart girth circumference (HG), body length from point of shoulder to pin bone (BL), width at loin (WL), width at hip (WH), and depth at chest (DC) were taken within 24 h of birth on 131 purebred Angus and 39 Charolais female calves.

Fifty-four Angus and 20 Charolais remained in the herd long enough to obtain estimates of A and k using Brody's model which is as follows: $W_t = A - B\, e^{(-kt)}$ where A, B, and k are parameters to be estimated, t is age measured in months, and W_t is body weight at time t. The parameter B is a constant of integration necessary for accurate curve fit, especially at early ages, and e is the base of natural logarithms.

Correlation and stepwise regression procedures were used to determine which traits would be predictors of A and k. Early weights and ADG (up to 1 yr of age) were also included in some models. Three models were examined by stepwise regression in an attempt to predict A and k. The

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first model included only body measurements taken at birth; the second included the body measurements and early weights. The third included the body measurements and early ADG. Traits were retained if the regression coefficients were significant at the $P < 0.15$ level.

Results and Discussion

Means for body measurements, weights, and ADG for the 131 Angus and 39 Charolais calves that were measured are presented in Table 1, and corresponding means for the 54 Angus and 20 Charolais calves that remained long enough to have growth curves generated, as well as mean growth curve parameters for this group, are presented in Table 2. Measurements were larger for Charolais than for Angus and, in general, only slightly different between the two groups of animals within breed. As would be expected, Charolais were heavier than Angus at all times, with the group of cattle kept long enough to generate growth curves being slightly heavier than the group of all cattle measured up to 205 d of age. There did not appear to be much difference in ADG between the two groups within a breed. Charolais gained faster than Angus at earlier intervals, and Angus gained faster than Charolais at later intervals. Angus matured faster ($k = 0.0584$ vs. 0.0502) but to a smaller size than Charolais ($A = 1154$ vs. 1404 lb).

All body measurements were correlated with A (Table 3; $P < 0.01$). Body length ($r = -0.54$; $P < 0.01$), forearm circumference ($r = -0.20$; $P < 0.10$), and width of loin ($r = -0.20$; $P < 0.10$) were correlated with k. All measurements were positively correlated with A and negatively correlated with k. All early weights were positively correlated with A ($P < 0.01$) but showed no relationship to k. Early ADG values (that is for intervals that begin with birth weight) were correlated with A ($P < 0.05$), while the opposite was true for k. The ADG traits ending at 360 d of age (specifically ADG from 120 to 360 d, ADG from 205 to 360 d, and ADG from 240 to 360 d) were correlated with k ($P < 0.05$).

Results for the stepwise regression analyses for A using three different models are presented in Table 4. The highest R^2 (0.46) was found with Model 1 (using body measurements only) where five of the seven body measurements were kept in the model. Including early weights (Model 2) gave a model that dropped three measurements and kept weight at 240 d of age. The R^2 was slightly smaller (0.42), but fewer traits were kept. Including ADG rather than weights in Model 3 gave an R^2 of 0.44. Body length and width at loin were kept in all three models.

Model 1 and Model 2 gave the same results for k (Table 4), where only body length was kept in the model with an R^2 of 0.29. Adding ADG traits in Model 3 increased the R^2 slightly to 0.32 and added the trait ADG from 205 to 360 d of age.

Previous investigators at Arkansas (Johnson, 1990) used birth and 360-d weights to predict A and k. Values of R^2 were 0.05 and 0.19 for A and k, respectively. Adding birth and 360-d weight of the dam increased R^2 values slightly to 0.06 and 0.20. Furthermore, adding various combinations of birth and 360-d weights of sire, maternal and paternal grandsires, and granddams increased R^2 values, but the number of observations became so low that the model was not significant in most cases.

Results of this study indicate that body measurements taken at birth may be useful in predicting mature weight and maturing rate of cows. Higher R^2 values were obtained for A than for k; however, more traits were retained in the model. Body length, in particular, seemed to be related to both parameters A and k. Width at loin was important for A but not k.

Implications

Early prediction of mature weight and maturing rate would allow producers the opportunity to identify a mature size range for their production resources, and once mature size is established, then to select for early maturing cattle to that particular mature size. As long as selection is in the linear phase of growth, selection for ADG would be similar to selection for maturing rate. Some breed associations are already using genetic prediction for mature weight, and the inclusion of maturing rate in genetic prediction would aid producers in the correct match of cattle to production resources. Additional research is needed to further characterize biological types and to determine the biological type that matches each production resource.

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Table 1. Means for body measurements taken at birth and early weights and gains by breed for female Angus and Charolais calves.

	Angus			Charolais		
Trait	n	Mean	SD	n	Mean	SD
Body measurement, in						
Leg length	131	9.75	0.72	39	11.16	0.53
Forearm circumference	129	6.84	0.49	39	7.72	0.52
Heart girth circumference	129	26.85	1.71	39	28.63	1.60
Body length	128	42.11	12.73	39	47.57	12.88
Width at loin	131	4.17	0.40	39	4.64	0.44
Width at hip	131	7.09	0.49	39	8.19	0.55
Depth at chest	131	10.15	0.71	39	10.83	0.59
Weight, lb						
Birth weight	131	69.21	11.86	39	89.72	12.31
Weight at 120 d of age	125	263.06	50.28	35	318.46	56.79
Weight at 205 d of age	102	382.60	51.44	28	470.36	67.02
Weight at 240 d of age	88	423.84	51.23	26	495.96	57.89
Weight at 360 d of age	85	566.73	62.00	26	629.65	80.73
ADG, lb						
Birth to 120 d of age	125	1.61	0.36	35	1.91	0.43
Birth to 205 d of age	102	1.52	0.23	28	1.84	0.30
Birth to 240 d of age	88	1.46	0.19	26	1.67	0.22
Birth to 360 d of age	85	1.37	0.16	26	1.49	0.22
120 to 205 d of age	101	1.28	0.24	26	1.62	0.29
120 to 240 d of age	87	1.19	0.21	24	1.28	0.24
120 to 360 d of age	84	1.19	0.17	24	1.19	0.25
205 to 240 d of age	88	0.91	0.71	26	0.48	0.59
205 to 360 d of age	85	1.13	0.26	26	0.97	0.32
240 to 360 d of age	85	1.21	0.32	26	1.11	0.42

Table 2. Means for body measurements taken at birth, early weights, and gains and growth parameters by breed for female Angus and Charolais calves.

	Angus (n = 54)		Charolais (n = 20)	
Trait	Mean	SD	Mean	SD
Body measurement, in				
Leg length	10.00	0.54	11.31	0.47
Forearm circumference	7.01	0.48	7.91	0.52
Heart girth circumference	27.68	1.29	29.20	1.49
Body length	45.28	11.92	46.60	14.04
Width at loin	4.30	0.38	4.75	0.34
Width at hip	7.30	0.44	8.30	0.56
Depth at chest	10.46	0.63	11.07	0.59
Weight, lb				
Birth weight	74.19	9.86	94.15	11.43
Weight at 120 d of age	281.81	37.42	347.50	46.27
Weight at 205 d of age	390.00	43.86	486.60	59.54
Weight at 240 d of age	425.13	51.70	500.20	62.32
Weight at 360 d of age	573.54	61.67	624.35	70.60
ADG, lb				
Birth to 120 d of age	1.73	0.28	2.11	0.34
Birth to 205 d of age	1.54	0.20	1.91	0.27
Birth to 240 d of age	1.46	0.20	1.69	0.23
Birth to 360 d of age	1.39	0.16	1.47	0.18
120 to 205 d of age	1.27	0.19	1.64	0.29
120 to 240 d of age	1.19	0.21	1.27	0.26
120 to 360 d of age	1.21	0.17	1.15	0.16
205 to 240 d of age	1.00	0.67	0.39	0.55
205 to 360 d of age	1.18	0.24	0.89	0.16
240 to 360 d of age	1.24	0.31	1.03	0.21
Growth parameters[a]				
A, lb	1153.82	223.19	1403.73	219.34
B, lb	1085.83	183.46	1289.40	187.26
k, rate/mo	0.0584	0.0242	0.0502	0.0143

[a] A estimated from model: $W_t = A - B\, e^{(-kt)}$ where A, B, and k are parameters to be estimated, t is age measured in months, and W_t is body weight at time t. The parameter B is a constant of integration necessary for accurate curve fit, especially at early ages, and e is the base of natural logarithms.

Table 3. Correlations of body measurements taken at birth and early weights and gains with growth parameters A and k.

Trait	Correlation with: A	k
Body measurement, in		
Length leg	0.51**	–0.14
Forearm circumference	0.50**	–0.20+
Heart girth circumference	0.48**	–0.10
Body length	0.32**	–0.54**
Width at loin	0.51**	–0.20†
Width at hip	0.54**	–0.18
Depth at chest	0.35**	–0.13
Weights, lb		
Birth weight	0.50**	–0.17
Weight at 120 d of age	0.45**	–0.05
Weight at 205 d of age	0.45**	–0.01
Weight at 240 d of age	0.47**	0.01
Weight at 360 d of age	0.39**	0.13
ADG, lb		
Birth to120 d of age	0.39*	–0.01
Birth to 205 d of age	0.40**	0.04
Birth to 240 d of age	0.42**	0.04
Birth to 360 d of age	0.33**	0.19
120 to 205 d of age	0.30**	0.09
120 to 240 d of age	0.27*	0.09
120 to 360 d of age	0.11	0.28*
205 to 240 d of age	0.01	0.01
205 to 360 d of age	–0.07	0.23*
240 to 360 d of age	–0.09	0.25*

† $P < 0.10$.

* $P < 0.05$.

** $P < 0.01$.

Table 4. Results of stepwise regression[a] using body measurements at birth to predict growth parameters, A and k.

Trait	A	k
Model 1[b]		
Intercept	–507.32	0.10018
Length of leg	126.20	
Forearm circumference	91.70	
Body length	6.25	–0.00096
Width at loin	171.41	
Depth at chest	–121.27	
R^2	0.46	0.29
Model 2		
Intercept	–457.66	0.10018
Body length	6.31	–0.00096
Width at loin	182.09	
Weight at 240 d of age	1.31	
R^2	.42	0.29
Model 3		
Intercept	–668.70	0.08135
Body length	6.43	–0.00091
Width at loin	131.07	
Width at hips	95.19	
ADG 120 to 205 d of age	215.24	
ADG 205 to 360 d of age		0.01510
R^2	0.44	0.32

[a] Regression coefficients for variables retained in stepwise regression are shown. All variables left in the model are significant at the 0.15 level.

[b] Model 1 included measurement traits only, Model 2 included measurement traits and early weights, and Model 3 included measurement traits and early ADG traits.

Heritability of Lactate Dehydrogenase Activity in Replacement Beef Heifers

A.H. Brown,[1] Jr., C.F. Rosenkrans, Jr.,[1] Z.B Johnson,[1] M.L. Looper,[2] and E.L. Oxford[1]

Story in Brief

Beef heifers (n = 193) from 26 sires representing Angus, Charolais, Hereford, and Red Poll breeds were used to estimate coefficients of heritability for lactate dehydrogenase (LDH) activity. After weaning, heifers were developed as contemporaries on mixed-grass pasture with grain supplement (0.37% $BW^{.75}$). Blood samples were drawn and serum harvested from heifers at weaning (7 to 8 mo of age), yearling (11 to 12 mo of age), and prebreeding (13 to 14 mo of age). Colorimetric assays were used to determine LDH activity and protein concentration of frozen/thawed serum samples for each heifer at each time point. Activity of LDH was corrected for protein concentration and was expressed as international units per milligram of protein at each collection time (LDHW, LDWY, and LDHPB, respectively). Heritabilities were calculated using an animal model and derivative-free restricted maximum likelihood methodology. Heritabilities for LDH at weaning, yearling, and prebreeding were 0.22, 0.32, and 0.13, respectively. These data suggest that LDH at the yearling stage would be useful in artificial selection and may be useful as a tool for selecting replacement beef heifers.

Introduction

Improvement of growth, as indicated by live weight, is an objective of most modern breeding programs. This is due to the fact that rate of growth affects efficiency of production. Generally, growth can be defined as the directive coordination of all physiological processes until maturity is reached. Physiological markers may serve as useful tools for selecting animals, provided the marker is moderately to highly heritable. Lactate dehydrogenase (LDH) activity may have potential for use as a physiological marker (Paria et al., 1997; Rosenkrans et al., 1998). Activity of LDH is representative of anaerobic glycolytic metabolism in the cell and is associated with growth and maturation in mice (Markert and Ursprung, 1962; Markert et al., 1975), cattle (Kaneko, 1989; Renand et al., 1995 ; Paria et al., 1997), and swine (Larzul et al., 1997). Based on these findings, our objective was to estimate heritabilites for serum LDH activity in replacement heifers at weaning, yearling, and prebreeding stages.

Materials and Methods

Data were obtained from replacement heifers in the registered Angus, Charolais, Hereford, and Red Poll herds of the University of Arkansas Agricultural Experiment Station near Savoy. Heifers were spring-born and weaned in the fall. After weaning, heifers were developed as contemporaries on common bermudagrass *(Cynodon dactylon)* and tall fescue (*Festuca arundinacea*) pastures, which were overseeded with winter annuals of wheat (*Triticum acstiuum*), ryegrass (*Lolium multiforum*), and the cool-season perennial red clover (*Trifolium pratence*). In addition, heifers received a daily supplement consisting of cracked corn, soybean meal, vitamins A, D, and E, limestone, and molasses. Average daily supplement on pasture from weaning (7 mo of age) to breeding (13 to 14 mo of age) was 0.37% $BW^{.75}$. Stocking rate on pasture was one heifer/acre, and daily feed was provided when all heifers were present at the feed bunk. Each heifer had 24 in of linear bunk space, which was adequate for each heifer to have received feed.

Most heifers weaned in the herd started the developmental process. There were two primary reasons for heifers being culled. First, heifers were culled at weaning, yearling, and prebreeding stages based on frame score, BW gain, and structural incorrectness. Second, heifers were culled if they did not conceive during the breeding period or if they did not wean a calf in their first parity. Most of the heifers that were culled failed to conceive at 14 to 15 mo of age. This made annual average heifer replacement about 20% in each breed group.

Blood samples were collected by jugular venipuncture at weaning (7 to 8 mo of age), yearling (11 to 12 mo of age), and prebreeding (13 to14 mo of age). Samples were allowed to clot overnight at 5°C, then centrifuged at 2,300 x *g* for 30 min.

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Serum was decanted and stored at –20°C until assayed for LDH activity and protein concentration. Serum samples drawn from heifers that experienced chronic illness and (or) extreme injury were not assayed. A distribution of serum samples that were assayed are shown by breed and year in Table 1.

Lactate dehydrogenase activity in each serum sample was evaluated using a quantitative, colorimetric assay kit from Sigma Diagnostics (St. Louis, MO), and values were adjusted for protein concentration. Total protein concentrations were determined using the Biuret method (Oser, 1965). Lactate dehydrogenase activity was expressed as international units per milligram of protein at weaning (LDHW), yearling (LDHY), and prebreeding (LDHPB).

Data were analyzed by restricted maximum likelihood (REML) methodology. Variance components for LDHW, LDHY, and LDHPB were estimated using an animal model with the multiple-trait derivative-free maximum likelihood (MTDFREML) program (Boldman et al., 1993). Included in the model were the fixed effects of year and breed, age as a covariate, and random animal effects. A three-generation pedigree was available for each animal, and relationships were included in the analysis. Heritabilities were calculated as the additive genetic variance divided by the total variance for each trait.

Results and Discussion

Table 2 presents the estimates of heritabilities for LDHW, LDHY, and LDHPB. The heritability for LDHY was higher than that for LDHW and LDHPB. The heifers had a more uniform environment during the postweaning phase of development, which could account for the higher heritability of LDHY.

The heritability of LDHPB was less than that of LDHW and LDHY. Perhaps the lesser heritability of LDHPB resulted from less phenotypic resemblance among relatives due to different states of metabolism associated with different rates of maturing among heifers (Brown and Stallcup, 1968; Prasse, 1969). Mean maturity rate differences for Angus, Charolais, Hereford, and Red Poll breed groups represented by heifers in this study are discussed by Brown et al. (1991).

In these data, mean LDH activity increased from 6.13 IU/mg protein at weaning to 7.67 IU/mg protein at yearling and then decreased to 7.45 IU/mg protein at prebreeding. Decreases in mean LDH activity with the progression of maturity corresponds with the general concept that the lower inflection point on the growth curve is the point at which the impetus for lean growth declines and the impetus for fattening begins. This concept is supported by Goodhart and Shils (1980) and Renand et al. (1995), who reported that LDH activity is related to the proportion of BW that is in lean muscle mass. Lactate dehydrogenase activity was correlated ($r = 0.25$) with protein and DNA content in homogenized bovine muscle tissue (Jurie et al., 1995). Cellular restructuring is another factor that might account for changes in serum total LDH activity (Prasse, 1969 and Lauerman et al., 1982). Total LDH should not, however, reflect cell restructuring because the observations for heifers that had chronic illness or extreme injury were deleted.

In our study, heritabilities for serum LDHW, LDHY, and LDHPB estimated with the animal model were moderate (0.22 and 0.32), and low (0.13), respectively (Table 3). Our estimates of heritability for serum LDHW and LDHPB were lower than the estimate (0.31) for muscle tissue LDH in Limousin cattle reported by Renand et al. (1995) and lower than the estimate (0.27) of plasma LDH in lactating dairy cattle reported by Torekhanov (1993), but our estimate of heritability of serum LDHY was greater than estimates reported by these scientists. Our heritability of LDHY was greater than the estimate of 0.31 for LDH activity in blood plasma, heart, and muscle tissue in mice reported by Major and Tawfik (1981). Our findings, and the findings of others, suggest a larger additive genetic effect and a lesser environmental effect for LDH activity. An exception was Maier et al. (1983) who reported a high environmental effect for LDH activity in Goltingen miniature pigs.

Estimates of heritability may be biased by selection if one sire's progeny is culled more frequently than progeny of other sires or if animals of one breed are culled more severely than those of other breeds in the sample. A small number of heifers were culled during the developmental process based on poor performance; this should not have been an important source of bias in these data, because the culling rate was about equally distributed across sires and breeds so no one sire's progeny or no one breed was discriminated against more than others.

Other researchers have recognized the potential for using blood and tissue enzyme activity as selection traits in cattle, pigs, and mice. Green et al. (1990) and Salak et al. (1990) reported coefficients of heritability for selected measures of immune response in cattle and pigs, respectively. Torekhanov (1993) reported that blood metabolites could be used in selection because they are heritable and related to milking capacity in dairy cattle. Renand et al. (1995) reported that metabolic enzyme activity in muscle tissue of cattle is moderately heritable. Larzul et al. (1997) estimated the heritability of metabolic enzymes in pig skeletal muscle. Maier et al. (1993) calculated coefficients of heritability of metabolic enzymes in miniature pigs. Major and Tawfik (1981) stated that heritability coefficients showed a high additive genetic effect on enzyme activity in blood plasma, heart, and muscle tissue in mice.

Implications

These data suggest that total serum LDH in yearling beef heifer, as an indicator of growth and composition, could be used as a selection trait. They suggest that LDH may be a physiological marker useful in selection.

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Table 1. Distribution of serum samples at weaning, yearling, and prebreeding stages by breed and year.

	Serum samples			
Breed	Weaning	Yearling	Prebreeding	Total
Angus	91	90	88	269
Charolais	27	26	26	79
Hereford	52	48	51	151
Red Poll	28	28	28	84
Total	198	192	193	583
Year	Weaning	Yearling	Prebreeding	Total
1991	69	68	69	206
1992	62	57	60	179
1993	67	67	64	198
Total	198	192	193	583

Table 2. Heritability estimates for LDHW, LDHY, and LDHPB activity.[a]

Trait[b]	Heritability estimate
LDHW	0.22
LDHY	0.32
LDHPB	0.13

[a] LDHW = lactate dehydrogenase activity at weaning (7 mo of age); LDHY = lactate dehydrogenase activity at yearling stage (11 to 12 mo of age); LDHPB = lactate dehydrogenase activity at prebreeding stage (13 to 14 mo of age).

[b] IU/mg protein = adjusted for total protein concentration.

Reduction of Microbial Pathogens in Ground Beef Utilizing Hurdle Technology and a Novel Ozone Generator

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Story in Brief

The objective of this study was to utilize multiple antimicrobial interventions (hurdle technology) to reduce the microbial load in ground beef. To do this, frozen beef trim was thawed to 4°C and inoculated with a mixture of *Escherichia coli* (ATCC #11775; EC) and *Salmonella typhimurium* (1769NR; ST). Next, antimicrobial treatments were applied in combinations as follows: 1) 1% ozonated water (15 min) and 5% acetic acid (OA), 2) 1% ozonated water (15 min) and 0.5% cetylpyridinium chloride (OC), 3) 200 ppm chlorine dioxide and 10% trisodium phosphate (CT), or 4) an untreated control (C). Trim was ground twice, placed in overwrapped trays, and stored under simulated retail conditions. Packages were evaluated on days 0, 1, 2, 3, and 7 of display for aerobic plate count, coliform, EC, ST, instrumental color, and sensory color and odor characteristics. Both OA and OC treatments were effective ($P < 0.05$) for controlling all microorganisms monitored, and ground beef from these treatments was lighter in color through display than beef in the C or CT treatments. The CT treatment was effective ($P < 0.05$) for reducing all monitored microorganisms except ST, and ground beef from this treatment maintained a redder and darker color ($P < 0.05$) than beef from all other treatments by day 7 of display. Sensory panelists did not detect ($P < 0.05$) odor differences between OC, CT, and C treatments. Also, sensory panelists indicated ($P < 0.05$) that ground beef from the CT treatment was brighter red in overall color and worst point color and had less surface discoloration than ground beef from the control. Therefore, it is possible to control microbial growth in ground beef by using multiple interventions while maintaining or improving color and odor characteristics.

Introduction

Although ground beef is a staple commodity, there has been limited research evaluating methods for improving its safety. In the past, the majority of meat safety research has focused on carcass microbial decontamination. Although such technologies as carcass washes and pasteurization have addressed slaughter contamination, these methods offer little protection during further processing.

Compounds such as trisodium phosphate, cetylpyridinium chloride, chlorine dioxide, and ozone have all been effective for reducing *Escherichia coli* O157:H7 and *Salmonella typhimurium* on poultry and beef carcasses (Dickson et al., 1992; Kim et al., 1996); however, it would be advantageous for these technologies to be applied closer to the finished product to protect against processing contamination. In addition to single-intervention technologies previously described, it would be beneficial to use hurdles to attack individual microorganism species weaknesses and supply an added degree of protection should a single intervention fail (Graves-Demore et al., 1998). Therefore, the objective of this research was to determine whether the use of multiple antimicrobial interventions on beef trimmings prior to grinding could reduce the microbial load and improve the safety of ground beef, while maintaining color and odor quality.

Experimental Procedures

Boneless, frozen (–20°C) cow beef trimmings were thawed to 4 °C and inoculated with *E. coli* (ATCC #11775) and a nalidixic acid resistant strain of *S. typhimurium* (ATCC #1769NR). Inoculums were prepared from frozen (–80°C) stock cultures that were maintained by brain heart infusion (BHI) broth with glycerol (20%). Frozen cultures of *S. typhimurium* and *E. coli* were thawed, and 0.1 ml of each culture was inoculated into separate 40-ml aliquots of BHI broth and incubated for 18 h at 37°C. Bacteria were harvested by centrifugation (3460 x *g* for 20 min at 37°C); resuspended in the same volume of 0.1% peptone water, and then pooled together (1600 ml of *E. coli* and 1600 ml of *S. typhimurium*) to make a bacterial cocktail. The cocktail (3200 ml; log 10^7/ml *E. coli* and log 10^7/ml *Salmonella typhimurium*) was cooled to 4°C and poured into a container with the meat (24 lb) and

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allowed to attach for 1 h. The meat was then drained and separated into 6-lb sub-batches and placed in a 4°C cooler for 12 to 14 h to allow further microbial attachment.

The 6-lb meat batches were then treated with one of the following: 1) 1% ozonated water bath for 15 min followed by mixing with 400 ml of 5% acetic acid (OA); 2) 1% ozonated water bath for 15 min followed by mixing with 400 ml of 0.5% cetylpyridinium chloride (OC); 3) mixing with 400 ml of 200 ppm chlorine dioxide followed by mixing with 400 ml of 10% trisodium phosphate (CT); or 4) left untreated (control; C). With the exception of the OA treatment, which was placed in a stainless steel vessel continuously replenished with ozonated water, each batch was placed in a meat tumbler along with the selected antimicrobial treatment and tumbled for 3 min. After tumbling, meat was removed from the tumbler and ground twice through a 1/8-in grinder plate. Samples were then packaged (1 lb per package) on an absorbent diaper in oxygen-permeable, overwrap trays made of Styrofoam, and stored under deluxe warm white fluorescent lighting at 4°C to simulate retail display. On days 0, 1, 2, 3, and 7 of simulated retail display, 25-g ground beef samples were placed into whirlpack bags with 225 ml of 0.1% buffered peptone water and buffered to a pH of 7 with sodium hydroxide. Serial dilutions and subsequent platings were made on *Salmonella Shigella* agar containing nalidixic acid, Petrifilm (3M Co.) aerobic plate count (APC) plates, and Petrifilm (3M) *E. coli*/coliform plate count plates. Plates were then incubated at 37°C in an aerobic incubation chamber. Aerobic plate count plates and *Salmonella Shigella* agar plates were read at 48 h, and *E. coli*/coliform plates were read at 24 h. Counts were recorded as colony-forming units per gram (CFU/g), then transformed to log counts prior to data analysis. Instrumental color was measured using a HunterLab Miniscan colorimeter, and a trained sensory panel was used to evaluate overall color, worst point color, percentage discoloration, beef odor, and off odor characteristics on days 0, 1, 2, 3, and 7 of display.

This experiment was replicated three times. The randomized complete-block factorial experiment was analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). For those variables confounded by interactions, interaction means were generated, separated using the PDIFF option of PROC GLM of SAS, then plotted. Least-squares means for all other variables were generated and separated using the PDIFF option of PROC GLM of SAS.

Results and Discussion

Table 1 shows the reduction of log (CFU/g) *E. coli*, coliform, *S. typhimurium* and APC using OC, OA, or CT treatments in ground beef through simulated retail display. With regard to the treatments, *E. coli* was reduced ($P < 0.05$; 1.68, 1.42 and 0.61 log CFU/g by OC, OA, and CT treatments, respectively) by all treatments evaluated compared to the control. Cutter et al. (1994) found that the use of 5% acetic acid on carcasses could reduce *E. coli* O157:H7 counts by 2 log CFU/cm^2. Likewise, Dorsa et al. (1998) found that using 2% acetic acid or 12% trisodium phosphate on beef trimmings destined for ground beef could reduce *E. coli* O157:H7 (1.8 and 1.5 log CFU/g, respectively) and *S. typhimurium* (2.7 to 3.5 log CFU/g and 2.2 log CFU/g respectively) through 7 d of display. Dickson et al. (1994), using sliced beef tissue inoculated with *E. coli* O157:H7, *Listeria monocytogenes,* and *S. typhimurium*, then treated with either 8 or 12% trisodium phosphate for up to 3 min, found that trisodium phosphate reduced bacterial numbers on the tissues by 1.0 to 2.5 log CFU/cm^2. Other coliforms were also reduced ($P < 0.05$; 1.88, 1.84 and 0.40 log CFU/g by OC, OA, and CT treatments, respectively) by all treatments evaluated compared to the control. However, *S. typhimurium* was reduced ($P < 0.05$; 1.77 and 1.66 log CFU/g, respectively) by the OC and OA treatments, but not by the CT treatment ($P > 0.05$) when compared to the control. All treatments were effective ($P < 0.05$) for reducing aerobic plate counts (1.50, 1.27, and 0.30 log CFU/g by OC, OA, and CT treatments, respectively) against the control. Gorman et al. (1995) used combinations of 12% trisodium phosphate and water, 0.5% ozone and water, and 2% acetic acid and water to reduce *E. coli* on adipose tissue of beef carcass brisket by 2.70, 1.38, and 1.74 log CFU/cm^2, respectively. Using other multiple interventions, Phebus et al. (1997) found that a combination of water and steamwashing could reduce *E. coli* O157:H7 and *S. typhimurium* by 3.5 to 5.3 log CFU/cm^2 on beef carcasses. Therefore, the use of multiple interventions, or "hurdle technology," in ground beef production systems proved to be an effective method for decreasing the amount of microbial contamination in ground beef through simulated retail display. Regarding instrumentally evaluated color and sensory odor, the OC and OA treated ground beef was lighter (L^*; $P < 0.05$) than the control; however, the CT treated beef was darker (L^*; $P < 0.05$) than the control (Table 1). Sensory panelists indicated no difference ($P > 0.05$) in beef odor or off odor intensities among the control, OC, and CT treatments. However, the OA treatment had less ($P < 0.05$) beef odor and less off odor intensities than the control, OC, or CT treatments.

By day 1 of display, the control was redder ($P < 0.05$; a^*) than the OC, OA, and CT treatments (Figure 1A). However, the CT treatment was more red (a^*; $P < 0.05$) and the OC and OA treatments were less red (a^*; $P < 0.05$) by day 7 of simulated retail display than the control. Likewise, the OA treatment was the only treatment that reduced ($P < 0.05$) product redness (a^*) compared to the control throughout the duration of simulated retail display. Although the CT treatment was less ($P < 0.05$) yellow (b^*) on day 0 of display than the control, no difference ($P > 0.05$) was observed in yellowness (b^*) between the control and the OC or OA treatments by day 1 of display (Figure 1B). Throughout display, the OA treatment tended to be less yellow (b^*) than the control treatment. However, there were no differences ($P > 0.05$) in yellowness (b^*) between the OC treatment and the control by day 7 of display. Likewise, there was no difference ($P > 0.05$) in orangeness (hue angle) initially (day

0) between the control and any of the treatments (Figure 1C). Also, there were no differences ($P > 0.05$) in color (hue angle) among the control, OC, or CT treatments from days 1 to 3 of display. However, by day 1, and throughout the duration of display, the OA treatment had a greater ($P < 0.05$) hue angle, indicating a different color or hue, than the control. Although there were no differences in saturation index (vividness of color) among the control, OC, and OA treatments on day 0 of display, the CT treatment had a lower ($P < 0.05$) saturation index (less vivid color) than any other treatment by day 1 of display (Figure 1D). In contrast, there were no differences ($P > 0.05$) in vividness of color (saturation index) among the control, OC, or CT treatments from day 1 through the duration of display.

Sensory panelists indicated that the CT treatment maintained ($P < 0.05$) a brighter purple-red overall (Figure 2A) and worst point color (Figure 2B) than the control, OC, or OA treatments by the end of display (day 7). Likewise, sensory panelists found the CT treatment to have a lower ($P < 0.05$) percentage of discoloration than any of the other treatments by day 7 of display (Figure 2C). And in general, sensory panelists found the CT treatment tended to maintain a brighter purplish red overall and worst point color and less surface discoloration than the control, OC, or OA treatments throughout the duration of display. However, sensory panelists indicated that the OA treatment was ($P < 0.05$) more brown in overall and worst point color than the control throughout display, and it had a higher ($P < 0.05$) percentage of discoloration by day 1 of display than any other treatment. Bell et al. (1986) found that dipping meat pieces in acetic acid (2.4%) for 10 min resulted in moderately discolored beef when compared to a control, which was moderately bright red.

Implications

The use of hurdle technology closer to the packaging stage was effective in reducing microbial numbers while maintaining odor or improving ground beef color characteristics. This technology, if approved, adopted, and used correctly, could become part of a Hazard Analysis Critical Control Point program for processors, ensuring an increased level of safety of meat products.

Acknowledgments

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Table 1. Effect of multiple antimicrobial treatments[a] applied to beef trimmings on least-squares means (± SE) log CFU/g *E. coli*, coliform, *S. typhimurium*, aerobic plate count and CIE L*[b] value, beef odor,[c] and off odor[d] intensities of ground beef through simulated retail display.

	Treatment				
	Control	OC	OA	CT	SE
Microorganism					
E. coli	6.77[z]	5.09[w]	5.35[x]	6.16[y]	0.09
Coliform	6.02[y]	4.14[w]	4.18[w]	5.65[w]	0.10
S. typhimurium	5.81[x]	4.04[w]	4.15[w]	5.52[x]	0.11
Aerobic plate count	7.06[y]	5.56[w]	5.79[w]	6.76[x]	0.09
Instrumental color					
CIE L*	48.35[x]	52.30[z]	49.87[y]	43.80[w]	0.31
Sensory odor					
Beef odor	6.44[x]	6.37[x]	3.98[w]	6.51[x]	0.14
Off odor	4.55[x]	4.36[x]	2.54[w]	4.60[x]	0.09

Least-squares means within a row with different letters are different ($P < 0.05$).

[a] OC = 15 minute ozonated water bath (1%; 45°C) and 0.5% cetylpyridinium chloride; OA = 15 minute ozonated water bath (1%; 45°C) and 5% acetic acid; CT = 200 ppm chlorine dioxide and 10% trisodium phosphate.

[b] 0 = black and 100 = white.

[c] Beef odor score: 1 = extremely non-beef-like and 8 = extremely beef-like.

[d] Off odor score: 1 = extreme off odor and 5 = no off odor.

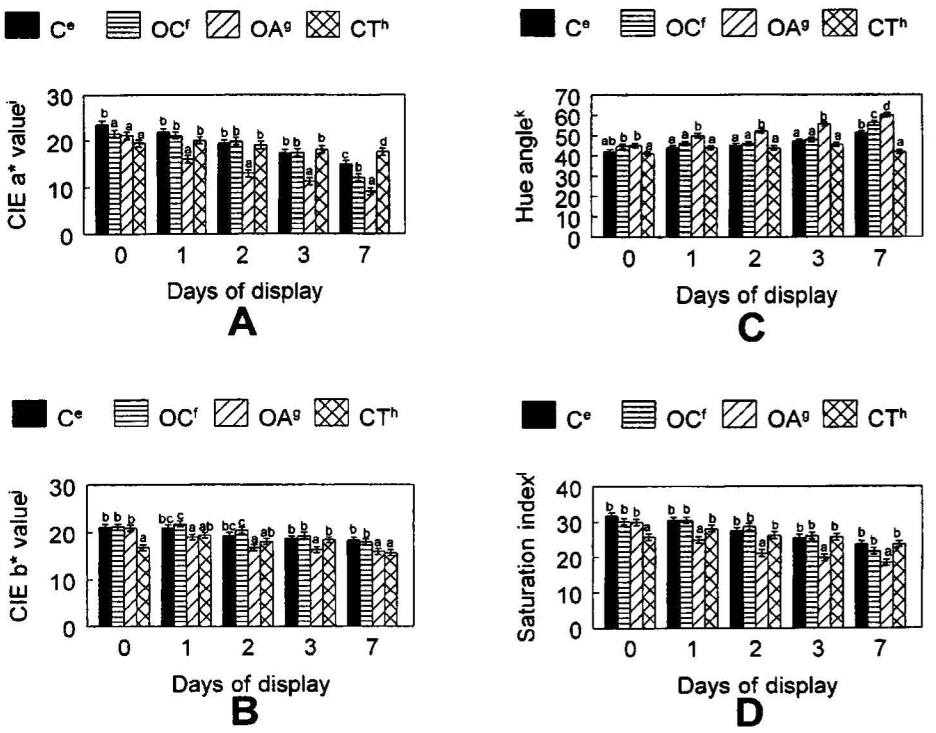

Figure 1. Day of display by antimicrobial treatment interaction effect on the least-squares mean (± SE) CIE (A) a* and (B) b* values, (C) hue angle, and (D) saturation index of ground beef through simulated display. [abcd]Least-squares means within a day with different superscripts are different ($P < 0.05$). [e]C = control; [f]OC = 15 min ozonated water bath (1%; 45°C) and 0.5% cetylpyridinium chloride; [g]OA = 15 min ozonated water bath (1%; 45°C) and 5% acetic acid; and [h]CT = 200 ppm chlorine dioxide and 10% trisodium phosphate. [i]a*: –60 = green and +60 = red. [j]b*: –60 = green and +60 = yellow. [k]Calculated as $\tan^{-1}(b^*/a^*)$. [l]Calculated as $(a^{*2} + b^{*2})^{0.5}$.

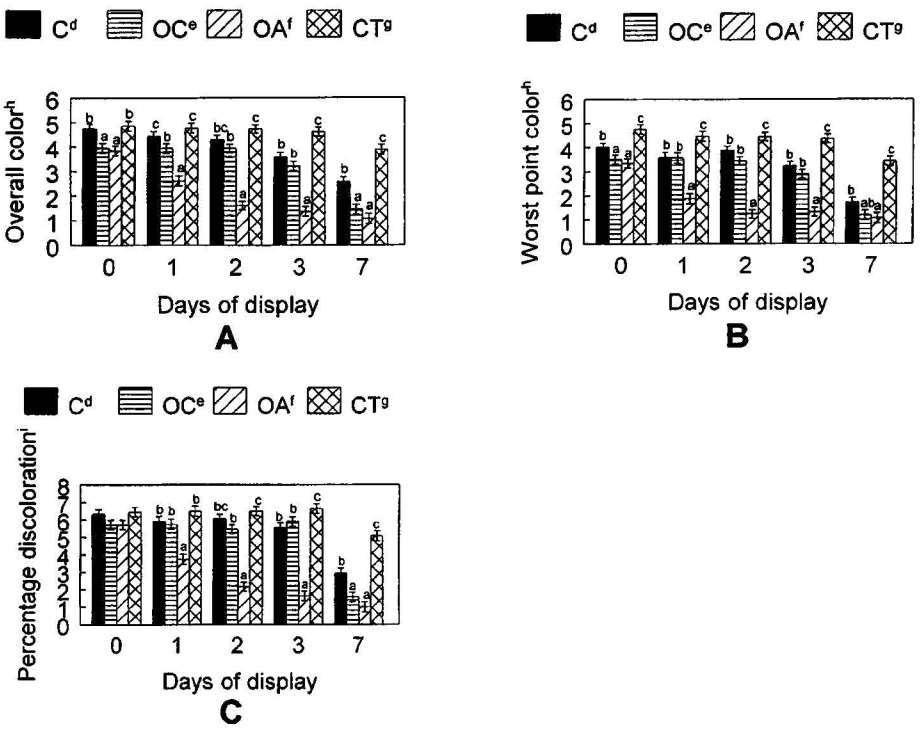

Figure 2. Day of display by antimicrobial treatment interaction effect on the least-squares mean (± SE) sensory evaluated (A) overall color, (B) worst point color, and (C) percentage discoloration, of ground beef through simulated display. [abc]Least square means within a day bearing different superscripts are different ($P < 0.05$). [d]C = control; [e]OC = 15 min ozonated water bath (1%; 45°C) and 0.5% cetylpyridinium chloride; [f]OA = 15 min ozonated water bath (1%; 45°C) and 5% acetic acid; and [g]CT = 200 ppm chlorine dioxide and 10% trisodium phosphate. [h]Color score: 1 = brown and 5 = bright purple-red. [i]Percentage discoloration: 1 = total discoloration and 7 = no discoloration.

Effect of Oxygen Concentration During Oocyte Maturation on Subsequent Bovine Embryo Cleavage and Development In Vitro

G.F. Miller[1] and R.W. Rorie[2]

Story in Brief

The objective of this study was to determine the effect of varying the incubator oxygen atmosphere on in vitro maturation of bovine oocytes. Bovine oocytes were matured for 24 h in a gas atmosphere of 5% carbon dioxide and either 5, 10, or 20% oxygen. After maturation, oocytes were fertilized with frozen-thawed spermatozoa. Oocytes cleaving to the 2- to 4-cell stage by 45 h post-insemination were co-cultured with oviductal cells in M-199 supplemented with 20% fetal bovine serum. The atmosphere for both in vitro fertilization and embryo culture was 5% carbon dioxide in air. After 6 d of co-culture, embryos developing to the blastocyst stage were fixed, stained, and nuclei number determined. The cleavage rate of oocytes matured in an atmosphere containing 20% oxygen was higher than that for maturation in atmospheres containing either 10 ($P = 0.05$) or 5% oxygen ($P = 0.07$). In contrast, more ($P = 0.07$) of the cleaved embryos continued development to the blastocyst stage when oocytes were matured in a reduced (5%) oxygen atmosphere. There were no differences in mean number of cells per blastocyst among the treatments ($P = 0.84$). The development rate of cleaved embryos to the blastocyst stage would indicate that reducing the oxygen atmosphere to 5% during bovine oocyte maturation may enhance oocyte developmental competence.

Introduction

Usually, less than 25% of the embryos produced through in vitro maturation and fertilization procedures will reach a developmental stage (morula or blastocyst) suitable for nonsurgical transfer. Development of procedures that increase the number of viable embryos produced through in vitro techniques is essential for these procedures to be used successfully on a commercial basis. A typical atmosphere for in vitro maturation of bovine oocytes is a humidified atmosphere of 5% carbon dioxide in air (about 20% oxygen). However, the oxygen concentration within the reproductive tract is about 5 to 8%. Some researchers suggest that by reducing oxygen within the culture environment, the problems associated with free radical formation and cellular damage will be reduced. This study was conducted to determine the effect of varying the atmospheric oxygen concentration for in vitro maturation of bovine oocytes, based on cleavage rates and the developmental competence of embryos after in vitro fertilization.

Experimental Procedures

Ovaries were collected from dairy and beef cows at a local abattoir. Cumulus cell-intact oocytes were recovered by slicing through follicles on the surface of the ovaries with a razor blade. The recovered oocytes were matured for 24 h in M-199 supplemented with 20% estrous cow serum, under gas atmospheres of 5% carbon dioxide and either 5, 10, or 20% oxygen. The balance of each gas atmosphere was nitrogen. Approximately 100 oocytes were cultured per well in 4-well culture plates. Cultures were carried out in modular incubator chambers that were placed into a larger incubator maintained at 39°C. The gas atmosphere within the modular chambers was equilibrated by gassing each modular unit with the appropriate gas mixture for 15 min.

Oocytes were fertilized using heparin-capacitated, frozen-thawed spermatozoa. Motile spermatozoa were selected by glass wool column filtration. Oocytes were fertilized in drops of fertilization medium (under silicone oil) containing heparin and bovine oviductal epithelial cells. Approximately 25 oocytes and 75,000 motile spermatozoa were placed into each drop of the fertilization medium. The oocytes remained in fertilization medium until 45 h post-insemination, at which time the oocytes/embryos were removed and evaluated for cleavage.

The cleaved (2- to 4-cell) embryos in each treatment were co-cultured with bovine oviductal epithelial cells in M-199 supplemented with 20% fetal bovine serum. After 5 d, embryos were removed from culture and evaluated for development to the blastocyst stage. After evaluation, embryos developing to the blastocyst stage were fixed and

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stained to count the number of cells (nuclei). Cleavage and embryo development data were analyzed using the PROBIT procedure of SAS (SAS Inst. Inc., Cary, NC). Cell number per blastocyst was analyzed using the GLM procedure of SAS.

Results and Discussion

Results of this study are presented in Table 1. At 45 h post-insemination the cleavage rate of oocytes matured in an atmosphere containing 20% oxygen was higher than after maturation in atmospheres containing either 10 ($P = 0.05$) or 5% oxygen ($P = 0.07$). These results are in agreement with those of Pinyopummintr and Bavister (1995) who reported the highest percentage of normal fertilization when bovine oocytes matured in 20, as compared to either 5 or 10% oxygen.

Although initial cleavage was highest in the present study when oocytes were matured in 20% oxygen, subsequent development to the blastocyst stage was higher ($P = 0.07$) for oocytes matured in an atmosphere of 5% oxygen. These results would suggest that the initial cleavage rate may not be a reliable indicator of oocyte developmental competence. Bovine oocytes undergo nuclear maturation to metaphase II under a variety of conditions ranging from totally defined, protein-free medium to media highly supplemented with different sera and hormones. Developmental competence requires acquisition of both nuclear and cytoplasmic maturation. The results of this study illustrate the difficulty in attempting to evaluate developmental competence based on only nuclear maturation or cleavage.

It has been suggested that the detrimental effect of atmospheric oxygen concentrations (about 20%) is due to cellular damage caused by an increase in the production of oxygen free radicals (Umaoka et al., 1992). The free radicals that appear to be of major concern are the hydrogen peroxide radicals, superoxide anions, and the hydroxyl radicals. Oxygen free radicals are highly reactive and cause cellular damage through lipid peroxidation of membrane lipids, inactivation of enzymes, and DNA damage. The toxic effects of atmospheric oxygen levels can occur rapidly but may not become apparent until the latter developmental stages, i.e., the morula or blastocyst stage (Pabon et al., 1989; McKiernan and Bavister, 1990). This might explain the results observed in this study, where initial cleavage was higher when oocytes were matured under atmospheric oxygen conditions, but subsequent development was decreased.

The mean cell number per blastocyst was similar ($P = 0.84$) among the various maturation treatments. This suggests that the various treatments had no effect on the developmental competence of the embryos that did achieve the blastocyst stage. We conclude that 5% oxygen concentration in the gas atmosphere is superior for in vitro maturation of bovine oocytes under conditions of this study. However, it is evident that the optimum oxygen concentration for oocyte maturation, fertilization and embryo culture is dependent on many factors including oocyte concentration, type of media, medium supplementation, and the presence or absence of co-culture.

Implications

Based on development of cleaved embryos to the morula or blastocyst stage in this study, oocyte developmental competence might be improved by reducing the oxygen atmosphere to 5% during bovine oocyte maturation. However, the optimum oxygen atmosphere for oocyte maturation, fertilization, and embryo culture is likely to vary with different in vitro systems and conditions. Therefore, optimal oxygen concentration must be determined for each in vitro system or laboratory.

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Table 1. Cleavage and development of bovine oocytes/embryos after in vitro maturation different oxygen atmospheres.

Oxygen atmosphere	No. oocytes matured*	% of oocytes cleaving	% of cleaved to blastocysts	Mean cells per blastocyst§
5%	462	53.0 ± 2.4^{a}	29.9 ± 0.6^{d}	93.9 ± 4.7
10%	478	52.5 ± 2.3^{a}	23.2 ± 0.5^{c}	96.2 ± 5.3
20%	540	58.7 ± 2.2^{b}	22.1 ± 0.5^{c}	91.2 ± 4.8

Cleavage rates with different superscripts differ ($P \leq 0.07$).

Percent blastocysts with different superscripts differ ($P = 0.07$).

* Data are from five replicates.

§ Mean cell number per blastocysts were similar ($P = 0.84$).

The Use of an Electronic Estrus Detection System to Evaluate the Effect of Embryo-Recipient Synchrony on Pregnancy Rate in Cattle

R.W. Rorie and T.D. Lester[1]

Story in Brief

When embryo recipients and donor cows are observed twice daily for estrus, a difference of several hours can occur between the actual and "detected" onset of estrus. This potential discrepancy makes it impossible to determine the exact synchrony between embryos and recipients. The use of an electronic estrus detection system to continuously monitor animals would allow for more precise timing of embryo transfers and might result in improved pregnancy rates. Therefore, the objective of this study was to use an electronic estrus detection system to evaluate the effect of embryo-recipient synchrony on transfer pregnancy rate. Also investigated was any possible effect of recipient estrus length or intensity on subsequent pregnancy rate. Multiparous, crossbred beef cows (n = 168) served as embryo recipients. At estrous synchronization treatment, HeatWatch mount transmitters were placed on the recipients. Embryo donors (n = 27) were also monitored with the HeatWatch system so that exact donor-recipient synchrony could be determined. Either fresh or frozen-thawed (frozen in glycerol or ethylene glycol) embryos were transferred approximately 7 d after detected estrus. Pregnancy was confirmed by palpation or ultrasonography at 45 to 60 d of gestation. Chi-squared was used to evaluate the effect of donor-recipient synchrony on pregnancy rate. The pregnancy rate tended ($P = 0.088$) to be higher for synchrony of ± 0 to 12 h than that of ± 12 to 24 h (60 vs. 46%, respectively). Neither estrus length nor intensity influenced subsequent pregnancy rate ($P \geq 0.278$). The results of this study suggest that continuous monitoring of embryo donors and recipients and selection of recipients with synchrony of ± 12 h can improve embryo transfer pregnancy rates.

Introduction

Embryo transfer (ET) involves the nonsurgical collection of embryos from valuable donor cows and then, transfer of recovered embryos to recipient cows for gestation. Close estrus synchrony between the embryo donor and recipient is necessary for optimum embryo survival after transfer. Synchrony is designated as zero, plus or minus, depending on whether the recipient cow comes into estrus at the same time, before or after the donor cow, respectively. Typically, embryos are transferred to recipients that are in estrus within ±24 h of the donor cow.

When embryo recipients and donor cows are observed twice daily for estrus, a difference of several hours can occur between the actual and "detected" onset of estrus. This potential discrepancy makes it impossible to determine the exact synchrony between embryo donors and recipients. The use of an electronic estrus detection system to continuously monitor animals would allow for more precise timing of embryo transfers, and might result in improved pregnancy rates. Therefore, the objective of this study was to evaluate the effect of embryo-recipient synchrony on transfer pregnancy rate, using an electronic estrus detection system. Also, length and intensity (mounting activity) of estrus were evaluated as possible indicators of embryo recipient quality.

Experimental Procedures

Multiparous, crossbred beef cows (n = 168) served as embryo recipients for this study. The recipients were synchronized either by two injections of PGF2alpha (Lutalyse) given 14 d apart, or by treatment with GnRH (Cystroelin) followed by an injection of Lutalyse 7 d later. At synchronization treatment, HeatWatch mount detection transmitters were placed on the recipients. Mount detection transmitters were also placed on the embryo donor cows (n = 27) so that the exact time of onset of estrus and thus, synchrony between donors and recipients could be determined.

The embryo donors were superovulated, using a 4-d descending dose regimen of follicle-stimulating hormone (Follitropin). Donors were inseminated at 12 and again at 24 h after the onset of estrus (day 0). Approximately 7 d later, embryos were recovered nonsurgically. Depending on availability of recipients, embryos were transferred fresh, or frozen in either glycerol or ethylene glycol and stored in liquid

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nitrogen until recipients were available. At 45 to 60 d of gestation, rectal palpation or ultrasonography was used to confirm pregnancy in recipients that did not return to estrus after embryo transfer. Data were categorized and analyzed for any effect of synchrony, length of estrus, and intensity of estrus (mounting activity) on pregnancy rate. Also, the pregnancy rate was compared for transfer of fresh vs. frozen embryos, and for embryos frozen in glycerol vs. ethylene glycerol.

Results and Discussion

There was no difference (P = 0.827) between pregnancy rates for embryos frozen in glycerol or ethylene glycol (51.5 vs. 49.1%, respectively). The pregnancy rate resulting from transfer of fresh embryos (62.2%) was similar (P = 0.279) to that for frozen-thawed embryos, so data for fresh and frozen-thawed embryos were combined for further analysis. Comparison of the various estrus synchrony categories (12-h intervals from –24 to +24 h) revealed a numeric trend for decreasing pregnancy rate with increasing asynchrony between the embryo donor and recipient (Table 1). Possibly because of the small number of embryo transfers in each category, this trend was not significant (P = 0.491). However, combining the data into two categories (± 0 to 12 h vs. ± 12 to 24 h) for comparison did reveal a tendency (P = 0.088) for increased pregnancy rates with better synchrony between embryo donors and recipients.

It is generally believed that acceptable pregnancy rates can be achieved by transferring embryos to recipients exhibiting estrus within ±24 h of the embryo donor. Without continuous monitoring of embryo donors and recipients, it is impossible to know their actual synchrony. Our results suggest that pregnancy rate can be improved by transfer of embryos to recipients with no more than 12 h asynchrony. The use of an electronic estrus detection system allows for better timing of embryo transfers.

Pregnancy rates were compared for recipients with estrus periods ranging from under 6 h to over 18 h. Typically, beef cows have estrus periods of 12 h or less. In the present study, 80% of the cows had estrus periods of 12 h or less. Abnormally long estrus periods could indicate a problem such as ovulation failure. However, there were no significant differences (P = 0.278) in pregnancy rate among recipients for any estrus length. The lowest numerical pregnancy rate occurred in recipients with long (over 18 h) estrus periods (Table 2) and would merit further study.

The Heatwatch system records every mount event during estrus and thus, makes it possible to determine if estrus intensity is related to subsequent pregnancy rates. The majority of recipients had 40 or fewer mounts during estrus. Mounting activity (Table 3) does not appear related to subsequent pregnancy after embryo transfer (P = 0.808).

Implications

The results of this study suggest that continuous monitoring of embryo donor and recipient cows and selection of recipients with synchrony of ± 12 h may improve embryo transfer pregnancy rates. Intensity of estrus (mounting activity) does not appear to be related to fertility. Further study is necessary to determine if length of estrus is related to embryo transfer pregnancy rates.

Table 1. Effect of recipient synchrony on embryo transfer pregnancy rate.

Estrus synchrony category	No. embryo transfers	Pregnancy rate (mean ± SE)
–12 to –24	21	47.6 ± 10.8
0 to –12	56	57.1 ± 6.6
0	9	66.7 ± 16.6
0 to +12	51	62.7 ± 7.0
+12 to +24	31	45.2 ± 9.0
± 0 to 12	116	60.3 ± 4.6
± 12 to 24	52	46.2 ± 6.9

Table 2. Effect of length of estrus on subsequent pregnancy rate.

Length of estrus (h)	No. embryo transfers	Pregnancy rate (mean ± SE)[a]
Under 6	44	61.5 ± 9.7
6 to 12	91	52.7 ± 5.2
12 to 18	7	63.6 ± 7.5
Over 18	23	28.6 ± 18.8

[a] Pregnancy rate was similar, regardless of estrus length (P = 0.278).

Table 3. Effect of estrus intensity on subsequent pregnancy rate.

No. mounts during estrus	No. embryo transfers	Pregnancy rate[a] (mean ± SE)
Under 20	75	54.7 ± 5.8
20 to 40	57	59.6 ± 6.6
41 to 60	19	47.4 ± 11.5
Over 60	17	58.8 ± 12.2

[a] Pregnancy rate was similar, regardless of estrus intensity (P = 0.808).

Performance of Stocker Steers and Heifers Implanted With Synovex-S and Synovex-H

S. McPeake, S. Gadberry, K. Combs, and D. Vangilder[1]

Story in Brief

A trial involving 56 steer and heifer calves was conducted to evaluate performance differences in calves that were implanted (Steers-Synovex S and Heifers-Synovex H) vs. calves that were not implanted. Steers and heifers having an average initial weight of 485 lb were randomly allocated within sex to remain either as nonimplanted controls or to receive a synovex implant. The calves were fed free choice hay plus a supplement for 100 d during the winter period (November 2, 1999, to February 10, 2000). During the 63-d spring period (February 10, 2000, to April 13, 2000), calves grazed bermudagrass pasture drilled with wheat, along with hay and supplement. During the winter period, there were no differences ($P > 0.05$) in ADG between the implanted calves and those in the control group. However, least-squares means for implanted calves vs. control calves did show a numerical difference in ADG (0.48 vs. 0.35 lb/d). During the spring period, implanted calves had greater ($P < 0.05$) ADG than control calves. Least-squares means were 1.69 lb/d for implanted calves vs. 1.26 lb/d for control calves. Average daily gain of calves over the entire trial period was 0.69 lb/d for nonimplanted calves and was improved to ($P < 0.05$) 0.96 lb/d for calves that were implanted.

Introduction

Anabolic implants have been used to increase gains of grazing cattle since the early 1950s. The products available are based on compounds that have estrogenic or estrogenic-like activity. The effectiveness of these types of implants is well documented. This trial serves to validate the effectiveness of implanting in a typical Arkansas environment.

Experimental Procedures

On November 2, 1999, 56 feeder calves, (30 heifers and 26 steers) having an average initial weight of 485 lb were randomly allocated within sex to remain as nonimplanted controls or to receive a synovex implant. The cattle were of mixed breeding containing Limousin, Simmental, and Brahman breeding and were retained by the owner.

On November 2, 1999, calves were given injectable ivomec for internal parasite control, and respiratory vaccinations (infectious bovine rhinotracheitis, bovine virus diarrhea, parainfluenza –3) and implanted. Calves were maintained during the winter period (November 2, 1999 to February 10, 2000) in a small pasture area and fed free choice hay plus 2 lb per animal per day of a supplement that was approximately 90% corn, 10% cottonseed meal, and added vitamins A, D, and E. Also a high magnesium-free choice mineral was provided.

On February 10, 2000, calves were weighed and ADG was calculated. Upon review of the gain information, some management changes were recommended. Higher quality hay was selected and recommended to be fed during the remainder of the trial. Since the calves had slowly gained weight, the supplement was increased to about 3 lb per animal per day or about 0.5% of body weight. Also, fecal samples taken at this time revealed that the calves had a parasite load. They were dewormed approximately 1 wk later with a pour-on avermectin product.

After February 10, 2000, the calves were maintained in a larger pasture area that had been drilled with wheat; however, due to low rainfall amounts, hay was still made available along with the supplement. The wheat pasture did not offer an adequate forage supply until early March. On April 13, 2000, final weights were collected.

Least-squares means for ADG and calf weights were generated using general linear model procedures of SAS (SAS Inst. Inc., Cary, NC).

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Results and Discussion

Steers and heifers gained at similar rates during the winter period, spring period, and the total trial. No interactions between sex and implant treatments were detected for ADG, indicating that both sexes tended to respond similarly to implants. Implanted heifers gained 1.66 lb/d during the spring period, while nonimplanted controls gained 1.30 lb/d (Table 1, $P < 0.05$). In addition, implanted heifers for the entire trial period (163 d) gained 0.92 lb/d vs. 0.71 lb/d for nonimplanted control heifers (Table 1, $P < 0.05$).

Implanted steers gained 1.71 lb/d during the spring period while nonimplanted steers gained 1.21 lb/d (Table 2, $P < 0.05$). Overall, implanted steers gained 1.00 lb/d for the entire trial period (163 day) vs. 0.68 lb/d for nonimplanted control steers (Table 2, $P < 0.05$).

Implanted calves gained 0.96 lb/d during the entire trial period (163 day) while nonimplanted calves gained 0.69 lb/d (Table 3, $P < 0.05$). However, most of the advantage in weight gain occurred during the spring period for implanted calves vs. nonimplanted controls (Table 3). During the spring period, implanted calves gained 1.69 vs. 1.26 lb/d for nonimplanted calves (Table 3, $P < 0.05$). There were no significant differences in gains between implanted calves and nonimplanted calves during the winter period. During the total trial implanted calves gained 69 more lb ($P < 0.05$) than nonimplanted calves. Most research shows that implants return $10 for each $1 invested.

It has been reported that the estrogenic implants (Synovex S, zeranol) increased the concentration of thyroxin in plasma by increasing its secretion from the thyroid gland (Gopinath and Kitts, 1982; Kahl et al., 1978) as reviewed by Gill (1985). In addition, slight increases in heart rate, fasting urinary nitrogen excretion, and fasting heat production also have been observed in cattle fed or implanted with DES and implanted with Synovex S, which suggests that the estrogenic implants slightly increase maintenance energy requirements (Rumsey et al., 1973, 1980; Tyrell et al., 1975). It is rather surprising that the implanted calves maintained their rate of gain compared to nonimplanted controls with gains being so low during the winter period.

Greathead (1984), as reviewed by Gill (1985), reviewed studies with zeranol implants and concluded that the response may be large and of short duration in rapidly growing cattle on high levels of energy intake. However, smaller improvements in growth rate, but occurring over a longer duration, are more typically observed in cattle gaining less than about 1.5 lb/d.

Implications

Animals respond better to implanting when on a higher level of nutrition than in restricted nutritional environments. Calves from this study did not have a significant response from implanting in the winter period until their nutritional environment improved in the spring. Implanting is a cost-effective way to increase ADG.

Acknowledgment

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Table 1. Least-squares means for heifer weights and weight gains (lb).

Item	Control	Synovex-H
Wt (November 2, 1999)	468	472
Wt (February 10, 2000)	500	518
Wt (April 13, 2000)	578	623
ADG, winter	0.35	0.45
ADG, spring	1.30[a]	1.66[b]
ADG, total	0.71[a]	0.92[b]

Means with different letters were different ($P < 0.05$).

Table 2. Least-squares means for steer weights and weight gains (lb).

Item	Control	Synovex-S
Wt (November 2, 1999)	484	524
Wt (February 10, 2000)	519	575
Wt (April 13, 2000)	559[a]	697[b]
ADG, winter	0.35	0.51
ADG, spring	1.21[a]	1.71[b]
ADG, total	0.68[a]	1.00[b]

Means with different letters were different ($P < 0.05$).

Table 3. Least-squares means for all calf weights and weight gains (lb).

Item	Control	Implanted
Wt (November 2, 1999)	476	498
Wt (February 10, 2000)	509	547
Wt (April 13, 2000)	569[a]	660[b]
ADG, winter	0.35	0.48
ADG, spring	1.26[a]	1.69[b]
ADG, total	0.69[a]	0.96[b]

Means with different letters were different ($P < 0.05$).

The Production of Stocker Cattle Supplemented With Aueromycin or Gain Pro While Grazing Fescue During the Fall and Winter

D.S. Hubbell, III,[1] L.B. Daniels,[2] K.F. Harrison,[1] and Z.B. Johnson[2]

Story in Brief

Seventy-two preconditioned, crossbred steers, averaging 500 lb BW, were randomly divided into nine groups of eight animals and assigned to nine 4-acre fescue pastures on November 9, 1999, until February 29, 2000. One-third of the steers were supplemented with 70 mg of aueromycin per animal per day, one-third supplemented with 20 mg of Gain Pro per animal per day, and one-third received no supplementation. All steers were fed 2 lb of corn per animal per day. There were no differences in ADG, total gain, or gain per acre of steers from feeding antibiotics. Numerically, steers supplemented with aueromycin had an ADG of 1.33 lb/d, Gain Pro 1.17 lb, and controls 1.11 lb. These data suggest that there is no benefit of supplementing either aueromycin or Gain Pro on growth of stocker cattle while grazing fescue in the fall and winter.

Introduction

Fescue is the predominant cool-season grass grown for forage in Arkansas. It is used as pasture for stocker cattle during the fall and winter, but cattle gains are usually small, averaging approximately 1 lb per animal per day. It is important that stocker cattle gains be as efficient and economical as possible. Therefore, feed additives are often used to promote growth, improve health, and reduce morbidity. Chlortetracycline (aueromycin) has been used for several years. Recently, bambermycin (Gain Pro) has been used as a feed additive for stocker cattle production. Rush et al. (1996) observed ADGs of stocker cattle that grazed crested wheat grass pastures were improved by 22.2% when Gain Pro was fed at 20 mg per animal per day. Therefore, it was the objective of this study to evaluate the effect of feeding aueromycin and Gain Pro to stocker cattle grazing fescue during the fall and winter.

Experimental Procedures

Seventy-two preconditioned crossbred steers, averaging 500 lb BW, were randomly divided into nine groups of eight animals and then assigned randomly to nine 4-acre fescue pastures. Calves were vaccinated with a seven-way black leg (alpha-7), tetanus, modified-live IBR-BVD-P13-BRSV (Express 4-HS) plus *Haemophilus Somnus pasturella* spp. (Pulmogard) and dewormed with injectable Ivomec. Bulls were castrated, and horns were tipped if necessary. Booster vaccines were given 17 to 21 d after initial vaccinations. Steers were implanted with Ralgro. The fescue pastures were established in 1996 and were Kentucky 31 endophyte-infected. One-third of the steers were supplemented with the feed additive aueromycin at the rate of 70 mg per animal per day, one-third with Gain Pro at the rate of 20 mg per animal per day, and one-third did not receive a feed additive. All steers were fed 2 lb of corn per animal per day, which was used as a carrier for the feed additive. The steers were preconditioned for 30 d prior to assigning them to their respective treatment. Steers were weighed initially using a nonshrunk weight and every 28 d thereafter. They received a commercial trace mineralized salt mix free choice. The data were analyzed by analysis of variance procedures of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

The ADG, total gain (TG), and gain per acre (G/A) for steers supplemented with aueromycin and Gain Pro are given in Table 1. There were no differences in ADG, TG, or G/A as a result of feeding aueromycin or Gain Pro. These data do not agree with that of Rush et al. (1996), who reported a 22% increase in ADG of stocker steers, supplemented with 20 mg of Gain Pro per animal per day while grazing crested wheat grass. However, their study was conducted during the summer, whereas the present study was conducted during

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the fall and winter. Gains in the present study were similar to those observed by Daniels et al. (2000) in which stocker heifers grazed stockpiled endophyte-infected fescue. It appears from these data that aueromycin and Gain Pro provide no growth advantage to stocker cattle while grazing endophyte-infected fescue during the fall and winter.

Implications

There appeared to be little or no growth advantage to supplementing stocker cattle with either aueromycin or Gain Pro while grazing infected fescue during the fall and winter.

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Table 1. ADG, total gain (TG), and gain per acre (G/A) of steers grazing fescue pasture and supplemented with aueromycin and Gain Pro.

	Treatment				
Trait	Aueromycin	Gain Pro	Control	SE	P value
ADG, lb	1.33	1.17	1.11	0.08	0.24
TG, lb	149.00	131.00	124.00	9.0	0.24
G/A, lb	299.00	251.00	248.00	20.0	0.25

Effect of Forage Environment on Milk Yield and Quality in Angus, Brahman, and Reciprocal-Cross Cows

M.A. Brown,[1] A.H. Brown, Jr.,[2] W.G. Jackson,[3] and J.R. Miesner[3]

Story in Brief

Milk yield (MY) and quality were observed on 93 Angus, Brahman, and reciprocal-cross cows over 3 yr to evaluate the interactions of direct and maternal breed effects and heterosis with forage environment. Milk quality traits were milk fat percentage (MF), milk protein percentage (PRO), and somatic cell count (SCC). Forage environments were common bermudagrass (BG), endophyte-infected tall fescue (E+), and a rotational system (ROT) of both forages where each forage (BG or E+) was grazed at appropriate times of the year. Heterosis for 24-h MY was large and similar among forages, averaging 1.09 lb ($P < 0.01$). There was little evidence of maternal effects for MY for any forage. Direct effects for MY were similar among forages and averaged 1 lb in favor of Brahman ($P < 0.10$). There was little evidence of heterosis or maternal breed effects for milk fat percentage. Direct breed effects for MF were similar across forages and averaged 0.86% greater for Brahman ($P < 0.01$). There was little evidence of direct or maternal breed effects for PRO, nor was there evidence of forage effects for this trait. Purebred cows exceeded crossbreds in PRO by 0.13% on ROT ($P < 0.10$). Crossbred cows had lower SCC than purebreds on BG ($P < 0.05$), E+ ($P < 0.01$), and ROT ($P > 0.30$). Maternal breed effects for SCC were greater for the Angus dams on ROT ($P < 0.10$) with similar nonsignificant trends on BG and E+. Direct breed effects for SCC were greater for the Brahman on ROT ($P < 0.10$) with similar trends on BG and E+. These results suggest that rotation of cows from E+ to BG in the summer can partially alleviate negative effects of E+ on MY. The results suggest direct and maternal breed effects and heterosis for MY and quality were relatively stable across the forage systems evaluated. Conclusions from the research also suggest an advantage to crossbred cows in SCC and provide evidence of both direct and maternal breed effects for this trait.

Introduction

Milk yield (MY) and quality [milk fat percentage (MF), milk protein percentage (PRO), and somatic cell count (SCC)] are important components of maternal performance of beef cows and have been shown to account for 40% of the variance in 205-d weights (Robinson et al., 1978). The effects of nutritional environment on MY and quality have been well documented and information in the literature has shown that cows grazing endophyte-infected tall fescue tend to have lower milk yield compared to cows grazing forages where the endophyte is not present or has been diluted (Brown et al., 1993, 1996). In the Mid-southern United States, common bermudagrass (BG) and endophyte-infected tall fescue (E+) are the major available warm-season and cool-season forages. Sleper and West (1996) suggested that removal of cows from E+ during the summer months is appropriate management of E+ to help alleviate problems associated with this forage. There is little documentation of interactions of genetic effects with management systems involving year-round management of BG, E+, or a system utilizing both forages during appropriate grazing seasons. Consequently, the objective of this research was to evaluate milk yield and quality of Angus, Brahman, and reciprocal-cross cows where cows were managed on BG, E+, or a combination of the two forages.

Materials and Methods

Milk yield and quality were estimated in 1995, 1996, and 1997 for 93 Angus (AA), Brahman (BB), and reciprocal-cross (AB and BA) cows born in 1988 to 1991. Cows were managed on 40-acre pastures (approximately 0.5 head/acre) of either BG or E+, with all breed types represented in each pasture. After weaning in the fall of 1994, approximately 10 cows from each breed group in each forage were randomly assigned to a new forage management treatment, i.e., E+ in the fall and spring (approximately November to May) and BG in the summer (June to October). Consequently, there

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were three 40-acre pastures of BG, three 40-acre pastures of E+, and two pairs of 40-acre BG and E+ pastures used in a rotational system (ROT). Stocking rates were about 0.5 head/acre for BG and E+ and an average of about 0.5 head/acre on ROT (approximately 1 head/acre on BG in summer and about 1 head/acre on E+ in fall and spring). Pastures were fertilized as suggested by soil tests.

Milk yield was estimated each year by milking machine using a single-cow portable machine. Milk yield was estimated in all years at an average 60, 89, 116, 145, 172, and 200 d postpartum. Dates of estimates were late April to late September. Cows and calves were separated at approximately 1700 h the evening before milking and held for approximately 14 h overnight with hay and water provided. There was no milk-out prior to separation. Ten minutes before milking, cows were sedated with 1.5 ml of acepromazine, and 1.0 ml of oxytocin (20 USP units/ml) was administered immediately before milking to induce milk let-down. After a cow was milked out, milk was weighed, and triplicate samples were taken for estimates of MF, PRO, and SCC. Milk fat, MP, and SCC were estimated by a commercial laboratory using a Milkoscan System 4000 (AOAC, 1990). Daily milk was estimated as twice the net weight of milk adjusted linearly to a 24-hour basis ([milk weight/14] • 24). Heterosis effects, maternal breed effects, and direct breed effects were calculated as ((AB + BA)/2 – (AA + BB)/2), AB – BA, and (BA + BB)/2 – (AB + AA)/2), respectively. Repeated measures analyses were conducted using least-squares mixed models procedures. The initial linear model included year, sire breed, sire nested in sire breed, dam breed, forage, age, the pooled interaction of sire nested in sire breed with fixed effects, month of lactation, and all possible interactions among fixed effects and a residual of the interactions of sire within sire breed with month effects. Sire nested in sire breed, the pooled interaction of sire nested in sire breed with fixed effects, and the residual were considered random and other effects in the model were fixed. Heterosis, maternal breed effects and direct breed effects were estimated as linear contrasts of least-squares means and tested using "t" statistics. Error terms for heterosis, direct breed effects, and maternal breed effects were constructed from combinations of appropriate random effects by PROC MIXED of SAS (SAS Inst. Inc., Cary, NC). Sample sizes for sire breed x dam breed x forage environment x month for MY and quality ranged from 6 to 12 animals in each cell.

Results and Discussion

Daily MY: Milk yield of cows on E+ was lower than for cows on BG and ROT for AA ($P < 0.01$), AB ($P < 0.10$), BA ($P < 0.01$), BB ($P < 0.10$), and averaged over breed group ($P < 0.01$) (Data not shown). Milk yield of AA on ROT was lower ($P < 0.01$) than for AA on BG, but MY was similar on BG and ROT for AB, BA, and BB cows. Rotating cows from E+ to BG was effective (compared to E+) for all breed groups ($P < 0.10$), but appeared to be most helpful in AA and BA. Heterosis for MY was similar across forages and averaged 1.09 lb ($P < 0.01$), although a trend existed for heterosis to be smallest on BG, intermediate on E+, and largest on ROT. Maternal effects for MY were not evident on any forage, while direct effects were similar across forages and averaged 1.0 lb in favor of the BB ($P < 0.10$) with a numerical trend for direct effects to be less on BG, intermediate on E+, and largest on ROT.

Milk yield for each average days of lactation is given in Figure 1. Divergence between the AA and BB increased as the summer progressed, probably reflecting the heat-tolerance of the BB. There was a trend for persistence to be less in the AA, compared to the BB or reciprocal-crosses as evidence by differences in 200-d MY vs. 60-d MY. Heterosis for 116 d was larger than for 89 d (0.93 vs. 1.35 lb, $P < 0.10$) due primarily to a larger decline by AA between 89 and 116 d of lactation compared to the reciprocal crosses (Figure 2).

Milk Fat: Milk fat percentage for cows on ROT was higher than that of cows on BG or E+ ($P < 0.10$), possibly due to a better sustained plane of nutrition for cows on ROT (Data not shown). There was little evidence of heterosis or maternal breed effects for MF, but direct breed effects averaged 0.86% in favor of BB.

Milk fat percentage for each average days of lactation is given in Figure 3. Direct breed effects were not consistent across days of lactation ($P < 0.05$) and approximated a cyclic pattern (Figure 4). Direct breed effects at 60 d were larger than at 89 d ($P < 0.11$); direct breed effects at 89 d were less than at 116 d ($P < 0.01$); direct breed effects at 116 d were larger than at 172 d ($P < 0.10$); and direct breed effects at 172 d were tended to be smaller than at 200 d ($P < 0.15$).

Milk Protein: Milk protein percentage was relatively stable across both breed group and forage with two exceptions; BA on E+ had higher PRO than contemporaries on BG and ROT ($P < 0.05$) and BB on ROT had higher protein than contemporaries on BG ($P < 0.05$) (Data not shown). Reasons for these differences are not evident nor is the practical significance of the differences. Heterosis for PRO was negative on ROT ($P < 0.10$), but there was little evidence of heterosis on BG or E+. There was also little evidence of maternal or direct breed effects for this trait. Milk protein was also stable across time (Figure 5) with the only anomaly being a small spike in PRO in BB at 116 d of lactation.

Somatic Cell Count: Angus on E+ tended to have higher SCC than AA on BG ($P < 0.11$), but there was little evidence of other forage differences in SCC (Data not shown). There was evidence of favorable heterosis BG ($P < 0.05$), E+ ($P < 0.01$), and averaged over forage ($P < 0.01$), maternal breed effects on ROT favoring AA ($P < 0.10$), and direct breed effects on ROT favoring BB ($P < 0.10$). Brown et al. (1996) reported heterosis for SCC on E+ but not BG and Brown et al. (1998) reported favorable heterosis for presence of mastitis-causing organisms in Brahman-Angus reciprocal crosses.

Average SCC for each of the days of lactation for each breed group is given in Figure 6. The SCC for crossbred cows

tended to decrease and (or) remain stable whereas purebred cows tended to cycle over time. These patterns resulted in greater heterosis for SCC for days 89 ($P < 0.05$), 116 ($P < 0.05$), 145 ($P > 0.15$), 172 ($P < 0.10$), and 200 ($P < 0.05$; Figure 7).

Implications

The negative effects of endophyte-infected tall fescue on milk production in beef cows can be partially alleviated by rotation of cows to a warm-season forage such as bermudagrass in the summer. Moreover, such a rotation may be helpful in improving milk fat content and thereby increasing energy available to the calves. Direct breed effects from Brahman can be beneficial in milk yield and milk fat, and heterosis from crossbred cows can be beneficial for milk yield and somatic cell count.

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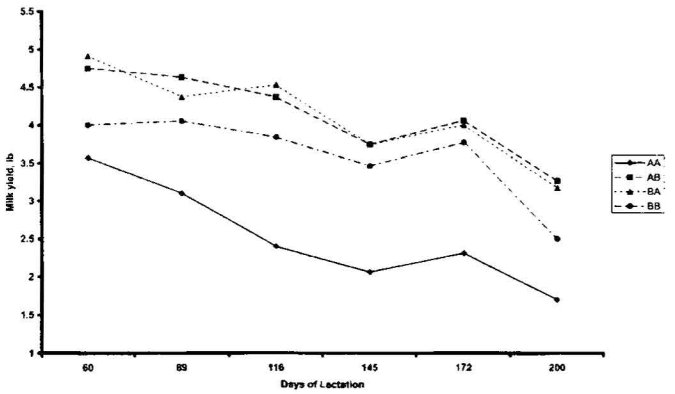

Figure 1. Twenty-four-hour milk yield for Angus (AA), Angus Brahman (AB), Braman Angus (BA), and Brahman (BB) by days of lactation.

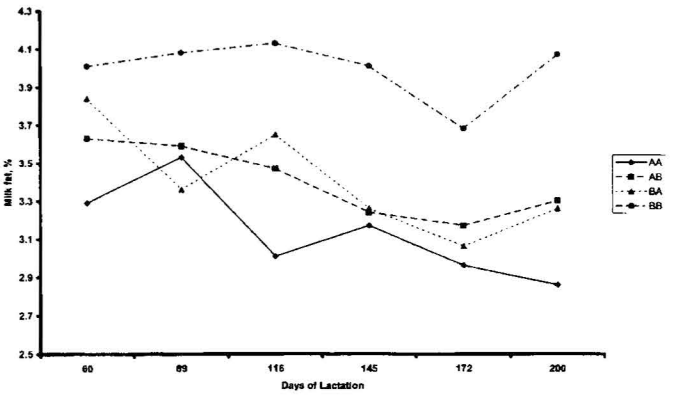

Figure 3. Milk fat percentage in 24-h milk yield of Angus (AA), Brahman (AB), Brahman Angus (BA), and Brahman (BB) cows by days of lactation.

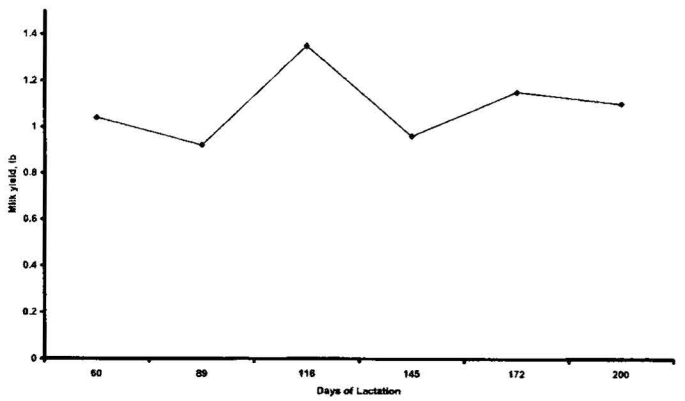

Figure 2. Heterosis for 24-h milk yield of Angus, Brahman, and reciprocal-cross cows by days of lactation.

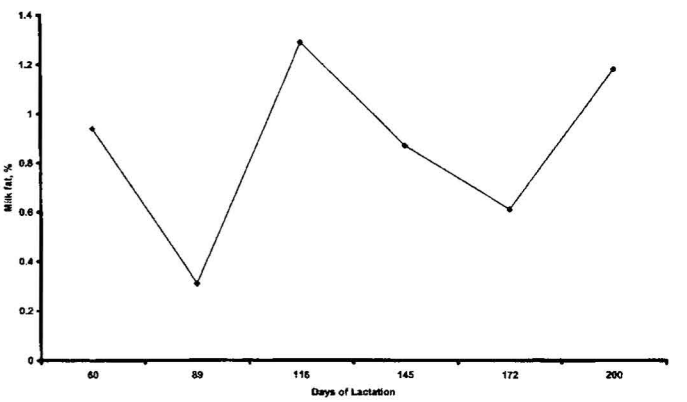

Figure 4. Direct breed effects for milk fat percentage in 24-h milk yield of Angus, Brahman, and reciprocal-cross cows by days of lactation.

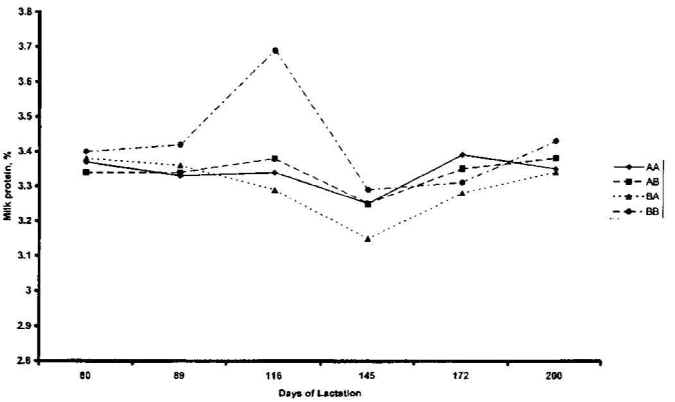

Figure 5. Milk protein percentage in 24-h milk yield of Angus (AA), Angus Brahman (AB), Brahman Angus (BA), and Brahman (BB) cows by days of lactation.

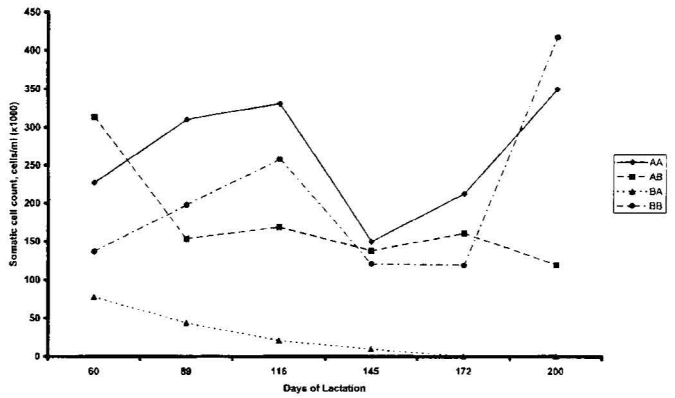

Figure 6. Somatic cell count in 24-h milk yield of Angus (AA), Angus Brahman (AB), Brahman Angus (BA), and Brahman (BB) cows by days of lactation.

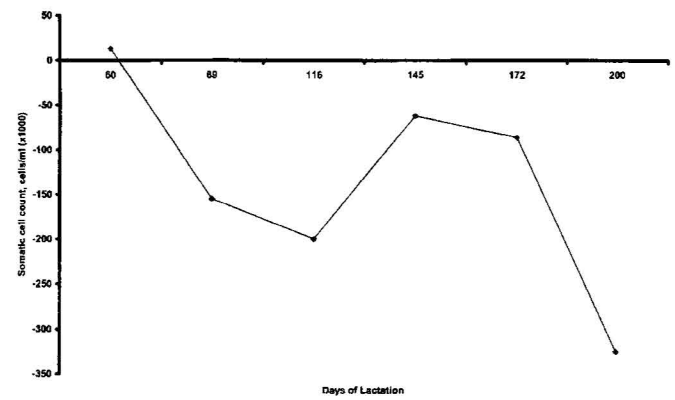

Figure 7. Heterosis for somatic cell count in 24-h milk yield of Angus, Brahman, and reciprocal-cross cows by days of lactation.

Effect of Backgrounding Diet During the Winter on Subsequent Performance of Growing Calves Grazing Tall Fescue

P. Beck,[1] J.M. Phillips,[1] S. Gunter,[1] K. Cassida,[1] and S. Freeman[2]

Story in Brief

During the fall of 1999, 96 calves received one of four backgrounding diets in drylot for 68 d to determine the effect of diet on subsequent performance of cattle grazing cool-season pasture. Two treatment groups were fed hay and supplemented with rice bran or a self-fed molasses-based liquid supplement. Another two treatment groups were program-fed high-concentrate diets to match drylot performance of hay-fed calves with either a liquid molasses-based or an oil-seed meal based protein supplement. After the drylot phase, there were no differences ($P > 0.05$) in BW, although calves fed hay supplemented with liquid supplement had lower ($P < 0.05$) ADG than those receiving the other treatments. Drylot cost of gain was higher ($P < 0.05$) with hay-based diets or with liquid supplements. During the first 14-d grazing period, calves program-fed high-concentrate diets gained 1.61 lb/d more ($P < 0.05$) than calves fed hay. The inclusion of liquid supplements improved ($P < 0.05$) performance by 0.50 lb/d during the initial 14 d of grazing. Grazing performance after the first 14-d period was not affected ($P > 0.05$) by previous drylot diet, but profitability was improved by approximately $18.50 per animal by programmed feeding of high-concentrate diets.

Introduction

Profitability of cattle production could be improved by retaining weaned calves through subsequent stages of production. Because of a seasonal shortage of high-quality forages after weaning in the fall, calves are often backgrounded in drylot before high-quality pasture is available. The growth of stocker cattle will often "stall" for up to 30 d after being switched from drylot diets to pasture. Lippke et al. (2000) observed a negative relationship between the magnitude of change in the ruminal acetate-to-propionate ratio and ADG of calves in the first 7 d of grazing immature wheat pasture. They suggested that this decrease in the ruminal acetate-to-propionate ratio may indicate digestive upset as a cause of poor initial grazing performance (Lippke et al., 2000). Lippke and Warrington (1984) used purified diets formulated to simulate the fiber, protein, and carbohydrate fractions that are commonly found in annual ryegrass and found ruminal acidosis conditions in calves in the first 8 d of feeding. Programmed feeding is a method in which the quantities of feed offered to cattle are calculated to meet a specific rate of gain by using the net energy requirements (Galyean, 1999). Research at our facility has shown that programmed feeding of high-concentrate diets to calves is an economic alternative to feeding hay (Beck et al., 2000). Initial daily gains of growing cattle grazing either fescue or winter-annual pastures (wheat, rye, and ryegrass) were 0.6 lb/d lower ($P < 0.05$) for cattle fed hay and supplement than those of cattle that had been program-fed a high-concentrate diet. The purpose of these experiments is to evaluate the use of four drylot diets on subsequent performance of beef cattle grazing stockpiled tall fescue pasture.

Materials and Methods

On October 14, 1999, 96 weaned calves from the University of Arkansas Southwest Research and Extension Center cow herd were divided into four treatments with two replications per treatment. In order to test the effect of backgrounding diet on subsequent grazing performance, two treatment groups were fed bermudagrass hay with either a rice bran-based supplement (DRY) or a molasses-based self-fed liquid supplement (MOL). Another two treatment groups were program-fed high-concentrate diets (as described by Galyean, 1999), using net energy requirements to match performance of DRY and MOL treatments. High-concentrate diets included either a dry-protein supplement (CON) or molasses-based protein supplement (CONMOL). Adjustments were made to feeding levels of diets throughout the backgrounding period to maintain similar animal ADGs among treatments. The composition of the high-concentrate diets is shown in Table 1. Calves in the DRY treatment were fed 2.5 lb/d of rice bran, which was analyzed to contained 15.3% CP, 0.86 mega-calories (Mcal), net energy for

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maintenance (NEm)/lb, and 0.57 Mcal net energy for gain (NEg)/lb. Rice bran normally contains around 12 to 15% fat. When program-fed calves exhibited signs of excess fat in the diet, the rice bran was analyzed for fat concentration and was found to contain 21% fat. Because of this high-fat content, the rice bran concentration was reduced in the program-fed diets from 44.9 and 36.6% to 22.5 and 18.75% for CON and CONMOL, respectively, on day 47 of drylot. Hay was analyzed and contained 11% CP, 0.44 Mcal NEm/lb and 0.20 Mcal NEg/lb. The molasses-based supplement was offered ad libitum in lick-wheel tanks, and the concentration of protein was adjusted to maintain the desired level of intake, which is from 1 to 3 lb/animal per day. The liquid supplement feeders were monitored daily and refilled as needed. The initial liquid supplement contained 18% CP, 49% TDN, 1% phosphorus, and 60% DM (as-fed basis). When excessive liquid supplement amounts were consumed, the protein concentration was increased to 26% (as-fed basis). Intake of the liquid supplement averaged 3.3 lb/animal per day over the drylot period.

One hundred acres of fall-growth tall fescue (Kentucky-31) were stockpiled from October 1 until December 21 by restricting grazing and fertilizing with 50 lb of nitrogen/acre the first week of October (Gerrish et al., 1993). During the winter grazing period, pastures consisted primarily of tall fescue (76%), cool-season annual grasses (15%), and volunteer annual ryegrass (7%). Forage availability was measured by rising plate meter in mid-January and mid-March. Average forage DM available was 2,961 lb/acre in January and 2,326 lb/acre in March.

On December 21, the calves were removed from drylot, shrunk for 16 h, weighed, and placed in the pasture. The calves were allocated to pastures by treatment, so each treatment was equally represented in each pasture. Calf weights were recorded after the first 14 d of grazing and at 28- to 35-d intervals thereafter (16-h shrink). In late January, near-record snowfall was recorded (19 in), which restricted grazing for nearly 10 d; during this time, bermudagrass hay was fed to the calves on pasture. On February 8, calves in four pastures were given access to liquid molasses-based supplements in lick-wheel-type feeders to test the effect of liquid supplements on performance of growing calves grazing spring regrowth fescue. The initial liquid supplement contained 18% CP, 49% TDN, 1% phosphorus, and 60% DM (as-fed basis). When excessive liquid supplement levels were consumed, the protein concentration was increased to 26% (as-fed basis) in order to reduce supplement consumption.

The effects of backgrounding treatment during the drylot and grazing periods were analyzed by analysis of variance using PROC GLM of SAS (SAS Inst. Inc., Cary, NC) as a completely randomized design with a 2 x 2 factorial arrangement of treatments. Drylot pens were considered the experimental unit, so the treatment effect was tested with pen within treatment as the error term. The effect of backgrounding treatments on performance during drylot and grazing were analyzed by separating least-squares means with contrasts.

Economic Analysis. Cost analysis for the backgrounding treatments, assumed $85/ton hay, which is based on the average current cost of high-quality grass hay including transportation costs of $106/ton corn, $78/ton rice bran, $200/ton liquid supplement, a $10/ton milling charge, and $0.30/animal daily charge for management, labor, and other overhead. The cost of feed ingredients was based on the 10-yr average price of corn ($2.41/bushel). The current price relationship between corn and byproduct feeds, plus a transportation cost of $10/ton and a $20/ton distributor markup, was used to estimate the cost of the byproducts used in the trials. For the economic analysis, program-fed diets were calculated at $110/ton for CON and $120/ton for CONMOL. The supplements used were assumed to cost $150 for DRY, and $200 for MOL based on retail costs of comparable supplements.

Value of gain ($79/cwt) for the stocker enterprise was determined using the 10-yr average price at Oklahoma City National Stockyards of a 400-lb steer in September ($85.86/cwt) and a 665-lb feeder steer in April ($83.12/cwt); this includes the seasonal price increase usually seen with fall-to-spring cattle ownership. The breakeven analysis and determination of enterprise profitability were calculated by subtracting the cost of gain from the $79/cwt value of gain then multiplying by the amount of gain.

Results and Discussion

The performance of calves during the drylot phase is shown in Table 2. At the end of the drylot period, calves on hay-based diets tended to be slightly lighter ($P = 0.08$) than calves on program-fed concentrated diets. There was no treatment interaction ($P = 0.17$) during the drylot period. The ADG of calves during drylot was lower for calves fed hay-based diets compared to calves program-fed concentrated diets ($P < 0.05$). This difference is the result of a tendency for lower ($P < 0.09$) performance of MOL calves compared to DRY, CON, and CONMOL. This lower performance may have been the result of the low energy content of the hay (0.44 Mcal NEm/lb) used in this trial, for which the liquid supplement could not adequately compensate at the desired level of consumption.

The performance of calves after the beginning of grazing stockpiled tall fescue is shown in Table 3. The backgrounding diet x pasture supplementation interaction was not significant ($P > 0.25$), so only the backgrounding effects will be discussed. During the first 14 d of the grazing period, calves fed hay-based diets lost ($P < 0.05$) BW. Calves from program-fed concentrated diets gained ($P < 0.05$) BW, resulting in a net increase in ADG of 1.61 lb/d ($P < 0.05$) compared to hay-fed calves. The calves fed liquid-based supplement gained 0.50 lb/d more ($P < 0.05$) than calves fed dry-protein supplements. Body weight of calves program-fed concentrated diets was higher ($P < 0.05$) than that of calves fed hay-based diets at the end of the first 14-d grazing period and tended ($P = 0.06$) to be higher at the end of the grazing

phase in April (Table 3). Drylot diets had no effect (P = 0.52) on overall pasture ADG, but program-fed calves held a numerical advantage of 0.13 lb/d over calves fed hay.

The profitability of the stocker cattle enterprise was improved (P < 0.05) by an average of $18.50/animal by programmed feeding of high-concentrate diets. The observations from this trial closely resemble those found by Beck et al. (2000), who reported that the programmed feeding of calves corn or corn gluten feed-based diets improved early-season grazing performance and overall profitability of the stocker cattle enterprise compared to backgrounding with hay-based diets.

Implications

Diets fed to calves during backgrounding in drylot before grazing does influence performance early in the grazing season. The addition of molasses to the backgrounding diets improved performance of calves during the first 14 d after the initiation of grazing by 0.50 lb/d. Program feeding concentrated diets improved performance during the same period by 1.61 lb/d. Program feeding concentrate diets to growing cattle during backgrounding improved feed efficiency and decreased feed costs.

Acknowledgments

This research was partially funded by a donation from the American Feed Industry Association – Liquid Feed Committee. We express our appreciation to Quality Liquid Feeds, Inc. (Dodgeville, WI), Fort Dodge Animal Health (Overland Park, KS), and Riceland Foods (Stuttgart, AR) for product donations that made this research possible.

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Table 1. Composition of program-fed diets used during drylot period.

Ingredient	CON I[a]	CON II	CONMOL I	CONMOL II
	% DM			
Rice bran	42.8	22.7	38.9	18.9
Corn	42.3	61.9	38.9	58.9
QLF 34/6[b]	-	-	9.0	9.0
Cottonseed hulls	10.0	10.0	10.0	10.0
Urea	1.3	1.8	-	-
Mineral premix	3.6	3.6	3.2	3.2
Composition				
Crude protein, %	15	15	15	14
NEm, Mcal/lb	0.80	0.81	0.79	0.83
NEg, Mcal/lb	0.52	0.53	0.51	0.54
Fat, %	12.4	8.5	10.8	7.2

[a] Diets fed before rice bran level was reduced in order to reduce fat content of diet are denoted with the Roman numeral I, and after rice bran level reduction, with Roman numeral II. CON treatment was program-fed high-concentrate diets without a molasses-based protein supplement. CONMOL treatment was program-fed high-concentrate diets including a molasses-based protein supplement.

[b] Quality Liquid Feed 34/6—contains 34% CP (with 6% from natural protein sources), 0.51 mcal NEm/lb, 0.36 mcal NEg/lb, and 60% DM.

Table 2. Effect of drylot diet on performance and cost of backgrounding calves.[a]

	Treatment[b]			
Item	DRY	MOL	CON	CONMOL
Body weight, lb				
10/14/1999	466	466	466	463
12/21/1999	551	535	553	552
ADG, lb/d[c]	1.20	1.01	1.28	1.30
Feed:gain, lb feed/lb gain[c]	12.7	15.9	11.8	11.8
Drylot cost, $/animal[cde]	$74	$74	$71	$76

[a] Least-squares means.

[b] Drylot treatments: Calves were fed bermudagrass hay with either a rice bran-based supplement (DRY) or a molasses-based self-fed liquid supplement (MOL) or were program-fed a high-concentrate diet with either a dry-protein supplement (CON) or a molasses-based protein supplement (CONMOL).

[c] Contrast—hay-based diets vs. program-fed ($P < 0.05$).

[d] Contrast—dry diets vs. liquid supplemented diets ($P < 0.05$).

[e] Contrast—dry/liquid vs. hay/program-fed interaction ($P < 0.05$).

Table 3. Effect of drylot diet on subsequent performance of calves grazing stockpiled tall fescue.[a]

	Treatment[b]			
Item	DRY	MOL	CON	CONMOL
Body weight, lb				
12/21/1999	551	535	553	552
1/5/2000[c]	527	521	555	561
4/4/2000	659	648	676	679
Pasture ADG				
Period 1 – 12/21 to 1/5[cd]	–1.47	–.97	.14	.64
Overall pasture ADG	1.05	1.08	1.17	1.22
Overall cost of gain, $/cwt[cd]	$65	$71	$61	$63
Gross margin,[e] $/animal[c]	$34	$21	$46	$46

[a] Least-squares means.

[b] Drylot treatments: Calves were fed bermudagrass hay with either a rice bran-based supplement (DRY) or a molasses-based self-fed liquid supplement (MOL) or were program-fed a high-concentrate diet with either a dry-protein supplement (CON) or a molasses-based protein supplement (CONMOL).

[c] Contrast—hay-based diets vs. program-fed ($P < 0.05$).

[d] Contrast—dry diets vs. liquid supplemented diets ($P < 0.05$).

[e] Calculated by subtracting cost of gain from a $79 /cwt value of gain then multiplying the amount of gain. Value of gain was determined using the 10-yr average price at Oklahoma City National Stockyards of 400-lb steers in September ($85.86/cwt) and 665-lb feeder steers in April ($83.12/cwt).

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

K. Cassida, B. Stewart, S. Gunter, and P. 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 and net return of rotationally and continuously stocked winter annual or bermudagrass pastures at three stocking rates in Southwestern Arkansas. At four calves/acre on winter annual pasture, rotational stocking improved gain/acre and ADG ($P < 0.05$) compared to continuous stocking, but the two systems did not differ at lower stocking rates. Calf performance did not differ between systems on bermudagrass pasture at any stocking rate. Gain/acre and ADG were higher for continuously than rotationally stocked pastures ($P < 0.05$) during the forage transition phase in 1999. In 1999, more hay was fed on continuously grazed pastures, but more hay was harvested from rotated pastures ($P < 0.05$). Benefits for rotational stocking vs. continuous stocking were seen only when stocking rates were pushed to high levels on winter annual pastures.

Introduction

Interest in rotational grazing methods is increasing because of perceived benefits to cattle ADGs, stocking rates, gain/acre, forage production, and control of forage utilization. However, it has proved difficult to demonstrate these effects in controlled research trials, especially on warm-season forages. One reason may be that most experiments comparing grazing systems are conducted using the put-and-take method, in which standing forage supply and quality are equalized across systems by frequent adjustments to the number of animals grazing. This eliminates one of the benefits cited for rotational grazing—that it allows better control of forage supply and quality than continuous stocking. It also does not reflect realistic production practices, because most producers deal with excess forage by haying it.

We are conducting a 6-yr trial to compare continuously and rotationally managed pastures at three fixed stocking rates. Fixed stocking rates are used to create pasture conditions of understocking, ideal stocking, and overstocking, and each pasture is managed for maximum productivity within the stocking rate restriction. Excess forage is harvested as hay. Calf performance for the pilot year and first full year are reported in this paper.

Experimental Procedures

Our farm system is defined as a stocker calf operation in which calves are purchased at weights near 450 lb, preconditioned, and grazed on winter annuals followed by warm-season grass pastures until they reach sale weight (approximately 750 lb), forage is exhausted, or winter annual planting time arrives (~ October 1). Excess forage is harvested as hay both during the grazing season and before winter annual planting. The trial is being conducted at the Southwest Research and Extension Center in Hope using 12 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 (SRs) designed to produce understocked (LOW), ideal (MED), and overstocked (HIGH) pasture conditions. The trial began in 1998 and will continue through 2003. Several management factors were changed between 1998 and 1999 to improve the study, so 1998 is considered a pilot year and the 2 yr cannot be statistically compared.

In 1998, SRs were 1.5, 2.5, and 3.5 calves/acre. In 1999, SRs were increased to 2, 3, and 4 calves/acre because overgrazing was not achieved at the highest 1998 SR. In 1998,

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calves were Limousin-cross heifers (average weight at turnout 500 lb), and in 1999 Angus-cross steers and heifers (average weight 521 lb; 58 steers, 16 heifers) were used. Calves were no more than 25% Brahman breeding and were vaccinated, dewormed, and dehorned if necessary prior to being blocked by weight and gender and turned out on pasture. Calves were grazed from May 15 to October 3 in 1998 and from February16 to August 18 in 1999. The late turnout date in 1998 was a result of pasture availability, and pastures had been uniformly grazed on a continuously stocked mineral supplementation study prior to initiation of this trial. The pulloff date in 1999 was early because cattle had reached their target sale weight of 750 lb. In 1999, calves were dewormed a second time with ivermectin in June. In 1998, calves did not receive growth promotant implants, at the owner's request. In 1999, steers and heifers were implanted with the appropriate Component S product for their gender just prior to turnout and again in June. Calves were shrunk overnight and weighed at the beginning and end of the grazing season. Interim weights (not shrunk) were obtained every 2 mo in 1998 and monthly in 1999. Calves were fed 1 lb/animal per day of a corn-based supplement containing monensin and a mineral premix. Supplement was fed three times per week. All cattle had water and shade available at all times. In 1998, all R pastures were moved on the same day regardless of paddock condition. In 1999, each pasture was managed independently of the others, with cattle moved to new paddocks whenever they had consumed approximately half of the available forage. Cattle on C pastures were fed hay whenever pasture forage biomass was less than 1000 lb/acre, and weights of hay fed were recorded. When cattle on R pastures had less than one day's worth of grazing in any paddock, they were fed hay in a sacrifice paddock until rotation could be resumed.

Winter annuals were drilled into short-grazed or mowed sods in October. There was no winter annual grazing period in 1998 because warm-season grass was already the primary sward component when cattle were turned out. 'Hickory' wheat and 'Marshall' ryegrass were a minor component of swards in mid-May 1998. In 1999, winter annuals were wheat (variety not stated, 90 lb/acre), Marshall ryegrass (20 lb/acre), crimson clover ('Dixie', 15 lb/acre), and ladino white clover ('Osceola', 3 lb/acre). Pastures were not grazed between annual planting in October 1998 and calf turnout in February 1999. The summer component of pastures was mixed common bermudagrass, Coastal bermudagrass, dallisgrass, and crabgrass. Nitrogen (30 to 50 lb/acre) was applied to annual stands near November, February, and April each year, and to warm-season grass stands in June, July, and August. Potash (total 110 lb/acre per year) was applied to warm-season grass stands in April and June 1999.

This trial is designed to study the total stocker cattle per forage production system. Data were also collected on forage biomass availability, growth rates, forage quality, forage utilization, botanical composition changes over seasons and years, weather conditions, costs of production, value of production, and mapped soil fertility gradients in the pastures. These data are not presented here because of space constraints.

Data were analyzed using analysis of variance, with initial animal weight as a covariate (SAS Inst. Inc., Cary, NC). In 1999, animal gender was also included in the model. Pasture was the experimental unit. Stocking rate effects were analyzed as linear and quadratic polynomial contrasts. Animal performance data are reported as least-squares means. Years were analyzed separately. In 1999, the grazing season was divided into three periods with different forage types. Periods were February to April (winter annual period), May to June (transition period), and July to September (warm-season-grass period).

Results and Discussion

In 1998, when calves were not turned out until warm-season grass was already the primary pasture component, the grazing system had no impact on performance at any date (Table 1). Other researchers have also reported no benefit to rotational grazing when cattle graze bermudagrass-based pastures (Aiken, 1998; DeRouen et al., 1999; Kee et al., 1991). Tharel (1989) reported improved gain/acre with rotational grazing on bermudagrass in Booneville, Arkansas. Gain/acre increased linearly ($P < 0.05$) with increasing SR, while ADG, final calf weight, and gain/calf decreased linearly ($P < 0.01$) with increasing SR. Hay feeding was not required in 1998. There were no treatment differences ($P > 0.05$) for hay harvested prior to winter annual establishment.

In 1999, the effects of grazing system and SR were not the same in each forage period (Table 2). More than 50% of the total season gain/acre was produced in the winter annual phase for all treatments except C-HIGH. When calves grazed winter annuals, grazing system interacted with SR for ADG ($P < 0.08$) and gain/acre ($P < 0.05$) such that these variables did not differ between C and R at LOW or MED SRs. However, at HIGH SR, ADG was 0.80 lb/d higher and gain/acre was 256 lb/acre higher for R than for C pastures ($P < 0.05$). Within grazing systems, ADG decreased linearly with SR on C pastures ($P < 0.10$). Gain/acre tended toward a quadratic relationship with SR ($P < 0.14$), with the highest gains at the MED rate. This suggests that we were successful in achieving an overstocked condition on the C-HIGH treatment. On R pastures, ADG was not affected by SR ($P > 0.05$), and gain/acre increased linearly with SR ($P < 0.05$). The lack of difference in ADG at different SRs indicates that animal performance was not being limited by forage availability or quality on R winter annual pastures.

During the transition period in 1999, ADG, gain/calf, and gain/acre were all higher ($P < 0.05$) for C than for R pastures. In the transition period, SRs did not affect ADG or gain/calf ($P > 0.05$), and gain/acre increased linearly with increasing SRs ($P < 0.01$). Forage quality samples are currently being analyzed to see whether diet quality was a factor in these differences. The R pastures had more available

forage than C pastures during the transition period (biomass data not shown), but forage quality was likely lower on the R pastures because R calves were grazing mature headed ryegrass, while C calves were grazing immature lush bermudagrass and dallisgrass (botanical composition data not shown). This occurred because C calves grazed out their winter annual forages early in the season, while rotational stocking maintained this forage component well into June. Weather also contributed to accumulation of over-mature forage by delaying harvest of excess hay from spring pastures until the end of May.

During the 1999 warm-season grass period, grazing system did not affect any aspect of calf performance ($P > 0.05$). Gain/acre increased as the SR increased ($P < 0.06$), but ADG was not affected by SR ($P < 0.05$).

For 1999 as a whole, treatment differences generally reflected those found during the winter annual period. Grazing system and SRs interacted ($P < 0.01$). There was no difference between C and R systems until the HIGH SR was reached, where ADG and gain/acre were higher on R than C pastures ($P < 0.05$). The relationship between SR and gain/acre tended to be quadratic within both C ($P < 0.15$) and R ($P < 0.01$), with numerical peaks reached at C-MED and R-HIGH within systems. On R pastures, season ADG was not affected by SR ($P > 0.05$), while ADG tended to decrease linearly with increasing SR on C pastures ($P < 0.12$)

There was a grazing system x SR interaction for hay fed in 1999 ($P < 0.05$). Hay feeding was required on C-MED and C-HIGH pastures in spring and for C-HIGH pastures in August, while R-HIGH pastures required only a small amount of hay feeding in spring. Hay was harvested from all LOW SR pastures and from R-MED pastures in spring, and from all pastures except C-HIGH just prior to winter annual planting. The total hay yield decreased as the SR increased ($P < 0.05$), and more hay was harvested from R pastures than from C pastures overall ($P < 0.05$). More hay was harvested than was fed for all R pastures and C-LOW pastures, while C-MED and C-HIGH pastures harvested less hay than was fed.

Implications

At high stocking rates on winter annual pasture, rotational stocking increased stocker calf ADG, gain/acre, and hay yield over continuous stocking and decreased the amount of hay fed. At lower stocking rates on winter annuals and on bermudagrass at all stocking rates, there was no advantage to either grazing system.

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Table 1. Calf performance when rotationally or continuously grazed at 1.5, 2.5, or 3.5 calves/acre (low, medium, high) stocking rates from May to October 1998.

	Continuous system			Rotational system			Statistical
Item	Low	Medium	High	Low	Medium	High	significance[a]
Body weight, lb	644	596	583	653	586	571	SR linear**
ADG, lb/day	1.22	0.89	0.80	1.29	0.82	0.71	SR linear**
Gain, lb/calf	175	127	114	184	116	102	SR linear**
Gain, lb/acre	260	302	396	275	290	365	SR linear**
Hay fed, lb DM/acre	0	0	0	0	0	0	NS[1]
Hay baled, lb DM/acre	2825	875	0	2600	1950	2650	NS

[a] ** Effects were different ($P < 0.01$) level of probability.

[1] NS = not significantly different.

SR = stocking rate, DM = dry matter.

Table 2. Calf performance when rotationally or continuously grazed at 2, 3, or 4 calves/acre (low, medium, high) stocking rates from February to August 1999.

	Continuous system			Rotational system			Statistical
	Low	Medium	High	Low	Medium	High	significance[a]
Winter annual period (February to April)							
Body weight, lb	743	714	658	728	736	690	Interaction*
ADG,[1] lb/d	3.06	2.37	1.42	2.83	2.73	2.22	System,† SR linear***
Gain, lb/calf	257	199	119	238	230	186	System,† SR[1] linear***
Gain, lb/acre	510	600	486	474	686	742	Interaction*
Forage transition period (May to June)							
Body weight, lb	830	794	735	776	780	751	Interaction**
ADG, lb/d	1.52	1.40	1.38	0.83	0.94	1.08	System**
Gain, lb/calf	87	80	78	47	54	62	System**
Gain, lb/acre	174	240	310	95	163	247	System*, SR linear**
Warm-season grass period (July to August)							
Body weight, lb	906	857	769	858	866	810	SR linear***
ADG, lb/d	1.26	1.54	1.44	1.75	1.57	1.24	NS[1]
Gain, lb/calf	54	66	62	75	68	53	NS
Gain, lb/acre	106	200	254	150	199	213	SR linear*
Year (February to August)[2]							
Body weight, lb	822	784	726	769	760	746	SR linear***
ADG, lb/d	1.90	1.56	1.12	1.54	1.56	1.40	Interaction**
Gain, lb/calf	349	286	207	283	286	257	Interaction**
Gain, lb/acre	696	863	828	565	860	1022	Interaction**
Hay fed, lb DM/acre	0	1426	2504	0	0	532	Interaction*
Hay baled, lb DM/acre	5771	540	0	5548	3393	2766	System,† SR linear*

SR = stocking rate.

[a] †,*, **, *** Effects were significantly different at the 0.10, 0.05, 0.01, and 0.001 levels of probability, respectively.

[1] NS = not significantly different.

[2] Weights for full-year data are based on shrunk weights; interim period weights are not shrunk.

Growth Performance by Stocker Steers Grazing Bermudagrass Pastures and Fed Soybean Hulls, Grain Sorghum, or a Combination of Soybean Hulls and Grain Sorghum

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

Story in Brief

A 107-d grazing study was conducted to evaluate the effect of feeding soybean hulls, grain sorghum, or a 50:50 mixture of the two on growth performance by stocker cattle grazing bermudagrass in the summer. A total of 72 mixed-breed stocker steers (550 ± 8.3 lb) were allocated randomly by weight into nine groups and grazed bermudagrass pastures from May 27 until September 11, 1999. Steers were fed 4.2 lb/d Monday through Friday of either soybean hulls, grain sorghum, or a 50:50 mixture of soybean hulls and grain sorghum. All steers were fed 0.5 lb/d Monday through Friday of a soybean meal-based supplement containing salt, trace minerals, and bambermicin. Weight gains did not differ (P > 0.10) among steers fed the various supplements. Therefore, when available and prices are favorable, soybean hulls can be substituted successfully for grain sorghum in supplements for stocker cattle grazing bermudagrass pastures.

Introduction

Numerous feedstuffs that are a byproduct from another process are available for feeding to ruminant animals. Soybean hulls are the external seed coat from soybeans and are a byproduct of processing of soybeans for oil and meal. Soybean hulls are high in fiber (66% neutral detergent fiber) but low in lignin (3%; NRC, 1996) and therefore are highly digestible. In previous studies, no differences in gain were observed in cattle fed either soybean hulls or corn while grazing smooth bromegrass (Anderson et al., 1988) or native grass pastures (Hibbert et al., 1987). The objective of this study was to compare growth performance by stocker cattle grazing bermudagrass and fed soybean hulls, grain sorghum, or a 50:50 mixture of soybean hulls and grain sorghum.

Experimental Procedures

Seventy-two mixed-breed steers were received at the University of Arkansas Southeast Research and Extension Center in Monticello on April 16, 1999, and had received respiratory and clostridial vaccinations and a growth-promoting implant prior to arrival at the station. Steers initially grazed late-season rye, wheat, and ryegrass that had been overseeded into bermudagrass pastures the previous fall. Steers were weighed on May 27 following a 12-h shrink, stratified by weight, and allocated randomly to one of nine groups. The groups were then allocated randomly to receive 4.2 lb/d Monday through Friday of soybean hulls, grain sorghum, or a 50:50 mixture of soybean hulls and grain sorghum. All steers were fed 0.5 lb/d (Monday through Friday) of a 48% soybean meal-based supplement containing salt, trace minerals, and bambermicin (Table 1). Groups of steers were then allocated randomly to one of nine bermudagrass pastures for a 107-d study. Pastures were fertilized with a complete commercial fertilizer to provide 50 lb/acre of each of nitrogen, phosphate, and potash in late May and 50 lb/acre nitrogen in early July.

Steers were weighed on July 15 and September 11 without prior removal from pasture and water. A 4% pencil shrink was applied to weights on September 11 to serve as a final weight. Data were analyzed statistically using SAS (SAS Inst., Inc., Cary, NC.) procedures for a completely randomized design.

Results and Discussion

Weight and gain did not differ (P > 0.10) among treatments. There was a slight numerical tendency for a reduction in gain (0.14 lb/d; P = 0.35) from steers fed soybean hulls compared with those fed the other treatments. Hibbert et al. (1987) also observed a slight but nonsignificant reduction in gain (0.08 lb/d) by heifers grazing native grass and supplemented with soybean hulls compared with those supplemented with corn. Anderson et al. (1988) reported no difference in gain by stocker steers grazing smooth

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bromegrass and fed soybean hulls or corn (2.11 vs. 2.08 lb/d for soybean hulls vs. corn, respectively). Anderson et al. (1988) also reported a 0.15 lb/d increase in gain by heifers grazing corn stalks and fed soybean hulls compared with corn. Therefore, gain by stocker calves should differ minimally when fed the same level of grain sorghum or soybean hulls.

Implications

Prices for feed commodities vary with season, year, and location. Often, surplus supplies of one feed commodity lead to a reduction in price relative to other commodities. Based on the results from this study and others, we conclude that price or convenience should be used to make decisions whether to feed soybean hulls or grain sorghum as an energy supplement for stocker calves grazing bermudagrass pastures. Relative differences in animal gain are not sufficient to warrant feeding one over the other based on expected differential in animal growth.

Acknowledgments

Appreciation is expressed to Riceland Foods, Stuttgart, AR, for donation of soybean hulls.

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Table 1. Composition of supplements fed to steers grazing bermudagrass pastures during the summer.

Item	% of supplement
Soybean meal	91.41
White salt	5.89
Liquid molasses	2.15
GainPro – 10	0.42
Trace mineral mix[a]	0.13

[a] Contains copper sulfate, zinc sulfate, 1% selenium premix, and calcium iodide.

Table 2. Growth performance by stocker steers grazing bermudagrass pastures and fed soybean hulls, grain sorghum, or a 50:50 mixture of soybean hulls and grain sorghum.[a]

	Grain sorghum	50:50 mix	Soybean hulls	SE
Initial weight, lb	550	550	550	0.2
Weight - day 49, lb	631	630	627	4.1
Final weight, lb	717	717	701	7.9
Total gain, lb	166	166	151	7.8
Daily gain, lb	1.55	1.55	1.41	0.073

[a] No significant differences were detected ($P > 0.10$).

Effects of Supplementation and Nitrogen Fertilization on Performance of Stocker Cattle Grazing Warm-Season Perennials

J. Weyers, S. Gunter, P. Beck, and K. Cassida[1]

Story in Brief

Seventy-six steers (average BW = 575 lb) were randomly assigned to 12 pastures, which were stocked at normal (2.5 and 3.5 steers/acre) and increased (3.0 and 4.0 steers/acre) rates. Six pastures were assigned to a low rate of nitrogen (N; 100 lb of N/acre) and six pastures were assigned to a high rate of N (166 lb of N/acre) along with three supplementation treatments. The supplement treatments (Farmland Beef Grow-Gest) were fed at 0.65% of BW and treatments within each N fertilization rate consisted of 1) nonsupplemented at normal stocking rates, 2) supplemented at normal stocking rates, or 3) supplemented at increased stocking rates. Across fertilization rates, supplementation fully compensated for the increased stocking rates. Across supplementation and stocking rates, the high rate of N fertilization did not provide the essential forage mass necessary to maintain adequate animal performance of the additional steer/acre. The high rate of N fertilization showed an increased gain/acre, but it was the result of the additional stocking rate and not increased individual animal performance. The low supplemental feed-to-added gain ratios suggest that supplementation is beneficial and economical at the lower N fertilization rate. However, the high supplemental feed-to-added gain ratios at the higher N fertilization rate indicates that forage probably was limiting.

Introduction

Supplementation has provided producers an option for manipulating the performance of pastures and cattle. Depending on management decisions, supplementation can extend the grazing season by conserving forage mass. Prior research has shown that if supplementation is provided at amounts greater than 0.45% of BW, a significant reduction in forage intake will be observed (Pordomingo et al., 1991; Mieres, 1992). If forage intake is reduced and nitrogen (N) fertilizer is applied, it should be possible to increase carrying capacity of the pasture, which would possibly enhance economic performance. Supplementation may also affect ADG and increase the performance of grazing stocker cattle. Research at the Southwest Research and Extension Center, Hope (Gunter et al., 1998) has shown that the most profitable stocking rates for stocker cattle grazing dallisgrass pastures are between 2.46 and 3.20 steers/acre, depending on the amount of N fertilizer applied. Utilization of both supplementation and a high rate of N fertilization to increase forage availability may allow for the addition of an extra animal per acre.

Therefore, this research was conducted to evaluate the effects of high-energy supplementation, N fertilization, and stocking rate on the performance of stocker cattle grazing warm season perennial pastures.

Experimental Procedures

This experiment was conducted at the Southwest Research and Extension Center on 24 acres divided into 12 2-acre pastures. The soil type was an Una silty clay loam, which consists of deep, poorly drained, level soils (slopes, 0 to 1%) located on a floodplain. This soil type has a seasonally high water table in the winter and spring and is predicted to produce approximately 7.5 animal-unit-mo/acre per year. These swards are primarily dallisgrass (39%), common bermudagrass (34%), and tall fescue (20%), but also contain other grasses and forbs.

Animals and Treatments. Seventy-six steer calves (initial shrunk BW = 575 lb) were obtained through local salebarns. After a 16-h shrink, the cattle were weighed, ear-tagged, implanted (Component-ES; Ivy Laboratories, Inc., Overland Park, KS), dewormed (Cydectin; Fort Dodge Animal Health, Inc., Overland Park, KS), and randomly assigned to one of the 12 pastures. The cattle had previously been vaccinated for infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza-3, and bovine respiratory syncytial virus plus *Haemophilus somnus*, and seven strains of *Clostridium* before arrival at the Research Center. Pastures were assigned one of to two rates of N fertilization (100 or 166 lb/acre) and one of three supplementation treatments.

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The supplement (Farmland Beef Grow-Gest; 15% CP) was fed at 0.65% of BW, adjusted at each weighing day. Treatments within each N fertilization rate consisted of 1) nonsupplemented (NS) at normal stocking rates (2.5 or 3.5 steers/acre for 100 or 166 lb N/acre, respectively), 2) supplemented (S) at normal stocking rates, or 3) S at an increased rate (3.0 or 4.0 steers/acre for 100 or 166 lb of N/acre, respectively). The cattle were allowed ad libitum access to water and a free-choice mineral supplement (Farmland B-1440), which provided 200 mg/d of lasalocid. Because of drought conditions (precipitation was 21% of normal), the planned 150-d grazing period was restricted to 104-d (May 13 to August 24). Steers were weighed unshrunk at 35-d intervals during the grazing period, and on day 70, they were reimplanted (Component-ES).

Pasture Management. Upon initiation of this trial, soil concentrations of phosphorus and potassium were increased to recommended levels according to the Arkansas Cooperative Extension Service for high production. Pastures were also fertilized with equal amounts of N in the form of ammonium nitrate during this time and at subsequent 50-d interval to total the specified rate of nitrogen.

Statistical Analysis. Dependent variables were analyzed as a 2 x 3 factorial arrangement in a completely random design with initial BW as a covariate. Because pasture was the experimental unit, pasture within treatment was the error term. Data were analyzed by analysis of variance, and least-squares means were separated using contrasts: 1) NS steers vs. S steers at the normal stocking rate; 2) S steers at normal stocking rate vs. S steers at the increased stocking rate; 3) NS steers vs. S steers at the increased stocking rate; and 4) 100 lb of N/acre vs. 166 lb of N/acre.

Results and Discussion

The effects of supplementation and N fertilization rate did not interact ($P > 0.15$) for the response variables of BW, ADG, or gain/acre (Table 1). At the normal stocking rate, ADG and gain/acre were less ($P < 0.05$) for the NS (1.23 and 1,035 lb, respectively) than for S steers (1.94 and 1,509 lb, respectively) across fertilizer rates, and ADG and gain/acre were greater ($P < 0.05$) for the S steers at the normal stocking rate than for the S steers at the increased stocking rate (1.65 and 1,332 lb, respectively). Supplemented steers at the increased stocking rate had a greater ($P < 0.05$) ADG and gain/acre than NS steers. These data suggest that supplementation of steers grazing at the increased stocking rate was sufficient to provide enough residual forage for the additional steer compared to NS steers.

Steers grazing pastures fertilized with the low rate of N had a greater ($P < 0.05$) ADG (1.72 lb) than steers grazing pastures fertilized at the high rate of N (1.48 lb), while the gain/acre was greater ($P < 0.05$) for high N pastures (1,383 lb) compared to that for steers grazing low N pastures (1,200 lb). The lower ADG for the high level of N fertilization is probably the result of a lack of rainfall during the trial, which decreased forage availability. The increased gain/acre for the high rate of N fertilization was expected because of the increased stocking rate but did not result from increased individual animal performance.

The ratios of supplemental DM to added gain interacted between S steers and N fertilization rate ($P < 0.05$; Table 1). The ratios of supplemental DM to added gain at the low N level were similar for both stocking levels (5.6 vs. 6.7 lb). On high N pastures, the ratio of supplemental DM to added gain was larger ($P < 0.05$) for the high stocking rate (6.6 vs. 16.5 lb for stocking rates of 3.5 and 4.0, respectively). The low rate of N fertilization coupled with a supplementation program provided adequate forage availability and supplemental nutrients for these animals to maintain and gain considerable amounts of BW. Also, the level of supplementation provided at 0.65% of BW did prove to be enough to suppress forage intake at the lower rate of N fertilization.

Implications

Supplementing grazing cattle, while applying N fertilizer at 100 lb/acre, seems to be a practical management decision. The low supplemental feed-to-added gain ratios obtained with this management technique would indeed be beneficial to a producer who is looking to increase the overall economical status of their pastures. In a year with adequate rainfall, the higher level of N fertilizer may produce a more economical gain, but this hypotheses needs to be tested.

Acknowledgments

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Table 1. Effects of supplementation, nitrogen fertilization, and stocking rate on stocker cattle grazing dallisgrass pasture.

Fertilizer rate	100 lb nitrogen/acre			166 lb nitrogen/acre			
Stocking rate, animals/ac	2.5	2.5	3.0	3.5	3.5	4.0	
Supplementation	No	Yes	Yes	No	Yes	Yes	SE[a]
Initial BW, lb	575	575	575	575	575	575	—
Day 34[bcd]	656	689	660	639	674	635	4.3
Day 69[bcd]	699	742	727	687	730	681	5.1
Day 104[bcde]	705	787	769	699	766	724	13.3
Period 1 ADG, lb[bcd]	2.39	3.34	2.50	1.89	2.91	1.76	0.13
Period 2 ADG, lb	1.22	1.52	1.89	1.42	1.60	1.31	0.24
Period 3 ADG, lb[be]	0.17	1.30	1.21	0.32	1.02	1.25	0.31
Overall ADG, lb[bcde]	1.25	2.04	1.87	1.19	1.84	1.44	0.06
Gain per acre, lb[bcde]	856	1,458	1,288	1,213	1,559	1,376	26.0
Supplemental DM/added gain, lb:lb[cdf]	—	5.6	6.7	—	6.6	16.5	0.8

[a] n = 2.

[b] Contrast of nonsupplemented steers vs. supplemented steers at normal stocking rates ($P < 0.05$).

[c] Contrast of supplemented steers at normal stocking rates vs. supplemented steers at the increased stocking rates ($P < 0.05$).

[d] Contrast of fertilizer rates, 100 vs. 166 lb/acre of nitrogen ($P < 0.05$).

[e] Contrast of nonsupplemented steers vs. supplemented steers at the increased stocking rates ($P < 0.05$).

[f] Contrast of interaction fertilizer rate by stocking rate ($P < 0.05$).

Evaluation of Small-Grain Forage for Stocker Cattle Production During Winter and Spring

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Story in Brief

Seventy-two preconditioned, crossbred steers (average BW = 500 lb) were placed on pastures containing various small-grain forage from January 6 to April 18, 2000. The pastures were 2 acres and were seeded to 1) 'Jaypee' wheat, 2) 'Elbon' rye, 3) 'Bob' oats, 4) 'Marshall' ryegrass, 5) Jaypee wheat plus Elbon rye, 6) Jaypee wheat plus Marshall ryegrass, 7) Elbon rye plus Marshall ryegrass, or 8) Jaypee wheat, Elbon rye and Marshall ryegrass. These treatments were replicated three times. No differences were measured in ADG, total gain, or gain per acre as a result of grazing on pastures of single small grains or combinations of small grains. The gains of steers were good, with the overall ADG of 2.87 lb/d, 321 lb/animal TG, and 475 lb gain/acre. These data suggest that all small grains or combinations of small grains provide excellent forage from January through April for stocker cattle production.

Introduction

Forage of small grains has been used as pasture for cattle in Arkansas for years. However, small grains have primarily been overseeded into bermudagrass pastures during late September and during October. Coffey et al. (2000) overseeded either Marshall ryegrass, Marshall ryegrass plus Madison soft red winter wheat, or Marshall ryegrass plus 'Bonel' rye during late September into a bermudagrass-dallisgrass sod. Total weight gain and return ($/animal) were greater, and cost of gain was lower for calves that grazed forage from small grains than calves fed hay and grain. Weight gains did not differ among calves which grazed forage of Marshall ryegrass, Marshall ryegrass plus 'Madison' soft red winter wheat or Marshall ryegrass plus Bonel rye, but cost of gain was lowest and return per animal highest ($/animal) for those calves that grazed ryegrass, followed by rye plus ryegrass. Daniels et al. (2000) reported excellent growth of steers that grazed soft red winter wheat forage, seeded in early September in a tilled seed bed, from November through April. Therefore, it was the objective of this study to evaluate the growth of stocker steers grazing wheat, rye, oats, ryegrass, wheat plus rye, wheat plus ryegrass, rye plus ryegrass and wheat, rye and ryegrass, seeded in a tilled seedbed, during winter and spring.

Experimental Procedures

Twenty-four 2-acre pastures were seeded on September 27, 28, and 29, 1999, into a prepared seedbed as follows:

1. 120 lb/acre of Jaypee 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 Jaypee wheat plus 75 lb of Elbon rye
6. 90 lb/acre of Jaypee wheat plus 20 lb of Marshall ryegrass
7. 90 lb/acre of Elbon rye plus 20 lb of Marshall ryegrass
8. 75 lb/acre of Jaypee wheat plus 75 lb of Elbon rye plus 20 lb of Marshall ryegrass.

All pastures were fertilized at seeding according to soil analyses. Seventy-two preconditioned, commercial, crossbred steers, averaging 500 lb BW, were placed on their respective pasture at a stocking density of 750 lb beef per acre (1.5 steers/acre) on January 6, 2000, and the steers grazed continuously until April 18, 2000. All steers were implanted with Ralgro and were fed 2 lb of corn per animal per day containing 70 mg/lb of rumensin. Steers were weighed, using a 12-h shrunk weight, initially and every 28 d thereafter.

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A commercial trace mineral salt was fed free choice. The data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

The ADG, total gain (TG), and gain per acre (G/A) of steers that grazed small-grain forage are reported in Table 1. No differences in ADG, TG, or G/A ($P > 0.05$) were observed for steers grazing from January 6 through April 18. Numerically, ADG was highest for those steers that grazed wheat and ryegrass (3.07 lb), followed by rye + ryegrass (2.99 lb), oats (2.95 lb), wheat + rye + ryegrass (2.93 lb), wheat + rye (2.90 lb), rye (2.77 lb), wheat (2.75 lb), and ryegrass (2.59 lb). These gains are greater than those reported by Coffey et al. (2000) for steers that grazed overseeded ryegrass (2.36 lb), rye + ryegrass (2.16 lb), or wheat plus ryegrass (2.12 lb) and by Daniels et al. (2000) for steers that grazed wheat forage (2.5 lb) seeded in a prepared seedbed. Our data show that wheat, oats, rye, ryegrass, or combinations of these seeded in a prepared seedbed produce excellent forage for stocker cattle.

Implications

Single small grains or combinations of small grains provide excellent forage for stocker cattle during the fall, winter, and spring. Stocker cattle producers need to consider planting small grains in a prepared seedbed in early September for forage. These small grains will provide seedbed in early September for forage and will provide ample, high-fidelity forage from late October to early May to promote over 2 lb of growth per animal per day.

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Coffey, K.P., et al. 2000. Ark. Agri. Expt. Stat. Res. Series 470:77.

Table 1. Average daily gain (ADG), total gain (TG), and gain per acre (G/A) of steers that grazed small grain forage.*

Treatment	ADG, lb	TG, lb	G/A, lb/acre
Wheat	2.75 ± 0.14	308.7 ± 15.2	463
Rye	2.77 ± 0.14	310.8 ± 15.2	466
Oats	2.95 ± 0.14	330.6 ± 15.2	496
Ryegrass	2.59 ± 0.14	289.6 ± 15.2	434
Wheat + rye	2.90 ± 0.14	324.8 ± 15.2	487
Wheat + ryegrass	3.07 ± 0.15	344.3 ± 16.3	458
Rye + ryegrass	2.99 ± 0.14	334.8 ± 15.2	502
Wheat + rye+ryegrass	2.93 ± 0.14	328.3 ± 15.2	493
Average	2.87 ± 0.14	321.5 ±15.2	475
SE			27

* No significant treatment effects were found ($P > 0.05$).

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

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Story in Brief

Thirty-two preconditioned Angus steers, averaging 503 lb of body weight, were randomly assigned on November 17, 1999 to 2-acre replicated pastures containing forage of either Agri Pro Foster, Agri Pro Shiloh, Agri Pro Elkheart, Pioneer 2580, Coker 9543, Coker 9663, Delta King 9027 or Jaypee cultivars of soft red winter wheat. Steers grazed for 161 d but forage was limited during the last 17 d of grazing. Steers which grazed Delta King 9027 forage had the highest ADG (3.87 lb), followed by those which grazed Coker 9543 (3.76 lb), Jaypee (3.59 lb), Agri Pro Elkheart (3.50 lb), Pioneer 2580 and Agri Pro Shiloh (3.49 lb), Coker 9663 (3.42 lb) and Agri Pro Foster (3.23 lb) after 144 d of grazing. However, ADG did not differ statistically (P = 0.30). All ADG were high suggesting that forage from all tested wheat cultivars is exceptional for producing stocker cattle from November through April.

Introduction

Over one million acres of soft red winter wheat are planted each year for grain production in Arkansas. 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 economical renewable resource (Daniels et al., 1999). Income is derived from both grain and the increased value as weight gain that is added to growing cattle that graze winter wheat forage (Daniels et al., 1999). Several cultivars of soft red winter wheat are planted in Arkansas each year for grain production. However, most of the predominant cultivars planted in the state have not been evaluated for the production of forage used in a stocker cattle operation. 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). Therefore, it was the objective of this study to evaluate growth performance of stocker cattle grazing forage of the common cultivars of soft red winter wheat planted in the state for grain production.

Experimental Procedures

Eight cultivars of soft red winter wheat were seeded at a rate of 120 lb/acre on September 27 or 28, 1999 in prepared seedbeds. The wheat was seeded in 2-acre pastures, and each cultivar was replicated. Cultivars planted were Agri Pro Foster, Agri Pro Shiloh, Agri Pro Elkheart, Pioneer 2580, Coker 9543, Coker 9663, Delta King 9027, and Jaypee. All pastures were fertilized according to soil analyses. Thirty-two Angus steers averaging 503 lb BW were assigned randomly to pastures at a stocking density of one steer (503 lb) per acre on November 17, 1999, and they grazed until April 26, 2000. All steers were born and raised at the Livestock and Forestry Branch Research Station and were weaned and preconditioned 30 d 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 mixture was fed free choice. Steers were weighed, using a 12-h shrunk weight, initially and at 28-d intervals. The data were analyzed using GLM procedures of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

The ADG and total gain (TG) of steers that grazed forage of various cultivars of soft red winter wheat for 144 and 162 d are given in Table 1. There were no differences in ADG or TG of steers that grazed 144 d of grazing; however, when these steers had grazed for 161 d, differences approached significance (P < 0.09). The ADG and TG of steers were lower during the last 17 d of grazing. The reduced

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gains were most likely due to shortage of forage, lower quality of forage because of the maturity of both the wheat plants the steers. These data differ from that reported by Horn et. al. (1994) and Gribble and Krenzer (1994), who observed differences in ADG and TG of steers that grazed forage of different cultivars of hard red winter wheat.

Average daily gain and TG were highest for steers that grazed Delta King 9027 (3.87; 3.71 lb), followed by Coker 9543 (3.76; 3.65 lb) and Jaypee (3.59; 3.54 lb) for 144 and 161 d of grazing, respectively. However, ADG and TG of steers that grazed forage of all soft red winter wheat cultivars were exceptionally high, averaging 3.54 and 3.43 lb at 144 and 161 d of grazing, respectively. These gains were higher than those reported by Daniels et al. (1999) for steers that grazed soft red winter wheat forage of Hickory or Jaypee cultivar and by Horn (1994) for steers that grazed hard red winter wheat. Daniels et al. (2000) observed that steers that grazed forage of the same eight cultivars of soft red winter wheat from November 1, 1998, through February 28, 1999, had lower ADGs and TGs than in the present study. During the 1998-99 study, steers had the following ADGs: Pioneer 2580 (2.7 lb), Agri Pro Elkheart (2.6 lb), Agri Pro Foster (2.5 lb), Coker 9543 (2.4 lb), Delta King 9027 (2.4 lb), Jaypee (2.3 lb), Coker 9663 (2.2 lb), and Agri Pro Shiloh (2.1 lb). Therefore, these data show that forage of these eight cultivars of soft red winter wheat is exceptional for producing stocker cattle from November through April.

Implications

These data show that soft red winter wheat cultivars Pioneer 2580, Agri Pro Elkheart, Agri Pro Foster, Agri Pro Shiloh, Coker 9543, Coker 9663, Delta King 9027 and Jaypee provide high quality forage for producing stocker cattle from November through April. These wheat cultivars should be planted in a prepared seedbed in early September.

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Table 1. Evaluation of eight cultivars of soft red winter wheat forage on ADG and total gain of grazing stocker steers at 144 and 161 d of grazing.

	ADG, lb		Total gain, lb	
Cultivar	144 d	161 d	144 d	161 d
Delta King 9027	3.87	3.71	557	598
Coker 9543	3.76	3.65	541	588
Jaypee	3.59	3.54	517	571
Agri Pro Elkheart	3.50	3.32	504	534
Pioneer 2580	3.49	3.23	503	520
Agri Pro Shiloh	3.49	3.37	503	542
Coker 9663	3.42	3.29	493	530
Agri Pro Foster	3.23	3.31	465	533
SE	0.18	0.11	0.25	0.17
P value	0.38	0.09	0.38	0.09

Degradation Kinetics of Nitrogen in Cereal-Grain Forages in Northern Arkansas

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Story in Brief

Wheat, oats, and rye were interseeded into a dormant bermudagrass sod and harvested throughout the spring. Plant growth stage was documented for each forage on each harvest date, and harvested forages were evaluated for quality characteristics of nitrogen (N). Digestion kinetics of N were evaluated by the in situ method. Concentrations of N were exceptionally high through the early stages of stem elongation for all forages. Ruminal degradation kinetics of N indicated that the potential extent and effective ruminal degradability were high, and rates were rapid. As a proportion of the entire N pool, the effective degradability of N declined to a minimum immediately before grain fill for all forages.

Introduction

Wheat, oats, and rye are drilled routinely into dormant warm-season grass sods to provide fall, winter, and spring grazing for ruminant production systems. This practice works well throughout the mid-southern United States because the climate is favorable for some continued growth of cereal grains throughout the late fall and winter. In contrast, growth of interseeded cereal grain forages in the northern portion of the bermuda adaptation zone is delayed until early or mid-March. At that time, cool-season perennials, particularly tall fescue, are growing, and they do not require yearly expenditures for establishment. Alternative conservation strategies for overseeded cereal grains can be observed throughout the northern portion of the bermuda adaptation zone; these include a single harvest for hay, balage, or chopped silage. Few studies have evaluated nitrogen (N) degradation kinetics over a wide range of harvest dates. The objective of this study was to evaluate sod-seeded wheat, oats, and rye forage harvested on six dates between March and June in northern Arkansas for quality characteristics of forage N, and for in situ N degradation kinetics.

Experimental Procedures

Establishment. This study was conducted at the Livestock and Forestry Branch Station located near Batesville. The base sod at this site was 'Tifton 44' bermudagrass that was harvested as hay in mid-August. Regrowth following haying was minimal because of droughty weather conditions; no further removal of existing vegetation was attempted before establishing the study. Cereal grain cultivars selected for this study included 'Jaypee' wheat, 'Elbon' rye, and 'Ozark' oats. Plots (10 by 30 ft) were fertilized to soil test recommendations of the Cooperative Extension Service and seeded in 10-in rows with a 80-in wide Tye Pasture Pleaser (Tye Company, Lockney, TX) no-till drill on September 24, 1997, at seeding rates of 90, 90, and 96 lb of pure live seed per acre for wheat, rye, and oats, respectively. Individual plots were drilled with a single drill pass and arranged in a randomized complete-block design with four replications. All plots were fertilized with an additional 50 lb of N per acre on February 14, 1998.

Sampling and Quality Analysis. Each forage was harvested to a 1-in stubble height with hand shears on six

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dates (March 4, March 24, April 15, May 4, May 26, and June 5). In association with each harvest, three plants in each plot were evaluated for growth stage by the method of Stauss (1994; Table 1). Forages were dried under forced air at 122°F. Samples were analyzed for N, neutral detergent insoluble N (NDIN), and acid detergent insoluble N (ADIN). Concentrations of N, NDIN, and ADIN were determined by a combustion procedure (LECO Model FP-428; LECO Corp., St. Joseph, MI). Concentrations of NDIN and ADIN were calculated and reported on the basis of total DM (NDIN-DM and ADIN-DM) and total N (NDIN-N and ADIN-N). Neutral detergent soluble N was calculated on a DM (NDSN-DM) and total N (NDSN-N) basis, where NDSN-DM = total N – (NDIN-DM) and NDSN-N = 100% – (NDIN-N). An estimate of potentially digestible cell wall-associated N was obtained by subtracting ADIN from NDIN. Concentrations of N, NDIN, ADIN, NDSN, and NDIN-ADIN were analyzed as a split-plot design with forage species as the whole-plot term and harvest dates as the subplot term. The error mean square of the interaction between forage species and block was used as an error term to test for the significance of forage species effects. The residual error mean square was used to test harvest dates and the forage species x harvest date interaction for significance. Mean separation for forage species x harvest date interaction means was performed with a least significant difference test.

In Situ Analysis of N Disappearance. Four 999-lb ruminally cannulated crossbred steers were used to determine in situ degradation characteristics of forage N. Steers were housed in individual 11 x 16-ft pens and offered a total mixed ration at 1.75% of BW throughout the trial. The diet contained (as-is basis) 49.3% shredded alfalfa hay (21.0% CP, 54.4% NDF, and 33.0% ADF), 45.9% cracked corn, 3.0% soybean meal, 1.0% molasses, 0.36% dicalcium phosphate, 0.46% salt, plus a vitamin premix. Water was provided for each steer for ad libitum intake. Steers were fed twice daily in equal portions (0700 and 1600 h) and were adapted to the basal diet for 10 d before initiating the trial. Standard in situ procedures were used in the trial. These have been discussed in detail in association with a previous report describing degradation kinetics of DM for these forages (Coblentz et al., 2000).

Following incubation in the rumen, forage residues were analyzed for N by the method described previously. Degradation data were fitted to the nonlinear regression model of Mertens and Loften (1980). Forage N was partitioned into three fractions on the basis of relative susceptibility to ruminal degradation. The A fraction was defined as the immediately soluble portion; this fraction is assumed to be degraded immediately in the rumen. The B fraction was composed of N degraded at a measurable rate, and the C fraction was considered undegradable in the rumen. Lag times, degradation rate constants, and fractions B and C were determined directly from the nonlinear regression model. The immediately soluble portion, fraction A, was calculated by difference [total N – (B + C)]. The maximum theoretical extent of degradation was determined similarly (total N – C). Effective degradability of forage N was calculated from the equations of Broderick (1994). The passage rate (0.042/h) for the basal diet was estimated from daily intake and total ruminal contents of acid detergent insoluble ash. Data for each forage species were analyzed as a randomized complete-block design with harvest dates as treatments and steers as the blocking term. An independent analysis of variance was conducted for each cereal forage. Forages harvested on March 4 were not evaluated in situ because of limited sample availability.

Results and Discussion

Forage Quality. For most N fractions, the forage type x harvest date interaction was significant ($P < 0.05$); therefore, only interaction means are presented in Table 2. The whole-plant concentration of N was not affected ($P > 0.05$) by forage type but was affected by both harvest date ($P < 0.001$) and the forage type x harvest date interaction ($P < 0.001$). Concentrations of N were high (≥ 3.11%) for all forages on the March harvest dates. All three forages exhibited a sharp decline in the concentration of N between the March 24 and April 15 harvest dates; this time interval generally coincided with a period of rapid stem elongation. During this time interval, concentrations of N declined by 39, 48, and 58% for oats, wheat, and rye, respectively. Further declines ($P < 0.05$) in concentrations of N occurred between the April 15 and May 4 harvest dates for all forages, but concentrations of N did not change ($P > 0.05$) for rye and wheat thereafter.

Generally, NDIN is believed to be slowly degraded in the rumen, and a high percentage of this fraction is believed to escape the rumen intact. When expressed on a DM basis, forage type had no effect ($P = 0.263$) on the concentration of NDIN in these forages (Table 2); however, this fraction was affected ($P = 0.001$) by forage type when it was expressed as a proportion of total N. In both cases, harvest date and the forage type x harvest date interaction were highly significant ($P \leq 0.003$). Concentrations of NDIN-DM declined ($P < 0.05$) over time for each forage type. These reductions were 73, 71, and 80% between March 4 and June 5 for oats, wheat, and rye, respectively, and occurred primarily in response to concurrent reductions in concentrations of total N. When expressed on the basis of total N, concentrations of NDIN-N generally ranged between 20 and 30% of the total N pool; however, this N fraction exceeded 35% of the total plant N for cereal rye on the final three harvest dates. There were no differences ($P > 0.05$) in concentrations of NDIN-N across sampling dates for oats.

Harvest date affected ($P < 0.05$) concentrations of ADIN-DM, but forage type and the interaction of main effects did not ($P > 0.05$). Averaged across all three forage species, concentrations of ADIN-DM were greatest on the June 5 harvest date, lowest ($P < 0.05$) on March 24 and April 15, and intermediate ($P < 0.05$) on March 4, May 4, and May 26. Concentrations of ADIN-DM exceeded 0.1% of DM on the initial and final harvest dates for all forages, but fell to ≤ 0.075% of DM on at least one interim date (Table 2). As a

proportion of the total N pool, ADIN increased ($P < 0.05$) over time for all forages, ranging from about 3.0% of the total plant N on the March 4 harvest date to > 12.0% of N on the final harvest date. Both main effects and their associated interaction affected ($P < 0.05$) concentrations of ADIN-N.

In Situ N Disappearance. All characteristics of ruminal N degradation are summarized in Table 3. The potential extent of N degradation for all forages was exceptionally high on the March 24 harvest date (≥ 95.4% of N) and subsequently declined ($P < 0.05$) over time. However, the potential extent remained relatively high (≥ 74.5% of N) for oats and wheat on all harvest dates. This was not true for rye; the potential extent of N degradation declined to < 60.0% of N on the May 4 and June 5 harvest dates. Fraction C, which represents that portion of forage N that is unavailable in the rumen, increased ($P < 0.05$) in all forages over time; for wheat and rye, maximum concentrations of fraction C were observed on May 4, but sharp ($P < 0.05$) reductions were observed by the following harvest date. In rye, this represented a decline of 17.2 percentage units from the concentration on May 4; however, concentrations of fraction C on May 4 and June 5 were similar ($P > 0.05$). Generally, maximum concentrations of ruminally unavailable N were substantially higher in rye (43.8% of N) than in wheat (25.5% of N) or oats (20.9% of N).

Lag times for degradation of N for all forages were short (≤ 2.4 h), and there were no differences ($P > 0.05$) across harvest dates for any forage type. Rates of N degradation for oats and wheat exhibited similar patterns over the five harvest dates evaluated. For both forages, rates of degradation were initially rapid (≥ 0.165/h), but exhibited nonsignificant ($P > 0.05$) declines between the March 24 and May 4 harvest dates in association with advancing plant maturity. Generally, degradation rates during this time period were similar to those described previously for other cool-season grasses harvested during stem elongation and at boot stage. Degradation rates of N for rye also were rapid on the March 24 and April 15 harvest dates (≥ 0.192/h), but then increased sharply ($P < 0.05$) to 0.548/h by May 4 and did not differ ($P > 0.05$) thereafter. Rapid decay rates should be expected as cereal forages partition increasingly large portions of the total N pool within the grain head and less N within the stover. This was observed in all forages harvested at advanced growth stages, but rates appeared to be more rapid for wheat and rye forages.

When expressed as a fraction of the total N pool, the effective ruminal degradability for all three forages was very high (≥ 79.0% of N) for the March 24 and April 15 harvest dates, indicating that about 20% or less of the intake N bypasses the rumen intact. The effective ruminal degradability of N for all forages in our study reached a minimum ($P < 0.05$) on the May 4 harvest date, which generally preceded grain fill and reflects the increased maturity of the stover in all forages. This trend was most pronounced in rye forage; degradable N declined ($P < 0.05$) to 54.8% of N on May 4, compared to 64.8 and 74.6% of N for wheat and oats, respectively, harvested on the same date. Degradable N increased ($P < 0.05$) thereafter for all forages, and remained ≥ 72.9% of N for wheat and oats on all subsequent harvests. On a DM basis, the effective ruminal degradability of all three forages declined ($P < 0.05$) over time, primarily in response to the declining ($P < 0.05$) concentrations of N in these whole-plant forages (Table 2).

Implications

The forages evaluated in this study had high concentrations of N on harvest dates in March, a finding indicative of exceptional forage nutritive value. Rye matured faster than the other forages and had a taller growth habit; therefore, concentrations of N in this forage declined at a more rapid rate than in wheat or oats. During the vegetative and stem elongation stages of growth, rates of N degradation were relatively rapid and similar to those reported for other cool-season grasses harvested at similar growth stages. As a proportion of the entire N pool, the effective degradability of N declined to a minimum for all forages immediately before grain fill. Generally, increases in effective ruminal degradability were observed as these forages partitioned N into the filling grain head. The cereal grains evaluated in this study posessed characteristics of high N degradability that are commonly observed in other cool-season grasses.

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Table 1. European (BBCH) uniform decimal code for describing morphological development of cereal crops (Stauss, 1994).

Code	Morphological descriptor
Principal growth stage 1: leaf development	
10	First leaf through coleoptile
11 to 18	Leaves 1 to 8 unfolded
19	9 or more leaves unfolded
Principal growth stage 2: tillering	
20	No tillers
21	Beginning of tillering, first tiller detectable
22 to 28	2 to 8 tillers detectable
29	9 or more tillers detectable
Principal growth stage 3: stem elongation	
30	Beginning of stem elongation
31	First node at least 1 cm above tillering node
32 to 38	Nodes 2 to 8 detectable
Principal growth stage 4: booting	
41	Early boot stage, flag leaf sheath extended
43	Mid boot stage, flag leaf sheath just visibly swollen
45	Late boot stage, flag leaf sheath swollen
47	Flag leaf sheath opening
49	First awns visible
Principal growth stage 5: heading	
51	Tip of inflorescence emerged from sheath, first spikelet just visible
53	30% of inflorescence emerged
55	50% of inflorescence emerged
57	70% of inflorescence emerged
59	Inflorescence fully emerged
Principal growth stage 6: flowering, anthesis	
61	Beginning of flowering, first anthers visible
65	Full flowering, 50% of anthers mature
69	End of flowering, all spikelets have completed flowering but some dehydrated anthers may remain
Principal growth stage 7: development of fruit	
71	Watery ripe, first grains have reached half their final size
73	Early milk
75	Medium milk, grain content milky, grains final size, but still green
77	Late milk
Principal growth stage 8: ripening	
83	Early dough
85	Soft dough, grain content soft but dry, fingernail impression not held
87	Hard dough, grain content solid, fingernail impression hard
89	Fully ripe, grain hard, difficult to divide with a thumbnail
Principal growth stage 9	
92	Over-ripe, grain very hard, cannot be dented by thumbnail
93	Grains loosening in day time
97	Plant dead and collapsing
99	Harvested product

Table 2. Growth stage and nitrogen analyses of three cereal grains harvested on six dates in 1998.

Forage/date	Growth stage[1]	N[2]	NDSN-DM	NDIN-DM	NDIN - ADIN	ADIN-DM[3]	NDSN-N	NDIN-N	NDIN - ADIN[4]	ADIN-N
		(% of DM)					(% of N)			
Oats										
March 4	29[e]	3.45[a]	2.55[a]	0.90[a]	0.79[a]	0.110	73.6	26.4	23.1	3.28[cd]
March 24	26[f]	3.11[b]	2.30[a]	0.81[b]	0.72[a]	0.092	73.9	26.1	23.1	2.99[d]
April 15	42[d]	1.89[c]	1.40[b]	0.49[c]	0.43[b]	0.060	73.8	26.2	23.1	3.11[d]
May 4	59[c]	1.24[d]	0.93[c]	0.31[d]	0.22[c]	0.091	75.0	25.0	17.7	7.32[bc]
May 26	78[b]	0.90[e]	0.61[d]	0.28[d]	0.19[c]	0.094	68.4	31.6	21.1	10.50[ab]
June 5	88[a]	0.95[e]	0.68[cd]	0.26[d]	0.15[c]	0.114	71.8	28.2	15.8	12.39[a]
Wheat										
March 4	31[e]	3.41[a]	2.51[a]	0.90[a]	0.79[a]	0.109	73.6[ab]	26.4[ab]	23.2	3.02[b]
March 24	31[e]	3.27[a]	2.40[a]	0.87[a]	0.79[a]	0.075	73.4[ab]	26.6[ab]	24.2	2.32[b]
April 15	50[d]	1.70[b]	1.33[b]	0.38[b]	0.30[b]	0.080	77.8[a]	22.2[b]	17.5	4.70[b]
May 4	70[c]	1.07[c]	0.79[c]	0.28[c]	0.17[c]	0.106	74.0[ab]	26.0[ab]	16.1	9.91[a]
May 26	84[b]	0.99[c]	0.67[c]	0.32[bc]	0.22[bc]	0.092	68.0[b]	32.1[a]	22.3	9.72[a]
June 5	89[a]	1.02[c]	0.74[c]	0.29[c]	0.15[c]	0.132	71.5[ab]	28.6[ab]	15.4	13.14[a]
Rye										
March 4	31[e]	4.06[a]	2.93[a]	1.12[a]	1.02[a]	0.106	72.1[a]	27.9[c]	25.3	2.63[c]
March 24	32[e]	3.29[b]	2.47[b]	0.82[b]	0.76[b]	0.062	75.1[a]	24.9[c]	23.0	1.90[c]
April 15	58[d]	1.38[c]	1.02[c]	0.36[c]	0.26[c]	0.103	73.7[a]	26.3[c]	18.8	7.44[b]
May 4	70[c]	0.71[d]	0.39[d]	0.32[cd]	0.21[cd]	0.108	55.2[c]	44.9[a]	29.5	15.31[a]
May 26	83[b]	0.66[d]	0.41[d]	0.25[d]	0.13[d]	0.121	61.1[bc]	38.9[ab]	20.2	18.66[a]
June 5	89[a]	0.89[d]	0.58[d]	0.31[cd]	0.17[cd]	0.134	67.8[b]	35.3[b]	18.7	16.53[a]
SEM[5]	0.6	0.10	0.10	0.03	0.03	0.011	2.4	2.4	2.4	1.43

[a,b,c,d] Means in a column within a forage species without common superscripts differ ($P \leq 0.05$).

[1] Growth stage at harvest (Stauss, 1994)

[2] Abbreviations: N = nitrogen, NDSN-DM = neutral detergent soluble nitrogen (% of DM), NDIN-DM = neutral detergent insoluble nitrogen (% of DM), ADIN-DM= acid detergent insoluble nitrogen (% of DM), NDSN-N = neutral detergent soluble nitrogen (% of N), NDIN-N = neutral detergent insoluble nitrogen (% of N), and ADIN-N = acid detergent insoluble nitrogen (% of N).

[3] Interaction of forage species and harvest date was not significant ($P = 0.11$). Main effect for harvest date was the only significant ($P < 0.001$) treatment effect.

[4] Interaction of forage species and harvest date was not significant ($P = 0.06$). Main effect for harvest date was the only significant ($P < 0.01$) treatment effect.

[5] Standard error of the forage species x harvest date interaction mean.

Table 3. In situ N degradation characteristics for three cereal grains harvested during 1998.[1]

Forage/ harvest date	A[2]	B	C	Potential extent[3]	Lag time	k_d	Effective Degradability[4]	Effective Degradability[5]
	(% of N)				h	h^{-1}	% of DM	% of N
Oats								
March 24	48.5^{e}	46.9^{a}	4.6^{d}	95.4^{a}	2.4	0.165^{ab}	2.67^{a}	85.8^{a}
April 15	56.1^{c}	37.4^{b}	6.5^{c}	93.5^{b}	0.5	0.124^{b}	1.59^{b}	84.0^{b}
May 4	50.5^{d}	34.0^{c}	15.6^{b}	84.4^{c}	0.6	0.109^{b}	0.93^{c}	74.6^{d}
May 26	73.6^{a}	9.8^{e}	16.6^{b}	83.4^{c}	1.3	0.233^{ab}	0.73^{d}	81.4^{b}
June 5	66.2^{b}	12.9^{d}	20.9^{a}	79.1^{d}	1.3	0.287^{a}	0.73^{d}	77.3^{c}
SEM[6]	0.6	0.7	0.5	0.5	0.67	0.0429	0.01	0.6
Wheat								
March 24[7]	43.9^{b}	51.5^{a}	4.6^{c}	95.4^{a}	1.2	0.171^{b}	2.78^{a}	85.2^{a}
April 15	49.3^{a}	42.5^{b}	8.2^{c}	91.8^{a}	0.4	0.117^{b}	1.37^{b}	80.6^{b}
May 4	47.8^{a}	26.7^{d}	25.5^{a}	74.5^{c}	0.7	0.085^{b}	0.69^{d}	64.8^{e}
May 26	44.2^{b}	36.1^{c}	19.7^{b}	80.3^{b}	0.9	0.476^{a}	0.77^{c}	77.4^{c}
June 5	39.6^{c}	37.3^{c}	23.0^{ab}	77.0^{bc}	0.6	0.383^{a}	0.74^{c}	72.9^{d}
SEM	0.6	0.7	1.1	1.1	0.50	0.0428	0.01	0.7
Rye								
March 24[7]	49.7^{b}	48.2^{a}	2.1^{d}	97.9^{a}	1.0	0.192^{b}	2.91^{a}	88.6^{a}
April 15	59.4^{a}	23.2^{cd}	17.3^{c}	82.7^{b}	0.8	0.229^{b}	1.09^{b}	79.0^{b}
May 4	38.3^{c}	17.9^{d}	43.8^{a}	56.2^{d}	2.1	0.548^{a}	0.39^{d}	54.8^{c}
May 26	39.2^{c}	34.2^{b}	26.6^{b}	73.4^{c}	0.3	0.614^{a}	0.47^{c}	71.1^{b}
June 5	30.0^{d}	28.9^{bc}	41.2^{a}	58.8^{d}	1.7	0.495^{a}	0.50^{c}	56.5^{c}
SEM	0.9	2.3	2.7	2.7	0.74	0.0823	0.02	2.6

^{a,b,c,d} Means in a column within a forage species without common superscripts differ ($P \leq 0.05$).

[1] Forages harvested on March 4 were not evaluated in situ.

[2] Abbreviations: A = Immediately soluble fraction, B = fraction degradable at a measureable rate, C = undegraded fraction, and k_d = degradation rate.

[3] Potential extent of degradation in the rumen.

[4] Effective degradability expressed on a DM basis.

[5] Calculated as $A + B(k_d/k_d + \text{passage rate})$, where k_d = fractional degradation rate for N. Mean passage rate for four animals was 0.042 per hour.

[6] Standard error of harvest date means (n = 4). Each cereal grain forage was analyzed by separate analysis of variance.

[7] Evaluated in three animals.

Quality Characteristics of Bermudagrass Hay as Affected by Moisture Content and Density of Square Bales

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Story in Brief

Bermudagrass was packaged in small square hay bales at five moisture concentrations (32.5, 28.7, 24.8, 20.8, and 17.8%) and two bale densities (high and low) and stored for 60 d in small, insulated haystacks. Concentrations of fiber components and acid detergent insoluble nitrogen (ADIN) generally increased with the initial concentration of moisture within the bale in linear or quadratic relationships. Bale density had no effect on most response variables. Concentrations of ADIN were positively related to the maximum internal bale temperature in close linear relationships ($r^2 \geq 0.919$). Based on the heating increments measured in these treatment bales and the proportions of nitrogen (N) bound within the acid detergent fiber matrix, N in bermudagrass appears to be very susceptible to Maillard reaction damage. This should limit the availability of N to animals consuming these bales.

Introduction

The harvest, storage, and cash sale of improved varieties of bermudagrass hay are a large component of the cattle and horse industries in Northwest Arkansas. Producers who package hay in conventional, small square bales routinely receive $140/ton for this product. Prevailing weather conditions throughout Arkansas include high relative humidity and a relatively high probability of rainfall during portions of the time bermudagrass is actively growing and being harvested. Producers are often faced with the choice of baling before adequate dessication has occurred or subjecting their crop to rain damage. The negative storage characteristics and quality changes that occur when alfalfa hay is baled at moisture concentrations > 20% are well documented. Considerably less information is available concerning the quality changes that occur in grass hays generally, and warm-season grass hays specifically. The objectives of this research were to examine the effects of initial bale moisture and density on the poststorage quality characteristics of bermudagrass hay and to relate concentrations of ADIN to maximum internal bale temperature and the 30-d average temperature by linear regression techniques.

Experimental Procedures

Field Procedures. A well-established stand of 'Greenfield' bermudagrass was harvested with a mower-conditioner on June 15, 1998, at the Forage Research Area in Fayetteville. During the following day, four small, rectangular bales (average size = 18.9 x 15.0 x 38.6 in) were made in each of three field blocks for each combination of moisture concentration (32.5, 28.7, 24.8, 20.8, and 17.8%) and bale density (high and low); each set of four bales was stacked independently in small stacks in an open-air pole barn. A detailed description of the baling procedures, stacking protocol, measurement of internal bale temperatures, DM loss, and mold development were reported previously (Coblentz et al., 2000). Prior to creating treatment stacks, two of each set of four bales were core sampled (Star Quality Samplers, Edmonton, Alberta) to provide forage samples that were subsequently used to determine the initial moisture concentration and forage quality characteristics of all treatment combinations before storage. After 60 d of bale storage, the two remaining bales from each stack were core-sampled in a manner identical to that described previously in order to characterize forage quality on a poststorage basis. All forage samples were dried to constant weight at 122 °F.

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Chemical Analysis of Forage. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) equipped with a 1-mm screen and subsequently analyzed for nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber, acid detergent insoluble nitrogen (ADIN), acid detergent lignin, and in vitro DM disappearance (IVDMD). Concentrations of ADIN were calculated and reported on the basis of total DM (ADIN-DM) and total N (ADIN-N). Total plant N and the concentration of N in ADF residues were determined using a macro-Kjeldahl procedure (Kjeltec Auto 1030 Analyzer, Tecator, Inc., Herndon, VA). Neutral detergent fiber, ADF, acid detergent lignin, hemicellulose, and IVDMD were determined by batch procedures outlined by ANKOM Technology Corp (Fairport, NY). Rumen fluid was obtained from a ruminally cannulated crossbred steer that was offered a diet of 80% bermudagrass hay and 20% concentrate at a maintenance level of intake. The steer was adapted to the diet for 10 d prior to collecting the rumen fluid. Concentrations of hemicellulose were calculated mathematically as the difference between NDF and ADF.

Statistical Analysis. Prestorage measures of nutritive value were analyzed as a split-plot design with five moisture concentrations as whole plots and two bale densities as the subplot treatment factor. Initial bale moisture was tested for significance using the mean square for the bale moisture x block interaction as the error term; bale density and the bale moisture x bale density interaction were tested with the residual error mean square as the error term. Actual treatment means were compared using Fisher's Protected Least Significant Difference Test.

Initially, all poststorage measures of nutritive value were analyzed as a split-plot design identical to that described previously. However, in order to identify trends in the data and to simplify the interpretation of results, these data were subjected to a trend analysis that partitioned the sum of squares for bale moisture into linear, quadratic, cubic, and quartic effects. The mean square for the bale moisture x block interaction was used as an error term to test these effects for significance. Bale density and the associated interactions of bale density with the linear, quadratic, cubic, and quartic effects of bale moisture were tested for significance with the residual error mean square. The relationship between ADIN and the associated maximum internal bale temperature were determined by linear regression techniques.

Results and Discussion

Prestorage Nutritive Value of Forages. On a prestorage basis, baling treatments had little effect on forage nutritive value. The split-plot model was not significant ($P \geq 0.125$) for N fractions (total N, ADIN-DM, and ADIN-N); similar results were observed for IVDMD. For fiber components (ADF, NDF, hemicellulose, and lignin), only ADF and lignin exhibited moisture effects ($P < 0.05$); however, the overall range for these indices was very small. These results suggest that little variability existed in the treatment forages when they entered storage. Because baling treatments had little effect on the nutritive value of the hay on a prestorage basis, these data were combined and presented as a single, overall mean (Table 1).

Poststorage Forage Nutritive Value. For measures of nutritive value in forages sampled after 60 d in bale storage, bale density and the interaction of linear, quadratic, cubic, and quartic moisture terms with bale density were generally not significant ($P > 0.05$). Therefore, to simplify discussion, only moisture means are presented in Table 1, and the discussion in the text is limited to the associated trend analysis based on initial bale moisture.

All indices of fiber composition (ADF, NDF, hemicellulose, and lignin; Table 1) increased in response to increased moisture content at baling. For each of these fiber components, the relationship with initial bale moisture was linear ($P < 0.001$). Higher order terms were not generally effective ($P > 0.05$) in explaining the relationship between concentrations of fiber components and initial bale moisture. Of these fiber components, the concentration of lignin exhibited the greatest increase on a percentage basis; the final concentration increased by 113% over the storage period. Typically, fiber components are not lost during hay storage or in response to the associated spontaneous heating that may occur; however, their concentrations increase indirectly because of the preferential oxidation of nonfiber components, particularly nonstructural carbohydrates. Clearly, these data support this premise.

Concentrations of IVDMD declined with increases in initial bale moisture (Table 1). The negative relationship between concentrations of IVDMD and initial bale moisture was explained by both linear ($P < 0.001$) and quadratic ($P = 0.011$) effects. There was essentially no change in IVDMD in bales made at 17.8 and 20.8% moisture, relative to prestorage concentrations. The quadratic effect can likely be explained on this basis, which suggests that concentrations of IVDMD are relatively stable when hay is baled within the 20% moisture threshold for acceptable storage described by Collins (1987). In bales made at 32.5% moisture, concentrations of IVDMD decreased by about 14 percentage units, relative to the prestorage concentration, thereby illustrating a profound effect of spontaneous heating on the digestibility of bermudagrass.

Concentrations of N increased linearly ($P = 0.009$) with moisture concentration at baling (Table 1); however, higher order terms had no effect ($P > 0.05$) on concentrations of N after storage. Increases in the concentration of N have been observed in numerous studies where hays were sampled after relatively short storage periods (30 to 60 d); this may be the indirect result of preferential oxidation of nonstructural carbohydrates early in the storage period.

Quantification of N that is insoluble in acid detergent (ADIN) is used to evaluate heat damage to forage N via the nonenzymatic (Maillard) browning reaction. Increased concentrations of ADIN are normally assumed to be the

product of nonenzymatic browning and are frequently associated with spontaneous heating in hay and silage. It is generally believed that ADIN cannot be utilized by ruminant animals. Generally, bermudagrass hays that have heated spontaneously have not been evaluated for ADIN. In this study, ADIN increased linearly ($P < 0.001$) with moisture content at baling; this was true when ADIN was expressed on both a DM (ADIN-DM) and N (ADIN-N) basis. The maximum proportion of N bound within the ADF matrix constituted about 14% of the total plant N in bales packaged at 32.5% moisture.

Regression of ADIN Indices of Spontaneous Heating. Effective heating period, temperature, moisture content, and forage species all contribute to the binding of protein within the ADF matrix by nonenzymatic browning. The primary reaction in this pathway involves the chemical polymerization of sugars and other carbohydrates with amino acids; the principal carbohydrates involved sucrose and hemicellulose, the latter of which occurs in much higher concentrations in grasses than in legumes. These factors were corroborated by the results of this study; ADIN-DM and ADIN-N were closely related linearly ($r^2 \geq 0.919$) to the maximum internal bale temperature (Figure 1).

Implications

Increased concentrations of fiber components and ADIN were observed in bermudagrass hays that heated spontaneously, especially when initial concentrations of bale moisture exceeded 20%. Clearly, this would be expected to have a negative effect on animal performance. Bale density had no effect on most measures of forage quality. Concentrations of ADIN were positively related to the maximum internal bale temperature in close linear relationships. Based on the heating increments measured in these treatment bales and the proportions of N bound within the ADF matrix, N in bermudagrass appears to be very susceptible to Maillard reaction damage. This implies that considerable portions of the N in bermudagrass can become unavailable to the animal when bales heat spontaneously.

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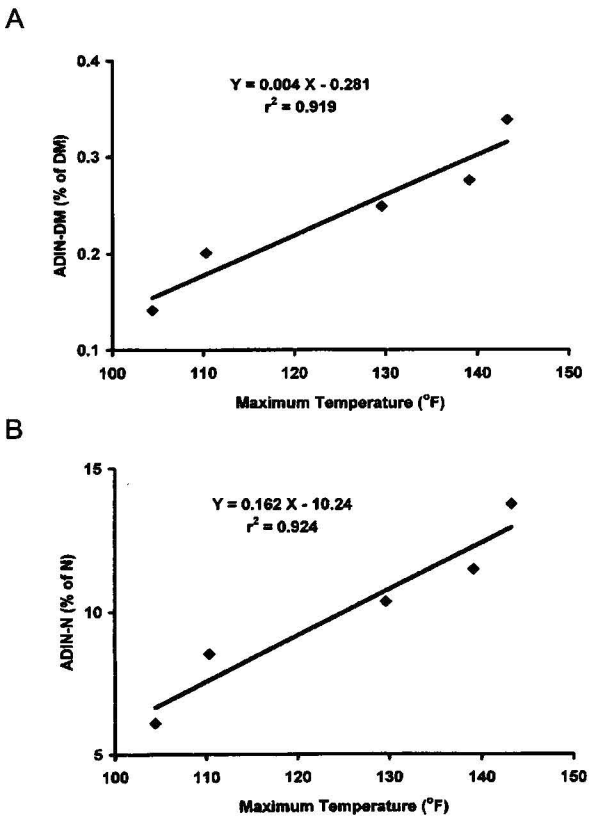

Figure 1. Relationship between ADIN and maximum internal bale temperature for bermudagrass hay bales packaged at five concentrations of moisture. Concentrations of ADIN are expressed on the basis of (A) DM (ADIN-DM) and (B) total N (ADIN-N).

Table 1. Concentrations of fiber components, in vitro DM digestibility (IVDMD), N, and ADIN for bermudagrass hay made at five concentrations of moisture and stored in small stacks for 60 d.

Moisture level, %	ADF	NDF	Hemicellulose	Lignin	IVDMD	N	ADIN-DM	ADIN-N
	% of DM							% of N
Prestorage Mean[a]	31.5	69.5	38.0	2.62	64.5	2.34	0.143	6.12
Poststorage								
32.5	35.8	76.6	40.8	5.59	50.8	2.49	0.339	13.75
28.7	34.4	75.8	41.4	4.83	55.2	2.40	0.276	11.48
24.8	34.8	73.8	39.0	4.30	61.7	2.40	0.249	10.36
20.8	33.2	71.3	38.8	3.50	64.3	2.35	0.201	8.52
17.8	31.8	70.6	38.2	3.23	63.4	2.30	0.141	6.10
SEM[b]	0.5	0.6	0.3	0.26	1.1	0.04	0.020	0.90
Response[c]	$P > F$							
Linear	***	***	***	***	***	***	***	***
Quadratic	NS[d]	NS	NS	NS	**	NS	NS	NS
Cubic	NS	NS	**	NS	NS	NS	NS	NS
Quartic	NS	NS	NS	NS	NS	NS	NS	NS

ADF = acid detergent fiber; ADIN-DM = acid detergent insoluble N expressed on a total DM basis; ADIN-N = acid detergent insoluble N expressed on a total N basis; NDF = neutral detergent fiber; and IVDMD = in vitro DM disappearance.

[a] Overall mean of all treatments for prestorage forages.

[b] Standard error of the moisture mean.

[c] Linear, quadratic, cubic, and quartic responses of moisture means.

[d] Nonsignificant effect ($P > 0.05$).

*, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively.

Impact of Heating Degree-Days in Bermudagrass Hay on Digestion by Lambs

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Story in Brief

Spontaneous heating in alfalfa (*Medicago sativa*) has reduced forage quality and DM and nitrogen (N) digestibility. Dry matter losses from microbial respiration in the bale as well as lowered N availability caused by spontaneous heating elicit these quality changes. The objective of this study was to evaluate the impact of heating degree-day (HDD) accumulation in stored bermudagrass (*Cynodon dactylon*) hay on nutrient utilization by lambs. Heating degree-days were defined as the duration and magnitude of heating above 95°F during storage. Twenty Rambouillet wether lambs (116 ± 1.63 lb) were stratified by weight, housed in metabolism crates and allocated randomly to hays that had previously accumulated either 9, 214, 362, 491, or 722 HDDs during a 60-d storage period. Lambs were offered a total of 1.5% (as fed) of BW of their respective hays in equal feedings at 0700 h and 1600 h. Dry matter intake did not differ ($P = 0.98$) among hays. Increased HDD above 362 HDDs decreased ($P < 0.05$) apparent digestibility of neutral detergent insoluble nitrogen and apparent N absorption while apparent DM and neutral detergent fiber digestibility was reduced at or above 491 HDDs. Nitrogen retention was lower ($P < 0.05$) at 491 HDDs but at 722 did not differ from other treatments. Spontaneous heating during storage of bermudagrass hay had a negative impact on DM and neutral detergent fiber digestion by lambs.

Introduction

Bermudagrass (*Cynodon dactylon*) is a major summer forage crop in Arkansas and throughout the South, and because of its high levels of production in the summer months, it is also a very productive hay crop. It is not uncommon for bermudagrass to contain high levels of moisture during packaging and for spontaneous heating to occur proportionally to that level of moisture. Coblentz et al. (2000) showed a significant increase in acid detergent insoluble nitrogen (ADIN) concentration in bermudagrass bales packaged at > 20% moisture.

The increase in heat accumulation in baled hay is due to microbial respiration and causes oxidation of soluble sugars leaving heat and carbon dioxide as byproducts of the reaction. As the soluble sugars are consumed, a loss in forage mass is experienced, causing several changes in the nutritional profile of the forage. As respiration takes place, concentrations of nitrogen (N), acid detergent fiber (ADF), neutral detergent fiber (NDF), ADIN, and neutral detergent insoluble nitrogen (NDIN) often increase. This response is simply due to the removal of soluble sugars via microbial respiration, thus changing the percentage of total matter that is represented by each component. The objective of this study was to evaluate the effect of heating degree days (HDDs) on DM, fiber, and nitrogen digestion by lambs.

Experimental Procedures

Twenty Rambouillet wether lambs (116.6 ± 1.63 lb) were housed inside in metabolism crates constructed of 1-in PVC pipe with rubberized grated floors. Each crate was fitted with plastic pans that allowed for the collection of both feces and urine. All lambs were weighed and dewormed with Ivomec (Merk AgVet Division, Whitehouse Station, NJ) sheep drench and allotted randomly to one of five treatments with four lambs per treatment.

Treatment diets consisted of five bermudagrass hays distinguished by heat accumulation measured in HDDs (Table 1). Hay was harvested from a well-established stand of 'Greenfield' bermudagrass, packaged in small square bales, and stacked. Experimental bales were placed on wooden pallets in a 2 x 2 stack (2 bales on the bottom tier and 2 bales on the top tier) with dry, nonheating bales on all sides and plastic foam sheeting on the top of the stack for insulation. Dry, nonheating bales were used to prevent heat contribution from bales other than the experimental hay. Heat accumulation in each bale was measured with a thermocouple thermometer for calculation of HDDs. Heating degree-days were calculated as the summations of the daily increment by which the mean internal bale temperature was > 95°F. All bales were ground to approximately a 1-in chop and composited by treatment for storage. Lambs were adapted to

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their respective diets for 10 d prior to the 5-d collection period.

Lambs were fed a total of 1.5% of BW daily in equal feedings at 0700 h and 1600 h and were closely observed to prevent feed spillage. Feed refusals were removed and placed in aluminum trays once daily prior to the morning feeding and were weighed and dried. Diet samples were taken every other day during the adaptation period and daily from 2 d prior to the initiation of collection through 2 d prior to the termination of collection.

During the 5-d collection period, all feces and urine were collected. Feces were weighed and subsampled for drying. Urine was weighed and a 10% aliquot was frozen for later analysis. Urine specific gravity was determined for volumetric urine output determination. Twenty-five milliliters of 10 normal H_2SO_4 was added to each urine pan to prevent volatilization of N. All forage and fecal samples were dried in a 122°F oven until no further weight loss was observed for calculation of intake and fecal output. Samples of feed, feces, and refusals were analyzed for DM, ash, NDF, ADF, NDIN, ADIN, and N. Apparent digestibility and absorption calculations were performed and tested for significance, and mean separations were performed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with the protection level set at 0.05.

Results and Discussion

Lamb weights, DM intake, NDF intake, ADF intake, and N intake did not differ ($P > 0.25$) among treatments. Forage analysis of the experimental hay (Table 1) suggested an increase in nitrogen associated with the ADF fraction of fiber (ADIN) as HDD increased. This indicates that heat accumulation in the hay package should reduce the availability of N. Numerical difference was small for DM, NDF, NDIN, and N percentages.

Significant differences were observed between treatments for apparent digestibility of DM, NDF, NDIN, and apparent N absorption and N retention (Table 2). Apparent DM digestibility was higher at the 9- and 214-HDD treatments than at the 491- and 722-HDD treatments. This suggests that a high level of heat accumulation reduced the availability of the forage as a whole. A similar effect was observed for apparent NDF digestion. Apparent N absorption was lower from hays having 491 or greater HDDs than those having lower HDDs.

The decrease in apparent NDF digestibility is likely due to the fact that heating causes the binding of N to fiber in hay via Maillard reactions (Van Soest and Mason, 1991). The N binding responsible for the reduction in apparent NDF digestibility is likely taking place in the hemicellulose fraction of NDF. This is further illustrated by the reduction in apparent NDIN digestibility. Nitrogen associated with NDF should be more susceptible to Maillard polymerization at higher levels of heat accumulation within the bale. This mechanism is also illustrated in the decreased apparent absorption of N as HDDs increased. Nitrogen retention accounts for N losses in urine as well as feces. Significant differences were detected that suggest a slight decrease in N retention at the 491-HDD level, further suggesting the decrease in N availability with increased heat accumulation.

Implications

If prestorage moisture levels are not appropriate, hay is susceptible to heat damage. Heat accumulation in hays can alter forage quality, specifically the availability of DM and NDF. Changes in forage quality caused by microbial respiration and its subsequent generation of heat can cause a sizable decrease in not only the commodity value of the stored forage, but also its value as a feedstuff to the ruminant. If heat damage is suspected in baled hay, ADIN content of the forage should be determined to predict the amount of nitrogen in the forage that is potentially unavailable to the animal. If heat-damaged forages are to be utilized, they should be analyzed in a laboratory and rations should be formulated accordingly.

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Table 1. Composition of bermudagrass hays.

Treatment	HDD	DM %	NDF %	NDIN-DM[a]	NDIN-N[b]	ADF %	ADIN-DM[a]	ADIN-N[b]	N %	CP %
1	9	88.7	76.9	1.19	64.0	33.8	0.12	6.45	1.86	11.68
2	214	89.2	77.0	1.25	64.4	35.0	0.16	8.25	1.94	12.13
3	362	88.9	77.7	1.22	63.2	36.9	0.24	12.44	1.93	12.09
4	491	88.1	77.0	1.12	61.2	36.7	0.25	13.66	1.83	11.45
5	722	87.5	76.2	1.18	61.8	37.1	0.34	17.80	1.91	11.99

All values except DM expressed on a DM basis unless noted.

[a] NDIN-DM and ADIN-DM are neutral and acid detergent insoluble nitrogen expressed as a percentage of total DM.

[b] NDIN-N and ADIN-N are neutral and acid detergent insoluble nitrogen expressed a percentage of total nitrogen.

Table 2. Apparent digestibilities (%) of DM, neutral detergent fiber, neutral detergent insoluble nitrogen, nitrogen, and representation of nitrogen retention.

	HDDs	DM	NDF	NDIN	N	N-retention[a]
1	9	58.3[b]	65.5[bc]	85.3[b]	59.9[b]	–0.013[b]
2	214	59.4[b]	66.5[b]	84.6[b]	59.9[b]	0.032[b]
3	362	56.6[bc]	64.4[bc]	80.6[c]	54.2[c]	0.040[b]
4	491	51.0[d]	60.4[d]	75.4[c]	46.4[d]	–0.273[c]
5	722	54.4[c]	62.5[cd]	77.0[c]	47.8[d]	–0.023[b]
SE		0.79	0.66	0.94	1.38	0.0370

HDD = heating degree-day.

Values within columns without a common superscript differ ($P < 0.05$).

[a] Expressed as the percentage of total nitrogen consumed that was retained by the animal.

Effects of Calendar Date and Summer Management on In Situ Dry Matter and Fiber Degradation of Stockpiled Bermudagrass

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Story in Brief

Five ruminally cannulated, crossbred steers were used to determine the effects of calendar date and previous summer management on the degradation kinetics of in situ DM and neutral detergent fiber (NDF) for stockpiled 'Greenfield' bermudagrass. Forage was stockpiled following summer hay or pasture management, and samples were taken inside and outside caged exclosures at 4-wk intervals beginning October 17, 1997, and ending January 9, 1998. At the hay site, degradation rates of DM for ungrazed forage decreased ($P < 0.05$) between October 17 and January 9, while the potential extent of degradation decreased ($P < 0.05$) during the same period. Degradation rates of NDF decreased ($P < 0.05$) between October 17 and November 14 but did not change ($P > 0.05$) thereafter. The potential extent of ruminal NDF degradation decreased ($P < 0.05$) dramatically throughout the sampling period. At the pasture site, rates of DM degradation did not differ across dates ($P > 0.05$); the potential extent of DM degradation decreased between October 17 and December 12. Rates of NDF degradation did not differ ($P > 0.05$) on the first three sampling dates but were slower ($P < 0.05$) on January 9. Moreover, the potential extent of ruminal NDF degradation decreased between October 17 and December 12. Significant losses in the nutrient availability of stockpiled bermudagrass occurred as the forage aged. Therefore, beef cows should utilize stockpiled bermudagrass by mid-December to avoid excessive depression of digestibility; cows could be maintained on hay or stockpiled fescue thereafter.

Introduction

Bermudagrass is an attractive forage source for producers in Northwest Arkansas because of its high yield potential and capacity to sustain high stocking rates. Traditionally, producers have allowed their livestock to graze bermudagrass pastures during the growing season, but considerable quantities are also harvested as hay. Alternatively, some producers prolong grazing of their pastures by stockpiling standing bermudagrass at the end of the growing season. This growth can then be used as winter pasture for grazing livestock, thereby minimizing reliance upon stored forage. Economic impact of extending the grazing season for pregnant beef cows have been shown to be profitable for various forages, primarily in response to decreased costs associated with hay production. However, the level of profitability is often dependent upon variable costs and weather conditions. Although the economic impacts of stockpiled bermudagrass systems appear to be promising, nutrient availability for this forage must be assessed before these management schemes can be fully endorsed. The objective of this study was to determine the effects of calendar date and previous summer management on the in situ degradation kinetics of DM and neutral detergent fiber (NDF) of stockpiled, dormant bermudagrass.

Experimental Procedures

Two sites receiving different amounts of N fertilizer were used to conduct this demonstration between October 17, 1997, and January 9, 1998. Methods used to harvest samples of stockpiled bermudagrass throughout the sampling period were outlined by Coblentz et al. (1999). Both pastures were located near Lincoln and all cattle management decisions were left to the producer who owned the property. During the summer prior to stockpiling, forage growth was harvested as hay at one site (hay site) but was stocked with heifers at a rate that allowed forage to accumulate at the other site (pasture site). These summer harvesting schemes were used because they represent typical practices of many producers in Northwest Arkansas.

In Situ Procedure: Five ruminally cannulated crossbred steers (average BW = 852 lb) were used to determine the in situ degradation kinetics of stockpiled

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bermudagrass. Surgical procedures and anesthesia for cannulations and care of steers were approved by the University of Arkansas Institutional Animal Care and Use Committee. Steers were housed in individual pens under an open-air pole barn, and were fed a basal diet of bermudagrass hay (14% CP, 63% NDF, and 32% ADF) and concentrate mix; the as-fed forage to concentrate ratio was 80:20. Primary ingredients of the concentrate mix included cracked corn and wheat midds (62 and 32% of concentrate mix DM, respectively); however, salt and trace minerals were also included. Steers were fed twice daily in equal proportions (0700 and 1700 h) at 2.2% of BW and allowed ad libitum access to water. Steers were adapted to the basal diet for 10 d prior to trial initiation.

Forage samples were ground to pass through a 2-mm screen, and dacron bags (10 x 20-cm, 53-mm pore size; ANKOM Technology Corp., Fairport, NY) were filled with 5 g of forage and sealed with an impulse heat sealer. Dacron bags for each time period were placed into 36 x 50-cm mesh bags, and all bags were soaked in tepid (102°F) tap water for 20 min prior to ruminal incubation to estimate DM or NDF disappearance at 0 h and to reduce the lag time associated with wetting. Mesh bags were inserted into the ventral rumen prior to feeding (except for 0-h bags), and incubated for 3, 6, 9, 12, 24, 36, 48, 72, or 96 h. Immediately after removal from the rumen, bags were rinsed in cold water in a top-loading washing machine. Zero-hour bags were machine-rinsed immediately following the tepid water soak. All bags were then dried to a constant weight at 122°F, allowed to equilibrate with the atmosphere for 16 h, and weighed.

In Situ Residue Analyses. In situ residues were analyzed for NDF by standard laboratory procedures. Total DM and NDF pools were divided into three fractions on the basis of susceptibility to ruminal degradation. Forage fractions were defined as follows: A = the immediately soluble fraction; B = the fraction that is degraded at a measurable rate; and C = the fraction unavailable in the rumen. Degradation kinetics were determined by nonlinear regression of the percentage of DM or NDF remaining on incubation time. Data were fitted to the nonlinear regression model described by Mertens and Loften (1980). Fractions B and C, lag times, and degradation rate constants (k_d) were determined directly from the nonlinear model. Fraction A was calculated mathematically as [100 – (B+C)], and the 96-h potential extent of degradation was calculated as [100 – C]. Effective ruminal degradabilities of DM and NDF were calculated as: [ruminally degradable DM or NDF = $A + B \times (k_d/(k_d + k_p))$], where k_p = fractional passage rate. The fractional passage rate of the basal diet was determined using acid detergent insoluble ash as an internal marker.

Statistical Analysis. In situ degradation kinetic parameters were analyzed as a randomized complete-block design with steers serving as blocks. An independent analysis of variance was conducted for forage samples harvested under and outside cages by the appropriate statistical procedures (analysis of variance or GLM) of SAS (SAS Inst. Inc., Cary, NC). To compare kinetic estimates inside and outside the cages on the same date, the numerical difference between these estimates was compared with zero using a Student's *t*- test.

Results and Discussion

Degradation Kinetics of In Situ DM. The potential extent of DM degradation for ungrazed forage decreased ($P < 0.05$) from 65.6 to 45.0% between October 17 and January 9 at the hay site (Table 1) and from 66.3 to 54.8% during the same period at the pasture site (Table 2). Potential extent decreased ($P < 0.05$) for grazed forage over the same period at both sites. Potential extent was consistently higher ($P < 0.05$) for ungrazed forage than grazed forage throughout the winter. The slowly degraded B fraction decreased ($P < 0.05$), while concentrations of the undegradable C fraction increased ($P < 0.05$) over the sampling period at both sites for forage harvested inside and outside the cages. These shifts resulted in a steady decline in the ruminal degradability of stockpiled bermudagrass as winter progressed.

Rates of DM degradation declined numerically over the sampling period inside and outside cages at both sites but did not differ ($P > 0.05$) across harvest dates on a consistent basis. In addition, when significant differences were observed, the overall changes were relatively small. Rates of DM degradation were slow on all harvest dates at both sites, never exceeding 0.048/h. However, this was not unexpected for a warm-season grass during the dormant season. Rates for grazed and ungrazed forage differed only on the December 12 harvest date at the hay site, indicating that grazing had little impact on rates of DM degradation.

At the hay site (Table 1), effective ruminal DM degradability decreased substantially ($P < 0.05$) for both ungrazed and grazed forage over the sampling period. Effective degradability at the pasture site (Table 2) decreased ($P < 0.05$) inside the cages between October 17 and December 12 but increased ($P < 0.05$) thereafter. Likewise, effective degradability decreased ($P < 0.05$) for grazed forage between November 14 and December 12 but increased slightly ($P < 0.05$) thereafter. Effective degradability was greater ($P < 0.05$) for ungrazed forage on January 9; however, the difference was only 3.7 percentage units. Increased degradability estimates on the January 9 harvest date at the pasture site were most likely due to the growth of immature, winter annual weeds during that time period that were not excluded from clipped samples. These winter annual weed species (henbit, cheat, and little barley) were not present at the hay site.

The degradability of stockpiled bermudagrass tended to decline as plants aged, reaching critically low levels on the January 9 harvest date. Concentrations of degradable DM on the initial sampling date (October 17) were indicative of moderate forage quality but were not unexpected for forage of that age. Declines in degradability indicate that animals grazing this stockpiled forage will utilize less of the forage nutrients as winter progresses.

Degradation Kinetics of In Situ NDF. The potential extent of NDF degradation decreased ($P < 0.05$) inside cages

by 20.4 percentage units at the hay site (Table 3) between October 17 and January 9. Similarly, the potential extent decreased ($P < 0.05$) inside cages at the pasture site (Table 4) between October 17 and November 14 but did not change thereafter. Similar trends were observed for grazed forages. The potential extent of NDF degradation was greater ($P < 0.05$) for ungrazed forage on all dates throughout the sampling period at both sites. These observations likely occurred in response to increasing lignin concentrations as the plots aged following the onset of dormancy. Differences in estimates of potentially degradable NDF for forages harvested inside and outside the cages reflect the impacts that grazing had on NDF degradation. Forage harvested outside cages probably contained a higher proportion of stems due to leaf senescence and removal by grazing. Therefore, differences in the potential extent of NDF degradation for grazed and ungrazed forage may have been associated with lower leaf-to-stem ratios in forage harvested outside cages.

Rates of NDF degradation for ungrazed forage at the hay site decreased ($P < 0.05$) between October 17 and November 14 but did not change ($P > 0.05$) during the final harvest interval. Degradation rates for grazed forage decreased ($P < 0.05$) between December 12 and January 9, but the overall range was relatively small (0.037 to 0.044/h). Degradation rates for forages harvested inside and outside cages differed ($P < 0.05$) only on December 12. At the pasture site, rates of NDF degradation in the rumen declined ($P < 0.05$) inside the cages between October 17 and January 9; rates did not differ ($P > 0.05$) for forage harvested outside the cages. Rates were faster ($P < 0.05$) for grazed forage on December 12 and January 9.

At the hay site (Table 3), the effective degradability of NDF for forages harvested inside and outside the cages decreased ($P < 0.05$) up to the December 12 harvest date but did not change ($P > 0.05$) thereafter. Degradability of NDF followed similar trends at the pasture site (Table 4) but actually increased ($P < 0.05$) during the final harvest interval; it is likely that this occurred in response to the presence of immature winter weeds. Effective degradability was relatively low on January 9 for grazed and ungrazed forage at both sites. These findings suggest that cell wall material of stockpiled bermudagrass becomes more resistant to ruminal degradation as plant age increases. This increased resistance to degradation likely occurs in response to increasing concentrations of lignin that occurred during the same period. However, leaf senescence or shatter (due to trampling) may be associated with these trends by decreasing leaf-to-stem ratios.

Implications

Significant losses in the ruminal availability of DM and NDF of dormant, stockpiled bermudagrass occurred as the forage aged. Ruminal degradability of DM and NDF was depressed to a low of 31.0% of DM and 22.0% of NDF. Beef cows grazing stockpiled bermudagrass would likely require supplementation with an energy source after mid-December as a result of limited DM and NDF degradation. Differences in degradation characteristics for grazed and ungrazed forage suggest that leaf loss during the dormancy period significantly affects the nutritive value of stockpiled bermudagrass. This leaf loss may be due to leaf senescence of the dormant forage but could also be a result of animal traffic. Therefore, winter grazing systems that minimize excessive trampling, such as strip grazing, may be helpful.

Literature Cited

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Table 1. In situ DM degradation characteristics of stockpiled bermudagrass managed for summer hay production.

Item	Harvest date				SE[1]
	October 17	November 14	December 12	January 9	
A,[3] % of DM					
Inside cage	21.7[a]	21.9[a]	17.2[b]	17.5[b]	0.29
Outside cage	–	20.0[a]	18.6[b]	20.8[a]	0.41
P > *T*[2]	–	0.001	0.005	0.001	–
B,[3] % of DM					
Inside cage	43.9[a]	33.9[b]	33.7[b]	27.5[c]	0.36
Outside cage	–	32.5[a]	25.6[b]	19.1[c]	0.76
P > *T*	–	0.167	0.001	0.001	–
C,[3] % of DM					
Inside cage	34.4[d]	44.3[c]	49.2[b]	55.0[a]	0.36
Outside cage	–	47.5[c]	55.8[b]	60.1[a]	0.62
P > *T*	–	0.004	0.001	0.001	–
Extent,[3] % of DM					
Inside cage	65.6[a]	55.8[b]	50.8[c]	45.0[d]	0.36
Outside cage	–	52.5[a]	44.2[b]	39.9[c]	0.65
P > *T*	–	0.001	0.001	0.001	–
Lag time, h					
Inside cage	2.75[a]	0.80[b]	1.48[b]	1.66[ab]	0.36
Outside cage	–	1.55	3.46	3.48	1.00
P > *T*	–	0.452	0.068	0.090	–
K_d,[4] per hour					
Inside cage	0.048[a]	0.040[b]	0.037[bc]	0.035[c]	0.002
Outside cage	–	0.043	0.047	0.041	0.004
P > *T*	–	0.600	0.073	0.258	–
Degradability,[5] % of DM					
Inside cage	47.1[a]	40.0[b]	34.6[c]	31.3[d]	0.22
Outside cage	–	38.0[a]	33.2[b]	31.0[c]	0.45
P > *T*	–	0.002	0.014	0.491	–

Means within rows with different superscripts differ ($P < 0.05$).

[1] SE = standard error of the mean.

[2] Probability that the difference between means inside and outside the cages is equal to zero.

[3] A = immediately soluble fraction; B = fraction degradable at a measureable rate; C = undegraded fraction; and total potential extent of degradation = 100 – C.

[4] Fractional degradation rate in the rumen.

[5] Effective degradability in the rumen = $[A + B \times (K_d/(K_d + K_p))]$, where the mean passage rate (K_p) for five steers was 0.035/h.

Table 2. In situ DM degradation characteristics of stockpiled bermudagrass managed for summer pasture production.

Item	Harvest date				SE[1]
	October 17	November 14	December 12	January 9	
A,[4] % of DM					
Inside cage	21.0[c]	21.8[b]	19.0[d]	29.2[a]	0.19
Outside cage[3]	–	20.0[a]	19.4[a]	26.2[b]	0.35
P > *T*[2]	–	0.004	0.329	0.001	–
B,[4] % of DM					
Inside cage	45.3[a]	37.6[b]	34.2[c]	25.6[d]	0.79
Outside cage	–	34.2[a]	30.6[b]	23.7[c]	0.34
P > *T*	–	0.002	0.002	0.255	–
C,[4] % of DM					
Inside cage	33.7[c]	40.6[b]	46.9[a]	45.2[a]	0.84
Outside cage	–	45.8[b]	50.1[a]	50.0[a]	0.2
P > *T*	–	0.001	0.001	0.001	–
Extent,[4] % of DM					
Inside cage	66.3[a]	59.4[b]	53.1[c]	54.8[c]	0.84
Outside cage	–	54.2[a]	49.9[b]	50.0[b]	0.20
P > *T*	–	0.001	0.001	0.001	–
Lag time, h					
Inside cage	1.93[a]	1.40[a]	1.27[a]	0.00[b]	0.29
Outside cage	–	1.46	2.19	1.36	0.29
P > *T*	–	0.910	0.090	0.071	–
K_d,[5] per hour					
Inside cage	0.044	0.044	0.039	0.038	0.003
Outside cage	–	0.047	0.046	0.042	0.001
P > *T*	–	0.202	0.020	0.169	–
Degradability,[6] % of DM					
Inside cage	45.8[a]	42.7[b]	37.1[c]	42.6[b]	0.47
Outside cage	–	39.7[a]	36.8[b]	38.9[a]	0.35
P > *T*	–	0.001	0.426	0.001	–

Means within rows with different superscripts differ ($P < 0.05$).

[1] SE = standard error of the mean.

[2] Probability that the difference between means inside and outside the cages is equal to zero.

[3] Forage harvested on January 9 at the pasture site was evaluated in only three animals.

[4] A = immediately soluble fraction; B = fraction degradable at a measureable rate; C = undegraded fraction; and total potential extent of degradation = 100 – C.

[5] Fractional degradation rate in the rumen.

[6] Effective degradability in the rumen = $[A + B \times (K_d/(K_d + K_p))]$, where the mean passage rate (K_p) for five steers was 0.035/h.

Table 3. In situ NDF degradation characteristics of stockpiled bermudagrass managed for summer hay production.

Item	Harvest date				SE[1]
	October 17	November 14	December 12	January 9	
A,[3] % of NDF					
Inside cage	4.3[b]	4.9[b]	5.9[b]	10.7[a]	0.58
Outside cage	–	6.3[b]	6.8[b]	11.6[a]	0.55
P > *T*[2]	–	0.022	0.087	0.111	–
B,[3] % of NDF					
Inside cage	56.6[a]	43.6[b]	39.6[c]	29.8[d]	0.72
Outside cage	–	38.9[a]	29.8[b]	20.2[c]	0.71
P > *T*	–	0.001	0.001	0.001	–
C,[3] % of NDF					
Inside cage	39.1[d]	51.5[c]	54.5[b]	59.5[a]	0.39
Outside cage	–	54.9[c]	63.4[b]	68.2[a]	0.37
P > *T*	–	0.001	0.001	0.001	–
Extent,[3] % of NDF					
Inside cage	60.9[a]	48.5[b]	45.5[c]	40.5[d]	0.39
Outside cage	–	45.1[a]	36.6[b]	31.8[c]	0.37
P > *T*	–	0.001	0.001	0.001	–
Lag time, h					
Inside cage	2.50[a]	0.60[b]	1.51[ab]	2.45[a]	0.44
Outside cage	–	1.27[b]	1.85[b]	4.29[a]	0.61
P > *T*	–	0.291	0.587	0.015	–
K_d,[4] per hour					
Inside cage	0.052[a]	0.038[b]	0.034[b]	0.032[b]	0.002
Outside cage	–	0.041[ab]	0.044[a]	0.037[b]	0.002
P > T	–	0.181	0.003	0.087	–
Degradability,[5] % of NDF					
Inside cage	37.9[a]	27.6[b]	25.5[c]	25.1[c]	0.65
Outside cage	–	27.3[a]	23.4[b]	22.0[b]	0.53
P > *T*	–	0.617	0.004	0.001	–

Means within rows with different superscripts differ (P < 0.05).

[1] SE = standard error of the mean.

[2] Probability that the difference between means inside and outside the cages is equal to zero.

[3] A = immediately soluble fraction; B = fraction degradable at a measureable rate; C = undegraded fraction; and total potential extent of degradation = 100 – C.

[4] Fractional degradation rate in the rumen.

[5] Effective degradability in the rumen = $[A + B \times (K_d/(K_d + K_p))]$, where the mean passage rate (K_p) for five steers was 0.035/h.

Table 4. In situ NDF degradation characteristics of stockpiled bermudagrass managed for summer pasture production.

Item	Harvest date				SE[1]
	October 17	November 14	December 12	January 9	
A,[4] % of NDF					
Inside cage	4.0[a]	6.3[b]	8.6[c]	18.3[d]	0.38
Outside cage[3]	–	6.0[c]	9.3[b]	17.5[a]	0.72
P > *T*[2]	–	0.632	0.296	0.412	–
B,[4] % of NDF					
Inside cage	56.7[a]	46.2[b]	38.8[c]	27.7[d]	1.21
Outside cage	–	40.6[a]	33.2[b]	25.4[c]	0.74
P > *T*	–	0.001	0.001	0.031	–
C,[4] % of NDF					
Inside cage	39.3[c]	47.4[b]	52.5[a]	54.0[a]	1.08
Outside cage	–	53.4[b]	57.5[a]	57.1[a]	0.56
P > *T*	–	0.001	0.001	0.001	–
Extent,[4] % of NDF					
Inside cage	60.7[a]	52.6[b]	47.5[c]	46.0[c]	1.08
Outside cage	–	46.6[a]	42.6[b]	42.9[b]	0.56
P > *T*	–	0.001	0.001	0.001	–
Lag time, h					
Inside cage	1.35[b]	1.52[ab]	1.95[ab]	2.90[a]	0.46
Outside cage	–	1.64	2.75	2.29	0.63
P > *T*	–	0.848	0.226	0.883	–
K_d,[5], per hour					
Inside cage	0.047[a]	0.045[a]	0.038[ab]	0.034[b]	0.004
Outside cage	–	0.048	0.046	0.043	0.002
P > T	–	0.294	0.006	0.006	–
Degradability,[6] % of NDF					
Inside cage	35.9[a]	32.4[b]	29.0[c]	31.8[b]	0.73
Outside cage	–	29.5[a]	28.3[a]	31.7[b]	0.58
P > *T*	–	0.002	0.259	0.981	–

Means within rows with different superscripts differ (P < 0.05).

[1] SE = standard error of the mean.

[2] Probability that the difference between means inside and outside the cages is equal to zero.

[3] Forage harvested on January 9 at the pasture site was evaluated in only three animals.

[4] A = immediately soluble fraction; B = fraction degradable at a measureable rate; C = undegraded fraction; and total potential extent of degradation = 100 – C.

[5] Fractional degradation rate in the rumen.

[6] Effective degradability in the rumen = $[A + B \times (K_d/(K_d + K_p))]$, where the mean passage rate (K_p) for five steers was 0.035/h.

Effects of Calendar Date and Summer Management on In Situ Crude Protein Degradation of Stockpiled Bermudagrass

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Story in Brief

Information is limited that describes the degradation kinetics of CP in dormant bermudagrass stockpiled for winter use by beef cows. In situ degradation kinetics of CP for 'Greenfield' bermudagrass that was stockpiled at two pasture sites were evaluated using five ruminally cannulated, crossbred steers. Beginning October 17, 1997, forage samples were harvested inside and outside caged exclosures at 4-week intervals; final samples were harvested on January 9, 1998. The potential extent of CP degradation inside cages at the hay site decreased from 74.7 to 57.8% of CP over the sampling period. Effective CP degradability decreased ($P < 0.05$) between November 14 (60.2% of CP) and December 12 (53.9% of CP), but it was greater than 50.0% of CP throughout the sampling period. At the pasture site, the potential extent of CP degradation decreased ($P < 0.05$) inside cages between October 17 (79.0% of CP) and January 9 (68.2% of CP). Effective CP degradability did not change ($P > 0.05$) between October 17 and December 12 (overall average = 59.0% of CP) but increased to 62.4% of CP on January 9. Increased degradability estimates on January 9 at the pasture site were likely due to the growth of winter annual weeds during that period that were not excluded from clipped samples. Although estimates of CP degradability for stockpiled bermudagrass declined throughout the winter, availability of CP may be high enough to meet the minimum requirements of dry, pregnant beef cows.

Introduction

Bermudagrass is one of the primary warm-season forages available to beef producers in Northwest Arkansas. Its capacity to sustain high stocking rates and high yield potential in response to N fertilization makes bermudagrass an attractive forage source for both grazing and hay production. Traditionally, farmers have allowed their livestock to graze bermudagrass pastures during the growing season, but many producers prolong grazing by stockpiling standing bermudagrass at the end of the growing season. This growth can then be used as winter pasture for grazing livestock, and costs associated with hay production are thereby reduced. Spring-calving beef cows are most often the class of animals allowed to graze stockpiled forages because of their low nutrient requirements in comparison to growing animals. Grazing pregnant beef cows on various stockpiled forages has been shown to be profitable. However, because CP supplements are expensive for producers to purchase, the availability of CP in stockpiled bermudagrass should be evaluated before this system is fully endorsed. The goal of this study was to determine the effects of calendar date and previous summer management on the in situ degradation kinetics of CP for stockpiled, dormant bermudagrass.

Experimental Procedures

Two sites receiving different amounts of N fertilizer were used to conduct this demonstration between October 17, 1997, and January 9, 1998. Both sites were located near Lincoln, and all cattle management decisions were left to the producer who owned the property. During the summer prior to stockpiling, one site was fertilized with high rates of N fertilizer and harvested as hay (hay site), while the other site (pasture site) was fertilized with moderate rates of N fertilizer and grazed by heifers. These summer management systems were chosen because they are commonly practiced by producers in Northwest Arkansas.

The forage management procedures used at these sites and the methods used to harvest samples of stockpiled bermudagrass were described previously by Coblentz et al. (1999). Standard in situ techniques were used to evaluate degradation kinetics; these have been described in detail in a

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companion paper (Scarbrough et al., 2000).

In Situ Residue Analyses. In situ residues were analyzed for N by standard laboratory procedures; CP was calculated as [%CP = %N x 6.25]. Total CP pools were divided into three fractions (A, B, and C) based on susceptibility to ruminal degradation. Fraction A was defined as the immediately soluble fraction; fraction B consisted of CP that was degraded in the rumen at a measurable rate; and fraction C was considered undegradable in the rumen. Fractions B and C, lag times, and degradation rate constants (k_d) were determined directly from a nonlinear regression model (Mertens and Loften, 1980). Fraction A was calculated mathematically as [100 – (B + C)], and 96-h potential extent of degradation was calculated as [100 – C]. Effective ruminal degradability of CP was calculated as: [ruminally degradable CP = A + B x (k_d / (k_d + k_p))], where k_p = fractional passage rate. The fractional passage rate of the basal diet was determined using acid detergent insoluble ash as an internal marker.

Statistical Analysis. A randomized complete block design was used to analyze the kinetic parameters of in situ CP degradation for stockpiled bermudagrass. An independent analysis of variance was conducted for forage samples harvested under and outside cages by the appropriate statistical procedures (analysis of variance or GLM) of SAS (SAS Inst. Inc., Cary, NC). For all kinetic parameters of in situ CP degradation, means were separated using a least significant difference test ($P < 0.05$). To compare kinetic estimates inside and outside the cages on the same date, the numerical difference between these estimates was compared with zero using a Student's *t*-test.

Results and Discussion

Subcomponent Fractions. Fraction A made up a large proportion (33.5 to 49.5% of CP) of the CP in stockpiled bermudagrass on all sampling dates in this demonstration. At the hay site (Table 1) concentrations of fraction A increased ($P < 0.05$) for ungrazed forage between October 17 and December 12 but did not differ ($P > 0.05$) on the initial and final sampling dates. Conversely, fraction A decreased ($P < 0.05$) for grazed forage between November 14 and January 9. Estimates of fraction A were greater ($P < 0.05$) for ungrazed forage on November 14 and January 9. At the pasture site (Table 2), fraction A increased ($P < 0.05$) in ungrazed forage throughout the winter; fraction A increased ($P < 0.05$) outside cages between November 14 and December 12, but not thereafter. Estimates of fraction A were not different ($P > 0.05$) for ungrazed and grazed forage on the January 9 sampling date. Increased estimates of fraction A on the January 9 harvest date at the pasture site were most likely in response to the growth of immature, winter annual weeds during that time period that were not excluded from clipped samples. These weed species (henbit, cheat, and little barley) were not present at the hay site.

The slowly degraded B fraction decreased ($P < 0.05$) sharply at the hay site between October 17 and January 9 for ungrazed forage but did not differ for grazed forage on any sampling date. At the pasture site, fraction B decreased ($P < 0.05$) as plants aged inside and outside the cages. Moreover, estimates of the slowly degraded B fraction did not differ ($P > 0.05$) for forage harvested inside and outside the cages on any sampling date, indicating that grazing had little impact this CP fraction.

The indigestible C fraction increased ($P < 0.05$) at the hay site for forage harvested inside and outside the cages between October 17 and January 9. Fraction C was larger ($P < 0.05$) for grazed forage on December 12 and January 9, but the magnitude of this difference never exceeded 6.5 percentage units. At the pasture site, the undegradable C fraction increased ($P < 0.05$) between October 17 and December 12 for forages harvested inside the cages but did not change thereafter. Estimates of fraction C increased ($P < 0.05$) for grazed forage between December 12 and January 9, but estimates on November 14 and January 9 were not different ($P > 0.05$).

Potential Extent. The potential extent of CP degradation decreased ($P < 0.05$) substantially throughout the sampling period for forage harvested inside and outside cages at the hay site (Table 1). In addition, the potential extent of CP degradation was 6.5 and 5.1 percentage units lower ($P < 0.05$) for grazed forages than ungrazed forages on the December 12 and January 9 sampling dates, respectively. At the pasture site (Table 2), the potential extent of CP degradation decreased ($P < 0.05$) between October 17 and January 9 for ungrazed forage. The potential extent outside cages varied across sampling dates ($P < 0.05$), but the overall range of response was small (65.5 to 69.1% of CP).

Degradation Rates. Rates of CP degradation inside the cages at the hay site (Table 1) were the slowest on December 12 (0.031/h), but this differed ($P < 0.05$) only from the rate observed on November 14 (0.064/h). Rates outside cages did not differ ($P > 0.05$) at any time throughout the sampling period and were not different ($P > 0.05$) from degradation rates inside cages on any date. At the pasture site (Table 2), rates of CP degradation inside cages were lowest ($P < 0.05$) on October 17 (0.044/h) but increased ($P < 0.05$) to 0.080/h on January 9 in response to the presence of immature winter annual weeds. Rates outside cages were lowest on December 12 (0.040/h); these rates differed ($P < 0.05$) from those on November 14 (0.069/h) but not those on January 9 ($P < 0.05$). Rates of CP degradation for grazed forage differed ($P < 0.05$) from rates for ungrazed forage only on the December 12 sampling date. Generally, these results indicate that degradation rates of CP in stockpiled bermudagrass were relatively unaffected as the winter progressed. In addition, grazing had little influence on rates of CP degradation.

Effective Degradability. The effective ruminal degradability of CP for forages harvested inside cages at the hay site (Table 1) decreased ($P < 0.05$) between November 14 and December 12 but did not change ($P > 0.05$) during the final sampling interval. The effective degradability of CP for forages harvested outside the cages decreased ($P < 0.05$) over the entire sampling period. Estimates of effective

CP degradability were smaller ($P < 0.05$) for grazed forage throughout the winter. Differences in the effective degradability of CP for forages harvested inside and outside cages may have been related to decreased leaf-to-stem ratios in forages outside cages that resulted from grazing, cow traffic, and leaf senescence.

At the pasture site (Table 2) the effective CP degradability for ungrazed forage did not change ($P > 0.05$) over the first three sampling dates but increased ($P < 0.05$) to 62.4% of CP on January 9. The effective CP degradability for grazed forage did not change ($P > 0.05$) throughout the sampling period. Estimates of effective CP degradability inside cages were greater ($P < 0.05$) than estimates outside cages on the November 14 and January 9 sampling dates. In addition, increased estimates of effective CP degradability on the January 9 sampling date were likely associated with the presence of some immature winter annual weeds.

Implications

Degradation characteristics indicate that substantial losses occur in the ruminal availability of CP in stockpiled bermudagrass as the dormant forage ages. However, total CP concentrations never fell below 10% of DM throughout the winter, and the ruminal degradability of CP never declined below 46.0% of total forage CP. Therefore, the concentration and availability of CP in stockpiled bermudagrass may be adequate to meet the minimum CP requirements of dry, pregnant beef cows. However, the relatively high CP concentrations throughout the winter were likely related to high N fertilization during the growing season. Concentrations and degradation characteristics of the CP in bermudagrass that is not fertilized with N would likely be different from those observed in this demonstration.

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Table 1. In situ degradation characteristics of CP in stockpiled bermudagrass managed for summer hay production.

Item	Harvest date				SE[1]
	October 17	November 14	December 12	January 9	
A,[3] % total CP					
Inside cage	37.0^{c}	47.8^{a}	44.0^{ab}	40.9^{bc}	1.83
Outside cage	–	42.2^{a}	41.0^{ab}	35.4^{b}	2.05
P > *T*[2]	–	0.037	0.216	0.041	–
B,[3] % total CP					
Inside cage	37.7^{a}	19.8^{bc}	21.1^{b}	16.9^{c}	1.13
Outside cage	–	23.8	17.6	17.3	2.05
P > *T*	–	0.101	0.148	0.881	–
C,[3] % total CP					
Inside cage	25.3^{c}	32.4^{b}	34.9^{b}	42.2^{a}	1.07
Outside cage	–	34.0^{c}	41.4^{b}	47.3^{a}	1.48
P > *T*	–	0.363	0.005	0.015	–
Extent,[3] % total CP					
Inside cage	74.7^{a}	67.6^{b}	65.1^{b}	57.8^{c}	1.07
Outside cage	–	66.0^{a}	58.6^{b}	52.7^{c}	1.48
P > *T*	–	0.363	0.005	0.015	–
Lag time, h					
Inside cage	7.44	3.88	7.77	2.02	2.08
Outside cage	–	2.93^{b}	6.81^{ab}	13.78^{a}	2.71
P > *T*	–	0.744	0.743	0.003	–
K_d,[4] per hour					
Inside cage	0.058^{ab}	0.064^{a}	0.031^{b}	0.053^{ab}	0.009
Outside cage	–	0.046	0.045	0.064	0.011
P > *T*	–	0.28	0.417	0.508	–
Degradability,[5] % total CP					
Inside cage	60.4^{a}	60.2^{a}	53.9^{b}	51.1^{b}	1.11
Outside cage	–	55.6^{a}	50.7^{b}	46.1^{c}	1.11
P > *T*	–	0.002	0.013	0.001	–

Means within rows with different superscripts differ ($P < 0.05$).

[1] SE = standard error of the mean.

[2] Probability that the difference between means inside and outside the cages is equal to zero.

[3] A = immediately soluble fraction; B = fraction degradable at a measureable rate; C = undegraded fraction; and total potential extent of degradation = 100 – C.

[4] Fractional degradation rate in the rumen.

[5] Effective degradability in the rumen = $[A + B \times (K_d/(K_d + K_p))]$, where the mean passage rate (K_p) for five steers was 0.035/h.

Table 2. In situ degradation characteristics of CP of stockpiled bermudagrass managed for summer pasture production.

Item	Harvest date				SE[1]
	October 17	November 14	December 12	January 9	
A,[4] % total CP					
Inside cage	33.5[c]	40.1[b]	40.6[b]	49.5[a]	1.28
Outside cage[3]	–	35.5[b]	45.1[a]	48.3[a]	1.58
P > *T*[2]	–	0.032	0.034	0.459	–
B,[4] % total CP					
Inside cage	45.4[a]	32.0[b]	26.6[c]	18.7[d]	1.73
Outside cage	–	33.5[a]	24.0[b]	17.2[c]	1.81
P > *T*	–	0.494	0.245	0.879	–
C,[4] % total CP					
Inside cage	21.0[c]	27.9[b]	31.8[a]	32.8[a]	0.93
Outside cage	–	31.0[ab]	30.9[b]	34.5[a]	0.94
P > *T*	–	0.031	0.131	0.414	–
Extent,[4] % total CP					
Inside cage	79.0[a]	72.1[b]	67.2[c]	68.2[c]	0.93
Outside cage	–	69.0[ab]	69.1[a]	65.5[b]	0.94
P > *T*	–	0.031	0.131	0.414	–
Lag time, h					
Inside cage	1.73	1.75	0.46	0.76	0.66
Outside cage	–	0.00[b]	1.60[b]	4.36[a]	0.90
P > *T*	–	0.147	0.316	0.103	–
K_d,[5] per hour					
Inside cage	0.044[b]	0.057[ab]	0.067[ab]	0.080[a]	0.008
Outside cage	–	0.069[a]	0.040[b]	0.052[ab]	0.010
P > *T*	–	0.338	0.053	0.151	–
Degradability,[6] % total CP					
Inside cage	58.9[b]	60.0[ab]	58.0[b]	62.4[a]	1.02
Outside cage	–	57.3	57.9	58.3	0.81
P > *T*	–	0.011	0.822	0.015	–

Means within rows with different superscripts differ ($P < 0.05$).

[1] SE = standard error of the mean.

[2] Probability that the difference between means inside and outside the cages is equal to zero.

[3] Forage harvested on January 9 at the pasture site was evaluated in only three animals.

[4] A = immediately soluble fraction; B = fraction degradable at a measureable rate; C = undegraded fraction; and total potential extent of degradation = 100 – C.

[5] Fractional degradation rate in the rumen.

[6] Effective degradability in the rumen = $[A + B \times (K_d/(K_d + K_p))]$, where the mean passage rate (K_p) for five steers was 0.035/h.

Effects of Rice Milling Procedures on Nutrient Composition of Rice Bran

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Story in Brief

Rice bran from various rice processors is highly variable in nutrient content because of various procedures used during the milling process. Rice bran samples were collected from five rice processors in Arkansas. Samples of defatted rice bran and bran that was processed from rice after the rice was parboiled were also collected. Fat content of the brans ranged from 3.4% in defatted bran to 22.2% in bran milled after the rice was parboiled. To prevent digestive problems, bran with over 20% fat should be fed to cattle at less than one-third of the total diet. Calcium content of the brans ranged from 0.09 to 4.86%. Calcium-to-phosphorus ratios (Ca:P) of bran varied from 2.7:1 to 1:15.7. Bran from three of the five processors averaged 0.15% Ca, which was similar to 0.10% Ca reported for rice bran by the National Research Council. In most cases, bran from these three processors should be supplemented with additional Ca to maintain proper Ca intake and adequate Ca:P ratio in cattle diets. Phosphorus content of brans ranged from 1.41 to 2.19%. The variable nutrient composition of these brans indicate that the nutrient contents of rice bran must be known before cattle diets can be properly balanced.

Introduction

Almost 50% of the rice produced in the United States is grown predominately in 32 Arkansas counties located in the eastern half and the extreme southwest areas of the state. Several rice mills in the state produce an abundance of byproducts from processing rice. Byproducts include rice hulls, rice bran, rice polishings, and broken rice grains. When harvested from the field, rice is in the form of paddy (or "rough") rice, where the kernel is fully enveloped by the rice hull. After being dried, the first stage in milling is the removal of the hull, yielding brown rice. Next, the outer layer is removed from the brown kernel to yield white rice. The separated brown layer is designated as rice bran.

The composition of rice bran can be quite variable because of the procedures used in the milling process. Some rice processing mills use limestone in the process of removing the bran from rice kernels. The amount of limestone used during processing often varies across processing mills. When limestone is used during processing, the Ca content of the bran is higher than in bran produced without limestone.

Other factors also influence the nutrient composition of rice bran. Some mills extract the fat from bran. Removing the fat from the bran increases the percentages of some of the nutrients, such as CP. However, removal of the fat substantially reduces the energy (TDN) content of the bran. The use of parboiling procedures (steam treatment of "rough" rice to make rice kernels harder) also affects the nutrient content of rice bran.

To formulate cattle rations, nutritionists often use National Research Council (NRC; 1996) "book values" for the nutrient values of byproduct feeds. Because the nutrient concentration of rice bran is quite variable, the use of tabular values of nutrient composition can result in under- and overfeeding cattle.

The purpose of this project was to determine the variability of the nutrient composition of rice bran produced in several processing mills throughout the state. A secondary objective was to assess whether NRC nutrient values for rice bran are reliable enough to use in formulating cattle diets.

Experimental Procedures

During March 1999, University of Arkansas county extension agents collected a total of 16 rice bran samples from rice processing mills located in Craighead, Crittenden, Desha, and Arkansas counties. Bran samples were collected from two processing mills located in Arkansas County and in only one processing mill located in each of the other three counties. Samples of rice bran were analyzed for various

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nutrients by the University of Arkansas Department of Animal Science.

Dry matter, ash, and CP were analyzed according to AOAC (1990) procedures. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Goering and Van Soest, 1970) were analyzed with an automated fiber apparatus (Ankom^{200} Fiber Analyzer; Ankom Technology Corp., Fairport, NY). Fat was determined using a supercritical fluid extraction (Suprex, Lincoln, NE). Mineral concentrations were determined after ash was dissolved in nitric and hydrochloric acid. Calcium was analyzed by atomic absorption spectroscopy (Perkin Elmer Model 5000; Norwalk, CT). A colormetric spectroscopy procedure was used for phosphorus analysis (AOAC, 1990).

Processing plant differences for the various nutrient contents of rice bran were determined by analysis of variance using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Least-squares means for each nutrient between processing plants were calculated and are reported.

Results and Discussion

The feed market is the traditional market for rice bran. Raw bran is typically sold for cash in bulk form at rice mill locations throughout the state. Rice bran is often included in cattle rations, often without much consideration of the rather large variability in the nutrient composition of rice bran processed by various mills throughout the state.

Table 1 shows the nutrient composition of rice bran collected at five processing plants in Arkansas. Parboiled rice bran samples were collected from Processor 4 and defatted rice bran samples were collected from Processor 5.

Rice bran is often referred to by animal nutritionists as 12-12-12; referring to 12% CP, 12% fat, and 12% crude fiber on an as-is basis. The rice bran samples involved in this study (Table 1) were not analyzed for crude fiber, but all of the samples contained more than 16% CP and only one sample (defatted rice bran) contained less than 12% fat.

Dry matter content varied ($P < 0.05$) among rice bran samples, ranging from 89.7 to 93.8%. These values were within a satisfactory range relative to acceptable moisture contents of bran for storage.

Crude protein content of defatted bran (Processor 5) was higher ($P < 0.05$) than that for all of the other bran samples. The higher CP content could be expected because removal of the fat from bran concentrates the CP in a smaller quantity of bran. Therefore, defatted bran contained a higher percentage of CP but a much lower percentage ($P < 0.05$) of fat. Because of the high energy level of fat, the removal of fat from bran would significantly reduce the TDN value of the bran. However, greater amounts of defatted bran could be used in cattle diets without causing the digestive problems associated with diets high (> 7%) in fat content.

A general guideline for using rice bran in cattle rations is that bran should be limited to no more than one-third of the diet. With the exception of defatted rice bran, the other bran samples ranged from 12.7 to 22.2% fat. The parboiled rice bran contained the greatest ($P < 0.05$) content of fat, followed by the bran from Processor 5. Both of these samples contained higher levels of fat than recommended for inclusion in diets when rice bran is to be fed at one-third of the diet. Rice bran containing more than 20% fat should be limited to less than one-third of cattle diets. Other sources of fat in cattle diets should also be taken into consideration. The total diet should contain no more that 7% fat.

Acid detergent fiber content of rice brans was variable, ranging from 12.1 to 22.3%. Rice bran from parboiled rice (Processor 4) had a higher content ($P < 0.05$) of ADF than all other bran samples except that from Processor 2. Parboiled rice had the highest concentrations ($P < 0.05$) of NDF, Ca, and ash.

The Ca content of the brans varied from 0.09 to 4.86%. Bran samples from Processors 1, 2, and 3 were not different ($P > 0.05$) in Ca content. Calcium contents of these brans were similar to the value of 0.10% Ca reported in NRC (1996). Apparently, these processors did not use limestone during processing to remove the bran layer from rice. The Ca:P of these three bran sources ranged from 1:6.2 to 1:15.7. An ideal Ca:P for beef cattle diets is usually near 1.5:1. Using up to one-third rice bran (from Processors 1, 2, or 3) in cattle diets could cause an unacceptable Ca:P in cattle diets unless supplemental Ca is added to the diet. The final Ca:P of the diet would also be influenced by the Ca and P contents of the other ration ingredients. The Ca:P of the defatted bran (1:1.7) was also less than ideal for cattle diets.

Calcium contents of brans milled by Processors 4 and 5 (including both parboiled and defatted brans) indicate that these processors used limestone to process rice and to remove the bran. Rice bran milled by Processors 4 and 5, with the exception of the defatted bran produced by Processor 5, had more ideal ratios of Ca to P, ranging from 1.4:1 to 2.7:1. These brans could likely be fed in cattle diets without adding supplemental Ca to balance Ca:P. The defatted bran produced by Processor 5 had a lower Ca content ($P < 0.05$) than the full-fat bran milled by Processor 5. This indicates that the process used to remove fat from the bran also removed some Ca.

Phosphorus levels of the bran samples ranged from 1.41 to 2.19%. Use of these brans in cattle diets should help provide most, if not all, of the needed P in cattle diets. Cows, even during lactation, seldom require more than 0.25% P in their diets. To meet this P requirement from the use of these rice brans would require that these brans be included in cow diets at 18% (based on rice bran from Processor 2) or less of the total daily diet.

The ash content of the brans was also variable, ranging from 8.33 to 21.03%. Parboiled bran had the highest ash content followed by bran from Processors 4 and 5. Brans milled by Processors 4 and 5 were not different ($P > 0.05$), but those brans contained more ash ($P < 0.05$) than the others. The brans low in Ca content (Processors 1, 2, and 3) also contained lower levels of ash. Again, the major concern about the mineral level of these brans is that supplemental Ca would likely be needed in the diets of cattle fed brans milled by Processors 1, 2 and 3.

Implications

Because of various milling procedures used by rice processors in the milling of rice, rice bran is highly variable in nutrient content. To use rice bran in balanced cattle rations and to prevent digestive problems and inefficiencies in utilization of nutrients, the nutrient composition of bran (especially CP, fat, Ca, and P) should be determined by laboratory analysis. The use of NRC tabular values of nutrient composition of rice bran can result in costly under- or overfeeding cattle.

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Table 1. Least-squares means and standard errors of nutrient composition of rice bran processed by five Arkansas rice mills.

Processor[1]	DM, %	CP, % DM	Fat, % DM	ADF, % DM	NDF, % DM	Ca, % DM	P, % DM	Ash, % DM
1	90.5 ± 0.2^{d}	16.1 ± 0.4^{c}	12.9 ± 0.6^{d}	14.6 ± 0.8^{c}	24.2 ± 1.2^{e}	0.23 ± 0.14^{e}	1.43 ± 0.10^{c}	8.33 ± 0.74^{e}
2	91.5 ± 0.2^{c}	16.1 ± 0.4^{c}	12.7 ± 0.7^{d}	21.4 ± 0.8^{a}	32.8 ± 1.2^{b}	0.09 ± 0.14^{e}	1.41 ± 0.10^{c}	11.46 ± 0.74^{cd}
3	91.5 ± 0.2^{c}	18.0 ± 0.4^{b}	15.8 ± 0.6^{c}	12.7 ± 0.8^{cd}	27.4 ± 1.2^{de}	0.14 ± 0.14^{e}	1.85 ± 0.10^{b}	9.57 ± 0.74^{de}
4	93.0 ± 0.2^{b}	16.8 ± 0.3^{c}	15.9 ± 0.5^{c}	13.7 ± 0.7^{cd}	24.9 ± 1.0^{e}	2.69 ± 0.12^{c}	1.91 ± 0.08^{b}	16.57 ± 0.60^{b}
4 (parboiled)	93.8 ± 0.2^{a}	18.7 ± 0.4^{b}	22.2 ± 0.6^{a}	22.3 ± 0.8^{a}	38.6 ± 1.2^{a}	4.86 ± 0.14^{a}	1.80 ± 0.10^{b}	21.03 ± 0.74^{a}
5	92.9 ± 0.2^{b}	19.2 ± 0.4^{b}	20.0 ± 0.6^{b}	18.7 ± 0.8^{b}	31.6 ± 1.2^{bc}	3.47 ± 0.14^{b}	1.66 ± 0.10^{bc}	16.45 ± 0.74^{b}
5 (defatted)	89.7 ± 0.2^{e}	22.4 ± 0.3^{a}	3.4 ± 0.5^{e}	12.1 ± 0.7^{d}	29.1 ± 1.0^{cd}	1.28 ± 0.11^{d}	2.19 ± 0.08^{a}	12.87 ± 0.60^{c}

Means within columns without a common superscript differ ($P < 0.05$).

[1] Two rice bran samples were analyzed from Processors 1, 2, 3, 4 (parboiled), and 5. Three samples were analyzed from Processors 4 and 5 (defatted).

Nutrient Composition of Forages in Arkansas, 1985–1999

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Story in Brief

The University of Arkansas Cooperative Extension Service forage database consists of nutrient analyses of 11,592 forage samples (10,246 hay, 1,001 pasture, and 345 silage). Samples were collected in 74 of the 75 counties. The objective of compiling this database was to determine the average composition of forages produced in Arkansas; this work should also provide good estimates of the variability in these forages.

Database values show that forages are highly variable in nutrient content. Bermudagrass, fescue, and mixed-grass hays are the primary hays produced in Arkansas. For beef cows and calves, TDN levels were deficient in a higher percentage of hays than were CP levels. Bermudagrass hay contained greater ($P < 0.05$) levels of CP and TDN but lower ($P < 0.05$) levels of phosphorus and magnesium than fescue or mixed-grass hays. Fescue and mixed-grass hays did not differ ($P > 0.05$) in CP, acid detergent fiber (ADF), neutral detergent fiber (NDF), or TDN concentrations. Mixed-grass hay contained greater ($P < 0.05$) levels of calcium but less ($P < 0.05$) sulfur than bermudagrass. Fescue hay had less ($P < 0.05$) copper and zinc than bermudagrass or mixed-grass hays. Sodium was the most deficient mineral in the hays. Only 6 to 10% of the hays analyzed for sodium contained adequate levels for beef cows and calves. Trace minerals selenium, copper, and zinc were deficient in 60, 52, and 41% of the samples, respectively. A lower percentage of the hays were deficient in phosphorus, calcium, magnesium, and sulfur. Iron, manganese, and potassium were deficient in 2% or less of the hay samples.

Wheat, ryegrass, legume-grass, and fescue pastures tended to contain greater levels of CP and TDN than the other pasture forages analyzed. Bermudagrass, corn silage, and sorghum-sudan silages contained greater ($P < 0.05$) levels of TDN than the other silages.

Introduction

A well-planned cool- and warm-season pasture program should provide most of the required nutrients needed by beef cattle for 10 or more months each year. Many Arkansas beef cattle producers provide hay to cattle herds for 2 to 5 mo during the winter and early spring. Because most beef cow herds calve in the late winter and early spring, feed supplementation is often necessary to maintain or improve a cows' body condition by the start of the breeding season. Also, hay is often provided to weaned calves or replacement animals when pasture is unavailable.

The silage produced in Arkansas is primarily fed to dairy cattle. Silage is used, however, to some extent by beef cattle stocker operations.

The quality of forages (hay, pasture, and silage) produced in Arkansas is highly variable in nutrient content. Therefore, to improve the utilization of forages and prevent costly mistakes by over- and underfeeding, forages should be analyzed for nutrient composition. When forage composition values are not available, the use of tabular values is usually better than visual appraisal alone. The objective of compiling this forage database was to provide county extension agents, cattle producers, and cattle-related industry personnel with a source of nutrient analysis data that could be used in estimating the nutrient content of forage whenever a forage test is unavailable.

Experimental Procedures

The forage composition database was compiled by the University of Arkansas Cooperative Extension Service from forage analysis reports provided by the University of Arkansas Diagnostic Laboratory in Fayetteville. Nutrient composition values in this report were compiled from 10,246 hay samples, 1,001 pasture samples and 345 silage samples collected throughout the state from 1985 to 1999.

Forage samples were submitted for analysis from 74 of the 75 counties. The 10 counties that submitted the most samples for analysis and the number of samples submitted per county were as follows: Washington – 1,458; Benton – 940; Independence – 672; Carroll – 554; Logan – 522; Crawford – 435; Hempstead – 340; Boone – 338; Sebastian – 331; and Madison – 323.

The number of forage samples analyzed by the Diagnostic Laboratory increased from 159 in 1985 to 889 in

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1999. The increase was due, at least partially, to promotion of forage testing by county extension agents.

Forage samples were analyzed for 1 to 14 nutrients. These included DM, N, acid detergent fiber (ADF), neutral detergent fiber (NDF), phosphorus, potassium, calcium, magnesium, sodium, sulfur, iron, manganese, zinc, and copper. Selenium analysis was conducted at Michigan State University on 55 hay samples. Crude protein content was calculated as N times 6.25, and TDN was estimated with prediction equations using CP, ADF, and for some species NDF.

Individual quality characteristics were tested for species main effect by analysis of variance using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Since samples submitted to the lab represented different farms from year to year, the main effect of year and year x species interaction effect on quality characteristics were not included in the analysis. Comparisons were made for the various species means, and differences were determined using predicted difference. Chi-squared analysis was used to test whether the percentage of hays deficient in CP and TDN for three different cattle groups (dry, gestating cows; lactating cows and growing calves) was the same for each. The percentage of hays deficient in Ca and P was tested as well, for each cattle grouping.

Results and Discussion

The DM, CP, ADF, NDF, and TDN values of forage samples from Arkansas farms are shown in Tables 1, 2, and 3. Twenty-three species of hay were analyzed, but only those with more than 30 samples were included in Table 1. The average nutrient values across all 23 species are shown as "all hays" in Table 1.

Table 1 shows that the average DM content of 8,242 hays in the database was 87.4%. Two-thirds of the hays contained 82.6 to 92.2% DM [± 1 standard deviation (4.8) from the average value]. Many of the hay samples were taken after the "sweat" period was over, so the average DM content of the hays would have been lower soon after the hay was baled.

Alfalfa hay contained greater ($P < 0.05$) levels of CP than any of the other 16 species of hay in Table 1. Alfalfa-grass mixtures contained more ($P < 0.05$) CP than the other species, except for pure alfalfa. Bahiagrass and bluestems contained less ($P < 0.05$) CP than the other species. Bermudagrass, fescue, and mixed-grass hays are the primary forage species produced in Arkansas. Of those three, the CP levels of fescue and mixed grass were not ($P > 0.05$) different, but both contained less CP ($P < 0.05$) than bermudagrass.

Acid detergent fiber is composed of lignin and cellulose, the more indigestible portion of forage plants. Neutral detergent fiber is an estimate of the total cell wall content in a forage which consists of ADF and hemicellulose. Alfalfa, alfalfa-grass, and bermudagrass hays contained less ($P < 0.05$) ADF than other hays, but bermudagrass contained greater ($P < 0.05$) levels of NDF except for bluestems.

Sorghum-sudangrass and johnsongrass contained greater ($P < 0.05$) levels of TDN than all forages except alfalfa. The TDN levels of fescue and mixed-grass hays were not ($P > 0.05$) different, but bermudagrass hay contained more ($P < 0.05$) TDN than either fescue or mixed grass.

Hays in the database were produced under various management conditions, with differences in plant maturity, soil fertility, rainfall, and other environmental influences. Bermudagrass is a warm-season grass and typically is better managed for hay production than either fescue or mixed grass. Summer weather is usually a more favorable time to harvest hay than during the cooler, wetter weather in the spring. Also, some hybrid bermudagrasses are known for their high DM yields and high forage quality. Fescue, however, is a cool-season grass that reaches a good compromise between yield and quality during the spring, but rainfall often interferes with harvest. Delayed harvest allows fescue to mature past the desired growth stage. Stage of maturity at harvest, as well as other factors, is related to the nutrient differences shown. Fescue and mixed-grass hays contained similar ($P > 0.05$) levels of CP, ADF, NDF, and TDN, but levels of CP, NDF, and TDN were all greater ($P < 0.05$) in bermudagrass hay than in fescue and mixed grasses.

Nutrient contents of pasture forages were quite variable (Table 2). Dry matter content of pasture forages ranged from 27.2% for ryegrass to 66.1% for bluestems. Bluestem pastures contained less ($P < 0.05$) CP than any of the other pasture forages and less ($P < 0.05$) TDN than all other pasture forages except orchardgrass. Wheat, ryegrass, legume-grass, and fescue, which are cool-season species, tended to contain greater levels of CP and TDN than the other species shown. Pasture forages generally appear to have greater levels of CP and TDN than the same species harvested as hay.

A moisture range of 60 to 67% (33 to 40% DM) is usually desirable for most crops to be stored as silage. The use of oxygen-limiting silos or sealed or plastic covers allows preservation of crops at 40 to 60% moisture. The most typical forages stored as silage include corn silage, sorghum silage, sorghum-grain type silage and sorghum-sudangrasses. These four silages (Table 3) contained moisture levels near ideal for conventional type storage. Also, they contained lower ($P < 0.05$) levels of CP than the other silages, with the exception of mixed-grass silage, which was not different ($P > 0.05$) from sorghum silage. Bermudagrass, corn silage, and sorghum-sudan silages contained greater ($P < 0.05$) levels of TDN than other silages.

The high variability in CP and TDN levels within the hay, pasture, and silage samples emphasizes the importance of obtaining a CP and TDN analysis on forage, especially hay, before it is fed. The quality of pasture grasses can change rapidly, making it more difficult to use a pasture analysis to make adjustments in feeding. Also, pastures are usually higher in nutrient content (CP and TDN) than stored forages, so supplementation of pasture diets is often not necessary. A hay analysis should be used to determine the deficiency of nutrients in the animal's diet. An analysis can also be used to balance diets more efficiently and reduce costly errors associated with over- and underfeeding.

Mixed-grass hay had greater ($P < 0.05$) levels of Ca than either bermudagrass or fescue (Table 4). Bermudagrass hay was lower ($P < 0.05$) in P content than fescue or mixed-grass hays. Fescue contained greater ($P < 0.05$) levels of K than bermudagrass or mixed grass. Magnesium content of bermudagrass was lower ($P < 0.05$) than for fescue or mixed grasses. Bermudagrass had a greater level ($P < 0.05$) of S than mixed grass hay. Bermudagrass, fescue, and mixed-grass hays contained low levels of Na relative to the requirements for cattle (0.08 to 0.10% Na in the diet).

Compared to mixed-grass hay, fescue hay contained less ($P < 0.05$) Fe, Mn, Cu, and Zn. Fescue also contained less ($P < 0.05$) Cu and Zn than bermudagrass hay.

Nutrient requirements of diets for beef cows and growing calves were reported in the Arkansas Animal Science Department Report, 1999 (p. 151, Table 2). Those requirements were compared with the nutrient composition values of "all hays" (Table 1) to determine the percentage of hays that were deficient in nutrients. The results are shown in Table 5 of the current report. More hay samples were deficient in nutrients for the growing calf, followed by the lactating cow and then the dry, gestating cow.

Compared to CP, TDN was deficient in a higher percentage of hays ($P < 0.05$) for each cattle group. To maintain adequate performance of these animals, TDN supplementation would be required with a high percentage of the hays, especially for growing calves (81%) and lactating cows (71%).

For lactating cows, P was deficient in a higher percentage of hays ($P < 0.05$) than Ca. However, for growing calves, Ca was deficient in a higher percentage of hays than P. Only a small percentage of hays (2% or less) were deficient in Fe, Mn, and K.

Sodium was the most deficient mineral in the hays tested. Only 6 to 10% of the hays analyzed for Na contained adequate Na. Trace minerals Se, Cu, and Zn were also deficient in a high percentage (> 40%) of the hay samples. Research has shown these three trace minerals are related to the immune function in cattle.

Data in Table 5 show that mineral supplementation is recommended with most hay diets to maintain optimum animal performance. The most common mineral deficiencies in hays for beef cows and calves were Na, Se, Cu, and Zn. A smaller percentage of the hays were deficient in P, Ca, Mg, and S, and to even a lesser extent Fe, Mn, and K.

Implications

Forages produced in Arkansas are highly variable in nutrient content. For beef cows and calves, TDN deficiency is more prevalent in hays than is CP deficiency. The most common mineral deficiencies in hays for beef cows and calves were Na, Se, Cu, and Zn. A lower percentage of the hays were deficient in P, Ca, Mg, and S, and only 2% or less of the hays were deficient in Fe, Mn, and K.

Table 1. Nutrient concentrations of hays produced on Arkansas farms, 1985 to 1999.

Species	DM (%)	CP (% DM)	ADF (% DM)	NDF (% DM)	TDN (% DM)
Alfalfa	88.0[1abc] 4.0 (364)[2]	18.5[a] 4.3 (367)	33.5[g] 6.8 (365)	43.1[i] 10.1 (133)	61.2[ab] 7.0 (365)
Alfalfa-grass mix	88.5[ab] 3.7 (64)	16.3[b] 4.5 (66)	33.6[g] 5.8 (66)	54.2[h] 9.8 (33)	59.7[c] 6.3 (66)
Bahiagrass	88.1[abc] 3.9 (173)	9.6[i] 2.5 (175)	38.0[bc] 3.9 (175)	71.3[b] 5.6 (174)	57.3[de] 5.8 (174)
Bermudagrass	87.6[abcd] 4.5 (2979)	12.4[ef] 3.5 (3015)	33.8[g] 4.3 (3011)	73.4[a] 5.2 (3003)	60.0[bc] 6.2 (3007)
Bluestems	86.6[de] 5.2 (57)	9.4[i] 3.3 (57)	39.6[a] 5.8 (57)	71.9[ab] 5.8 (57)	56.1[ef] 7.6 (57)
Clover	87.2[bcd] 4.9 (45)	14.0[c] 3.7 (48)	36.6[def] 7.6 (47)	53.8[h] 9.6 (21)	56.1[ef] 7.1 (48)
Dallisgrass	88.8[a] 3.1 (32)	10.8[hi] 3.3 (33)	37.9[bcd] 6.1 (33)	71.3[b] 6.3 (32)	58.6[cd] 8.6 (32)
Fescue	87.3[bcd] 4.9 (906)	11.2[ghi] 3.0 (908)	38.7[ab] 5.1 (906)	67.1[cd] 6.0 (345)	53.8[gh] 4.7 (904)
Johnsongrass	85.3[f] 5.9 (123)	11.0[ghi] 3.8 (128)	38.2[bc] 5.5 (127)	67.5[c] 5.4 (42)	61.9[a] 5.5 (127)
Legume-grass mix	86.6[de] 5.3 (200)	12.6[de] 3.7 (207)	37.2[cde] 5.3 (207)	62.2[g] 8.3 (96)	55.0[fg] 5.4 (206)
Mixed grass	87.6[abcd] 4.8 (2376)	11.1[ghi] 3.1 (2408)	38.7[ab] 4.8 (2396)	67.1[cd] 6.1 (1127)	52.9[h] 4.7 (2394)
Native grass or weeds	87.9[abcd] 5.2 (138)	10.5[i] 3.9 (142)	37.8[bcd] 5.2 (142)	65.6[cde] 7.9 (58)	53.2[h] 5.5 (142)
Orchardgrass	86.9[cd] 4.8 (157)	13.5[cd] 3.9 (159)	36.3[ef] 5.2 (155)	65.4[de] 6.3 (76)	57.0[e] 4.3 (155)
Rye	85.4[ef] 7.7 (33)	12.6[e] 5.2 (33)	38.6[ab] 7.4 (33)	66.1[cde] 7.5 (19)	53.8[gh] 7.5 (33)
Ryegrass	86.9[cd] 4.9 (195)	11.8[efg] 3.9 (198)	37.5b[bcde] 5.0 (197)	64.8[e] 6.7 (102)	55.9[ef] 4.2 (197)
Sorghum- sudangrass	84.3[f] 6.5 (254)	11.6[fgh] 3.4 (270)	38.0[bc] 6.7 (266)	64.3[ef] 5.7 (92)	62.0[a] 6.9 (265)
Wheat	86.6[de] 5.8 (66)	11.3[ghi] 3.6 (67)	35.7[f] 5.5 (65)	62.7[fg] 7.0 (27)	55.1[fg] 4.8 (65)
All hays[3]	87.4 4.8 (8242)	12.0 3.8 (8364)	36.4 5.4 (8330)	69.8 8.2 (5469)	56.8 6.6 (8316)

Means within columns without a common superscript differ ($P < 0.05$).

[1] Average value. All nutrient values except DM are shown on a DM basis.

[2] Standard deviation and (number of samples included in the average).

[3] Contains alfalfa, alfalfa-grass mixtures, bahiagrass, bermudagrass, bluestem, bromegrass, clover, dallisgrass, fescue, johnsongrass, legume-grass mixtures, mixed grass, native grass, oat, orchardgrass, rye, ryegrass, sorghum-sudangrass, sorghum, soybean, straw of small grain, triticale, and wheat.

Table 2. Nutrient concentrations of pastures produced on Arkansas farms, 1985 to 1999.

Species	DM (%)	CP (% DM)	ADF (% DM)	NDF (% DM)	TDN (% DM)
Bermudagrass	47.7^{b} (37)[1]	13.9^{cde} (40)	32.4^{bcd} (38)	71.9^{a} (38)	63.1^{ab} (38)
Bluestems	66.1^{a} (7)	8.2^{f} (7)	42.7^{a} (7)	75.3^{a} (7)	51.4^{d} (7)
Fescue	34.7^{bcd} (42)	17.7^{abc} (40)	28.6^{def} (40)	55.7^{bcd} (12)	64.7^{ab} (40)
Legume- grass mix	31.9^{cd} (18)	19.1^{ab} (21)	26.6^{ef} (21)	52.5^{cd} (9)	66.4^{ab} (21)
Mixed grass	44.8^{bc} (23)	16.5^{bcd} (24)	30.5^{cde} (24)	60.3^{bc} (9)	62.1^{bc} (24)
Orchardgrass	47.0^{b} (7)	13.7^{de} (7)	36.5^{b} (7)	–	56.8^{cd} (7)
Ryegrass	27.2^{d} (9)	19.6^{ab} (9)	27.4^{ef} (9)	53.6^{cd} (4)	64.4^{ab} (9)
Sorghum- sudangrass	37.0^{bcd} (12)	12.2^{e} (12)	34.7^{bc} (12)	63.4^{b} (2)	65.3^{ab} (12)
Wheat	27.5^{d} (13)	21.5^{a} (13)	25.7^{f} (13)	49.1^{d} (5)	68.7^{a} (13)
All pastures[2]	40.5 (667)	16.7 (746)	30.2 (742)	65.4 (318)	63.5 (742)

Means within columns without a common superscript differ ($P < 0.05$).

[1] The average value and (number of samples included in the average). All nutrient values except DM are shown on a DM basis.

[2] Contains same species as "all hays" (Table 1) except no alfalfa-grass, bromegrass, or straw of small grain samples.

Table 3. Nutrient concentrations of silages produced on Arkansas farms, 1985 to 1999.

Species	DM (%)	CP (% DM)	ADF (% DM)	NDF (% DM)	TDN (% DM)
Bermudagrass	44.4[1a] 11.9 (18)[2]	13.9[a] 2.9 (18)	34.8[b] 2.9 (18)	65.7[a] 7.6 (18)	66.5[a] 7.1 (18)
Corn silage	35.7[bc] 9.8 (64)	9.2[c] 1.8 (56)	29.0[c] 5.9 (56)	52.6[cd] 6.9 (27)	63.8[a] 4.4 (56)
Fescue	48.9[a] 10.2 (9)	13.3[a] 4.0 (9)	35.1[b] 7.5 (9)	57.8[bc] 3.6 (4)	57.7[bc] 5.7 (9)
Mixed grass	35.3[bc] 11.7 (20)	12.2[ab] 2.7 (21)	39.4[a] 7.9 (16)	60.0[abc] 11.4 (7)	53.2[d] 6.8 (16)
Ryegrass	33.1[bc] 10.0 (10)	12.5[a] 4.4 (10)	34.5[b] 5.2 (10)	55.8[cd] 12.0 (5)	58.5[b] 4.3 (10)
Sorghum- sudangrass	30.9[c] 11.3 (30)	9.6[c] 2.7 (37)	37.2[ab] 8.1 (37)	65.0[ab] 5.9 (15)	62.9[a] 8.4 (37)
Sorghum- grain type	37.7[b] 12.2 (10)	9.9[c] 2.1 (10)	35.4[b] 7.7 (10)	49.5[d] 2.2 (2)	54.0[cd] 7.8 (10)
Sorghum- silage type	32.6[bc] 8.8 (74)	10.2[bc] 4.3 (74)	33.3[b] 6.0 (73)	58.2[abc] 5.1 (17)	55.8[bcd] 5.0 (73)
Wheat	31.5[bc] 8.0 (30)	13.6[a] 2.9 (18)	36.9[ab] 4.7 (18)	57.1[c] 5.3 (6)	56.0[bcd] 4.7 (18)
All silages[3]	34.8 10.7 (282)	11.0 3.7 (270)	34.0 6.9 (264)	58.5 8.6 (112)	59.3 7.2 (264)

Means within columns without a common superscript differ ($P < 0.05$).

[1] Average value. All values except DM are shown on a DM basis.

[2] Standard deviation and (number of samples included in the average).

[3] Contains alfalfa, alfalfa-grass mixtures, bermudagrass, corn silage, fescue, johnsongrass, legume-grass mixtures, mixed grass, rye, ryegrass, sorghum-sudangrass, sorghum-grain type, sorghum-silage type, and wheat.

Table 4. Mineral composition (DM basis) of hays from Arkansas farms, 1985 to 1999.

Mineral	Item	Bermudagrass	Fescue	Mixed grass	All hays[1]
Calcium, %	Avg[2]	0.51[b] (319)[3]	0.50[b] (83)	0.58[a] (349)	0.58 (981)
	SD[4]	0.163	0.15	0.25	0.27
Phosphorus, %	Avg	0.28[b] (345)	0.30[a] (81)	0.30[a] (352)	0.29 (1006)
	SD	0.07	0.08	0.10	0.09
Potassium, %	Avg	1.89[b] (317)	2.11[a] (78)	1.82[b] (328)	1.89 (940)
	SD	0.54	0.70	0.64	0.62
Magnesium, %	Avg	0.22[b] (318)	0.25[a] (80)	0.26[a] (336)	0.24 (952)
	SD	0.07	0.06	0.10	0.08
Sulfur, %	Avg	0.26[a] (330)	0.24[ab] (72)	0.21[b] (306)	0.23 (918)
	SD	0.09	0.33	0.06	0.12
Sodium, %	Avg	0.04 (159)	0.03 (31)	0.03 (135)	0.04 (452)
	SD	0.04	0.03	0.04	0.04
Iron, ppm	Avg	212[ab] (219)	154[b] (45)	244[a] (251)	220 (673)
	SD	209	92	305	240
Manganese, ppm	Avg	175[ab] (218)	150[b] (45)	201[a] (253)	184 (675)
	SD	115	96	142	128
Copper, ppm	Avg	11.0[a] (233)	8.9[b] (55)	11.2[a] (266)	10.7 (729)
	SD	4.4	3.7	5.5	4.7
Zinc, ppm	Avg	34.3[a] (219)	29.3[b] (45)	38.3[a] (252)	35.3 (676)
	SD	13.1	13.1	19.2	15.7
Selenium, ppm	Avg	0.09 (15)	0.08 (12)	0.09 (20)	0.09 (55)
	SD	0.05	0.04	0.05	0.06

Means within rows without a common superscript differ ($P < 0.05$).

[1] All hays include the following species: alfalfa, alfalfa-grass mixtures, bahiagrass, bermudagrass, bluestem, bromegrass, clover, dallisgrass, fescue, johnsongrass, legume-grass mixtures, mixed grass, native grass, oat, orchardgrass, rye, ryegrass, sorghum-sudangrass, sorghum, soybean, straw of small grain, triticale, and wheat.

[2] Average value.

[3] Number of hay samples included in the average.

[4] Standard deviation.

Table 5. Percentage of hay samples deficient in CP, TDN and mineral content for cows and calves.[1]

Item (No. samples)	Dry, gestating cow[2]	Lactating cow[3]	Growing calf[4]
Crude protein (8364)	11	41	45
Total digestible nutrients (8316)	25	71	81
Calcium (981)	3	7	27
Phosphorus (1006)	7	16	19
Potassium (940)	<1	1	<1
Magnesium (952)	2	30	<1
Sulfur (918)	8	8	8
Sodium (452)	90	94	90
Iron (673)	2	2	2
Manganese (675)	2	2	<1
Zinc (676)	41	41	41
Copper (729)	52	52	52
Selenium (55)	60	60	60

[1] Includes all hay samples.

[2] 1100 lb dry, gestating cow, 11 mo since calving.

[3] 1100 lb lactating cow, 2 mo since calving, 20 lb peak milk.

[4] 500-lb weaned calf, 1.5 lb ADG.

Effect of Mannan Oligosaccharide (Bio-Mos) Addition With and Without Zinc Oxide on Performance and Immunocompetence of Weanling Pigs

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

Story in Brief

An experiment involving 216 weanling barrows (1/2 Large White x 1/4 Duroc x 1/4 Landrace; 21 ± 2 d of age; 13.7 ± 0.07 lb initial BW) was conducted to determine the efficacy of Bio-Mos as an alternative to growth-promoting concentrations of zinc oxide. Pigs were blocked by initial BW and penned in groups of six with nine pens/treatment in an off-site nursery. Treatments were arranged as a 2 x 2 factorial with two concentrations of Bio-Mos (0% and 0.2%) and two concentrations of dietary Zn (165 ppm and 2465 ppm). Experimental diets were fed throughout the study and contained 1.5% lysine during Phase 1 (day 0 to 10), 1.35% lysine during Phase 2 (day 10 to 24), and 1.2% lysine during Phase 3 (day 24 to 38). Two pigs/pen were bled via venipuncture, and a lymphocyte blastogenesis assay was performed. Addition of zinc oxide increased ($P < 0.05$) ADG during Phase 1, ADFI during Phase 1 and 2, and F/G in the overall study (day 0 to 38). In Phase 2 and overall, ADG increased when Bio-Mos was added to diets containing 165 ppm Zn but decreased when Bio-Mos was added to diets with 2465 ppm Zn (interaction, $P < 0.08$). Response to Bio-Mos supplementation in early-weaned pigs appears to be dependent on the level of ZnO in the diet.

Introduction

Bio-Mos is a mannan oligosaccharide derived from the cell wall of yeast and has resulted in improved weight gain and feed efficiency when fed to broiler chicks and weanling pigs. Polysaccharides derived from yeast cell wall material have also been implicated in enhancing immune function. Researchers in aquaculture have found that yeast glucan enhances the nonspecific defense mechanism and survival in fish (Engstad et al., 1992). Similarly, performance has been improved in early-weaned pigs fed a glucan isolated from yeast (Schoenherr et al., 1994). Because of these observed improvements in performance, Bio-Mos could serve as a potential replacement for additions of high levels of trace minerals such as ZnO and copper sulfate that are added in excess of the pigs' dietary requirement. The objective of this study was to further assess the efficacy of Bio-Mos in improving performance in weaned pigs, and determine its potential as a replacement for ZnO in nursery pig diets. The effect of diet on immunocompetence of weanling pigs was also evaluated.

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; 13.7 ± 0.07 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 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.

Four dietary treatments were fed consisting of two concentrations of inorganic Zn (165 and 2465 ppm) with and without the addition of Bio-Mos (0 or 0.3% Bio-Mos, Alltech, Nicholasville, KY.) in a 2 x 2 factorial arrangement of treatments. Because results in field studies suggest that pigs may respond better to a Bio-Mos regimen in which Bio-Mos supplementation is greater during the initial nursery period than in the latter nursery phases, Bio-Mos was supplemented at 0.3% of the diet during Phase 1 and 0.2% during Phase 2 and 3. The specific diets during the first 10 d postweaning (Phase 1) consisted of the following: 1) a

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negative control diet containing Zn at 165 ppm from $ZnSO_4$ (Table 1); 2) the negative control diet plus 2300 ppm Zn as ZnO; 3) the negative control diet supplemented with 0.3% Bio-Mos; and 4) the negative control diet plus 2300 ppm Zn as ZnO, and supplemented with 0.3% Bio-Mos. Substitutions in all diets were made at the expense of corn. Phase 1 diets were formulated to contain 1.50% lysine, 0.87% methionine plus cystine, 0.90% calcium, 0.80% phosphorus, and 14.53% lactose and were fed for a period of 10 d. Upon completion of the Phase 1 diet, pigs were fed a Phase 2 diet (1.35% lysine) from day 10 to 24 and a Phase 3 diet (1.20% lysine) from day 24 to 38 postweaning (Table 1). 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, a five-hole feeder, and Maxima nursery flooring. 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/wk.

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, and approximately 15 ml of blood was collected in heparinized tubes by venipuncture for isolation of mononuclear cells. Cells were plated at a concentration of 2×10^6 cells/ml, and phytohemagglutinin (PHA) and pokeweed mitogen (PWM) were used as mitogens for cellular proliferation at a concentration of 10 mg/ml. Incubation, labeling with [3]H-thymidine, and cell harvesting followed procedures outlined by van Heugten and Spears (1997). Uptake of [3]H-thymidine served as the measure of cell proliferation.

Performance 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 procedures of SAS (SAS Inst. Inc., Cary, NC). The effects of block, ZnO, Bio-Mos, and Bio-Mos x ZnO interaction effects were evaluated.

Results and Discussion

Treatment means are presented where a Bio-Mos x ZnO interaction was observed (Table 2), while data in which no such interaction was observed and the results of the lymphocyte proliferation assay are presented as main-effect means (Table 3). Average daily gain ($P < 0.01$), ADFI ($P < 0.01$), and F/G ($P < 0.01$) improved in pigs fed diets containing 2465 ppm Zn during Phase 1 compared to those fed diets with 165 ppm Zn.

Average daily gain increased ($P < 0.01$) during the first week (day 10 to 17) of Phase 2 in pigs fed diets supplemented with 2465 ppm Zn. Additionally, Zn supplementation increased ADFI from day 10 to 17, day 17 to 24, and overall in Phase 2 ($P < 0.01$, $P = 0.06$, and $P < 0.01$, respectively). Average daily gain and F/G increased during the second week (day 17 to 24) of Phase 2 and the entire phase (day 10 to 24) with the addition of Bio-Mos at 165 ppm Zn but were similar when Bio-Mos was added to diets with 2465 ppm Zn. This resulted in a tendency for a Bio-Mos x ZnO interaction during days 17 to 24 of the trial and a significant interaction overall in Phase 2 (day 10 to 24) for ADG ($P = 0.14$ and $P < 0.05$, respectively). Also a tendency for an interaction for F/G ($P = 0.14$) for these two intervals was observed.

During the fourth week of the study (day 24 to 31), ADG increased with the addition of Bio-Mos at 165 ppm Zn but decreased with the addition of Bio-Mos to diets supplemented with 2465 ppm Zn. This resulted in a Bio-Mos x ZnO interaction for ADG ($P < 0.05$). There were no significant interactions or main effects observed during the overall Phase 3 (day 24 to 38) period.

For the overall study (day 0 to 38), ADG and ADFI increased with the addition of Bio-Mos at 165 ppm Zn, but decreased with the addition of Bio-Mos in diets with 2465 ppm Zn. This resulted in a Bio-Mos x ZnO interaction for ADG ($P < 0.05$) and a tendency for an interaction for ADFI ($P = 0.14$). Feed/gain was improved ($P < 0.05$) in pigs fed diets with 2465 ppm Zn compared to those fed diets containing 165 ppm Zn. Dietary treatments did not affect lymphocyte proliferation after mitogen stimulation in samples taken on days 10, 11, 14, and 15, postweaning.

As observed in the current study, addition of ZnO at pharmacological levels in previous experiments resulted in increased gain and feed intake in young pigs (Hahn and Baker, 1993; Smith et al., 1997). However, response to the addition of Bio-Mos was not as pronounced as observed in a prior study comparing it with copper sulfate addition (Davis et al., 1999). This may be due to the higher level of Bio-Mos fed during Phase 1 of this study (0.3% of the diet) compared to the level fed in the previous experiment (0.2% of the diet). Several tendencies for a Bio-Mos x ZnO interaction were observed, in which ADG increased with Bio-Mos addition to the low Zn diets but decreased with the addition of Bio-Mos when the diet was supplemented with 2300 ppm ZnO. Titration of a yeast glucan product (Macrogard) indicated that performance does not increase linearly with increasing dosage (Schoenherr et al., 1994). Additionally, immunostimulants often have a maximum level that can be administered, after which there is a lack of a response or a toxic effect on performance (Raa, 1998).

The effect of dietary Bio-Mos and ZnO addition on the immunocompetence of weanling pigs was evaluated by mitogen-stimulated lymphocyte proliferation. As observed in a previous experiment (Davis et al., 1999), neither Bio-Mos nor ZnO had a significant effect on the proliferation of lymphocytes in vitro; however, stimulated cell cultures from pigs supplemented with Bio-Mos and 2465 ppm Zn had numerically greater proliferation of lymphocytes.

Implications

The results of this study suggest a tendency for Bio-Mos added at 0.2% of the diet to improve weanling pig performance in pigs fed 165 ppm Zn during Phase 2 (day 10

to 24), Phase 3 (day 24 to 38), and the overall trial (day 0 to 38). However, addition of Bio-Mos at 0.3% of the diet during Phase 1 (day 0 to 10) tended to increase F/G and may indicate a negative effect associated with the higher dietary Bio-Mos level.

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Table 1. Composition of basal diets.[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 (Optipro)	6.75	-	-
Soybean meal, 48% CP	10.00	28.30	30.00
AP-301	2.00	2.00	-
AP-920	3.75	-	-
Select menhaden fish meal	8.50	4.00	-
Soybean oil	4.00	4.00	-
Fat	-	-	4.00
Ethoxyquin	0.03	0.03	0.03
Lysine HCl	-	-	0.16
Threonine	0.05	-	-
Methionine	0.15	0.12	0.07
Tylan-40	-	-	0.125
Neo-terromycin 10/5	1.00	1.00	-
Mineral premix (NB-8557B)[b]	0.15	0.15	0.15
Vitamin premix (NB-6157B)[b]	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
Methionine + cystine	0.90	0.82	0.72
Calcium	0.90	0.80	0.80
Phosphorus	0.80	0.70	0.70
Metabolizable energy, kcal/lb	1533	1542	1557
Lactose	14.53	8.3	-

[a] Basal diets were supplemented with 0.32% ZnO or with Bio-Mos added at 0.3% (Phase 1) or 0.2% (Phase 2 and 3) to provide four diets in each phase with and without Bio-Mos and with and without 2465 ppm Zn. Zinc oxide and Bio-Mos were added at the expense of corn.

[b] Vitamins and minerals met or exceeded NRC (1998) requirements.

Table 2. Treatment means showing interaction effects of Bio-Mos and zinc oxide on gain, feed intake, and efficiency of segregated early weaned pigs.

Bio-Mos, %	0	0	0.2	0.2	
Zinc oxide, ppm	165	2465	165	2465	SE
Phase 2 (days 17 to 24)					
ADG, lb[a]	1.08	1.16	1.15	1.10	0.04
F/G[a]	1.33	1.35	1.26	1.35	0.02
Phase 2 (days 10 to 24)					
ADG, lb[b]	0.83	0.95	0.91	0.92	0.03
F/G[a]	1.45	1.38	1.35	1.38	0.04
Phase 3 (days 24 to 31)					
ADG, lb[b]	1.13	1.28	1.26	1.23	0.05
Overall trial (days 0 to 38)					
ADG, lb[b]	0.88	0.98	0.93	0.95	0.03
ADFI, lb[a]	1.35	1.44	1.38	1.41	0.05

[a] Tendency for Bio-Mos x zinc oxide interaction; $P = 0.14$.

[b] Bio-Mos x zinc oxide interaction; $P < 0.05$.

Table 3. Main effects of Bio-Mos and zinc oxide addition to nursery pig diets.[a]

	Bio-Mos[b]			Zinc oxide		
	–	+	SE	–	+	SE
Phase 1 (days 0 to 10)						
ADG, lb[c]	0.40	0.40	0.02	0.35	0.45	0.02
ADFI, lb[c]	0.52	0.52	0.02	0.48	0.56	0.02
F/G[d]	1.34	1.33	0.05	1.41	1.26	0.05
Days 10 to 17						
ADG, lb[c]	0.67	0.70	0.03	0.62	0.75	0.03
ADFI, lb[c]	0.98	0.98	0.03	0.92	1.04	0.03
F/G	1.49	1.42	0.04	1.50	1.41	0.04
Days 17 to 24						
ADFI, lb[e]	1.52	1.49	0.03	1.46	1.54	0.03
Phase 2 (days 10 to 24)						
ADFI, lb[c]	1.25	1.24	0.03	1.19	1.29	0.03
Days 24 to 31						
ADFI, lb	1.72	1.69	0.06	1.70	1.71	0.06
F/G	1.42	1.34	0.05	1.42	1.34	0.05
Days 31 to 38						
ADG, lb	1.27	1.24	0.04	1.25	1.26	0.04
ADFI, lb	2.26	2.29	0.05	2.27	2.28	0.05
F/G	1.76	1.84	0.04	1.81	1.80	0.04
Phase 3 (days 24 to 38)						
ADG, lb	1.24	1.24	0.03	1.23	1.26	0.03
ADFI, lb	1.99	1.99	0.05	1.98	1.99	0.05
F/G	1.59	1.59	0.03	1.61	1.57	0.03
Overall trial (days 0 to 38)						
F/G[d]	1.47	1.45	0.02	1.49	1.43	0.02
Lymphocyte proliferation, cpm[f]						
Unstimulated	488	424	169	341	571	158
PHA, 30 mg/ml	34942	36790	3412	35143	36588	3251
PWM, 10 mg/ml	29325	30597	3092	28697	31225	2946

[a] Data are means of nine pens/treatment with six pigs/pen. Pigs were 15 to 21 d of age and averaged 13.7 ± 0.07 lb of BW at the initiation of the study.

[b] Bio-Mos was supplemented at 0.3% during Phase 1 and at 0.2% during Phase 2 and 3.

[c] Zinc oxide effect; $P < .01$.

[d] Zinc oxide effect; $P < .05$.

[e] Zinc oxide effect; $P = .06$.

[f] Data are means of nine pens/treatment with two pigs/pen. One blood sample was collected from each pig on one of 4 d beginning on day 10 and ending on day 15 of the trial. Data are expressed as counts per minute (cpm).

Effect of Concentration of Mannan Oligosaccharide (Bio-Mos) Addition With and Without Zinc Oxide on Performance and Immunocompetence of Weanling Pigs

E. Davis, C. Maxwell, D. Brown, 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; 10.1 ± 0.01 lb BW) were used to determine the potential for Bio-Mos to serve as a replacement for pharmacological concentrations of zinc oxide. Pigs were blocked by initial BW and penned in groups of six with six pens/treatment in an off-site nursery. Treatments were arranged as a 2 x 3 factorial with three concentrations of Bio-Mos (0%, 0.2%, and 0.3%) and two concentrations of Zn (165 ppm and 2465 ppm). Experimental diets were fed throughout the study and contained 1.5% lysine during Phase 1 (day 0 to 10), 1.35% lysine during Phase 2 (day 10 to 24), and 1.2% lysine during Phase 3 (day 24 to 38). Two pigs/pen were bled via venipuncture, and a lymphocyte blastogenesis assay was performed. The addition of ZnO improved ($P < 0.05$) ADG, ADFI, and F/G during Phase 1 and in the overall trial (day 0 to 38). Supplementation with Bio-Mos at 0.3% increased ADG and improved F/G during Phase 1 and in the overall study when compared to pigs fed 0.2% Bio-Mos, but performance was not different from pigs fed diets without Bio-Mos. During Phase 2, ADG decreased in pigs fed 0.2% Bio-Mos in diets containing 165 ppm Zn but increased with the addition of 0.3% Bio-Mos. However, the addition of Bio-Mos at 0.2% and 0.3% in diets containing 2465 ppm Zn improved ADG (interaction, $P < 0.05$). Lymphocyte proliferation in response to pokeweed mitogen increased in pigs fed diets containing 2465 ppm Zn with 0.2% Bio-Mos when compared to pigs fed 0 or 0.3% Bio-Mos but was similar for all Bio-Mos concentrations in diets with 165 ppm Zn (tendency for an interaction, $P = 0.13$). Response to Bio-Mos seems to be dependent on the concentration of Bio-Mos and ZnO in the diet.

Introduction

Bio-Mos is a mannan oligosaccharide derived from the cell wall of yeast that has resulted in improved weight gain and feed efficiency when fed to weanling pigs and broiler chicks. The effect of Bio-Mos on the immune system is not as well documented. Previous research with yeast glucans reported an enhancement of nonspecific immunity in fish (Engstad et al., 1992) and an improvement in the immune response of young pigs. In addition, the conditions under which Bio-Mos is an effective supplement in weanling pig diets needs to be assessed. Previous work comparing Bio-Mos and the addition of copper sulfate (Davis et al., 1999) resulted in significant ADG and F/G responses to Bio-Mos. The pigs used for this study were from a facility with a history of several disease problems. In a subsequent experiment (Davis et al., 2000) comparing Bio-Mos and ZnO addition and obtaining pigs from a different source, main effects due to the addition of Bio-Mos were not observed, although there were some tendencies for Bio-Mos x ZnO interactions. Therefore, this study was conducted to confirm the previous response to Bio-Mos using the same source of pigs as in the initial nursery study and to further evaluate the efficacy of Bio-Mos supplementation in diets with and without growth-promoting levels of ZnO. In addition, a second concentration of Bio-Mos was evaluated based upon results of a study conducted at Louisiana State University and our previous observations of a decreased performance in pigs fed 0.3% Bio-Mos in Phase 1.

Experimental Procedures

A total of 216 weanling barrows (21 ± 2 d of age; 10.1 ± 0.01 lb BW) were obtained from a single source and transported to the University of Arkansas off-site nursery facility. Pigs were blocked by initial BW and penned with six pigs/pen (six pens/treatment). Six dietary treatments consisted of two concentrations of inorganic Zn (165 and 2465 ppm) and three concentrations of Bio-Mos (0, 0.2%, or 0.3%, Alltech, Nicholasville, KY) in a 2 x 3 factorial arrangement of treatments. The specific diets during the first 10 d postweaning (Phase 1, Table 1) consisted of the

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following: 1) a negative control diet containing Zn as $ZnSO_4$ at 165 ppm; 2) the negative control diet supplemented with 0.2% Bio-Mos; 3) the negative control diet supplemented with 0.3% Bio-Mos; 4) the negative control diet plus 2300 ppm Zn as ZnO; 5) the negative control diet plus 2300 ppm Zn as ZnO, and supplemented with 0.2% Bio-Mos; 6) the negative control diet plus 2300 ppm Zn as ZnO, and supplemented with 0.3% Bio-Mos.

Treatment diets were fed throughout Phase 2 and 3. Substitutions in all diets were made at the expense of corn. Phase 1 diets were formulated to contain 1.50% lysine, 0.90% methionine plus cystine, 0.90% calcium, 0.80% phosphorus, and 14.53% lactose and were fed for a period of 10 d. Pigs were then fed a Phase 2 diet (1.35% lysine) from day 10 to 24 and a Phase 3 diet (1.20% lysine) from day 24 to 38 postweaning (Table 1).

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

Pig BW and feed intake were determined at the initiation of the study and weekly to evaluate ADG, ADFI, and F/G. *In* vitro cellular immune response was measured using a lymphocyte blastogenesis assay (Blecha et al., 1983), in which a total of 72 pigs (18 pigs/treatment) were sampled and approximately 15 ml of blood was collected in heparinized tubes by venipuncture for isolation of mononuclear cells. Phytohemagglutinin (PHA) and pokeweed mitogen were used as mitogens at a concentration of 30 and 20 mg/ml, respectively. Uptake of [3]H-thymidine served as the measure of cell proliferation.

Performance 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 procedures of SAS (SAS Inst. Inc., Cary, NC). The effects of block, ZnO, Bio-Mos, and Bio-Mos x ZnO 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, and the same procedure was used to separate Bio-Mos main effect means.

Results and Discussion

Data in which no Bio-Mos x ZnO interactions were observed are presented as main effect means (Table 2), while treatment means are presented graphically when there was a Bio-Mos x ZnO interaction. Average daily gain increased ($P < 0.05$) and F/G improved ($P < 0.05$) during Phase 1 and in the overall study (days 0 to 38) when Bio-Mos was supplemented at 0.3% when compared to pigs fed 0.2% Bio-Mos. However, there was no difference between pigs fed 0.3% Bio-Mos and those fed diets without Bio-Mos. Addition of 2465 ppm Zn as ZnO to in the diet in Phase 1 improved ADG, ADFI and F/G ($P < 0.05$).

During week 1 of Phase 2 (days 10 to 17), performance was not significantly affected by Bio-Mos addition at either the 0.2% or 0.3% level. However, ADG, ADFI, and F/G were improved in pigs fed 2465 ppm Zn ($P < 0.05$). During week 2 of Phase 2 (days 17 to 24), ADG was improved in pigs fed Bio-Mos at the 0.2% level in combination with 2465 ppm Zn. However, ADG decreased in pigs fed 165 ppm Zn in combination with the 0.2% concentration of Bio-Mos. Gain was similar in pigs fed either concentration of Zn at the 0.3% concentration of Bio-Mos supplementation. This resulted in a Bio-Mos x ZnO interaction ($P < 0.02$, Figure 1). Average daily feed intake increased ($P < 0.05$) with ZnO addition from days 17 to 24. For the combined Phase 2 period (days 10 to 24), pigs fed Bio-Mos at either the 0.2% or 0.3% concentration in combination with 2465 ppm Zn tended to have improved ADG, whereas gain tended to be reduced at both concentrations of Bio-Mos supplementation when pigs were fed diets containing 165 ppm Zn (interaction, $P < 0.04$; Figure 2).

For the overall study (days 0 to 38), ADG, ADFI, and F/G improved ($P < 0.05$) when ZnO was supplemented in the diet, while Bio-Mos addition improved ($P < 0.05$) F/G when supplemented at 0.2%. Lymphocyte proliferation in response to PWM tended to be increased in pigs fed diets containing 2465 ppm Zn with 0.2% Bio-Mos, but was similar for all Bio-Mos concentrations in diets with 165 ppm Zn (tendency for an interaction, $P = 0.13$; Figure 3).

As in a previous study conducted at the University of Arkansas comparing Bio-Mos and ZnO (Davis et al., 2000) and in other studies evaluating the young pig's response to Zn (Hahn and Baker, 1993; Smith et al., 1997), ZnO supplementation improved performance during Phase 1 and 2 of the current trial. Response to Bio-Mos in the current study was more pronounced than in a previous trial comparing Bio-Mos and ZnO (Davis et al., 2000). This may be a response to the different disease status between the two herds. The pigs in the first study with Zn were from a farm without any evident disease problems, while the pigs used in this study were from the same facility as pigs in a trial comparing $CuSO_4$ and Bio-Mos (Davis et al., 1999) in which a response to Bio-Mos was observed.

As in the similar study presented in this report (Davis et al., 2000), a Bio-Mos x ZnO interaction for ADG was observed during Phase 2 of the experiment in which response to Bio-Mos supplementation depended on the concentration of Zn in the diet. However, in the current study, response to Bio-Mos supplementation was improved at 2465 ppm Zn but not at 165 ppm, while in the previous experiment Bio-Mos response improved when supplemented to diets with 165 ppm Zn, but not those with 2465 ppm.

Additionally, pigs fed Bio-Mos in the current study tended to have a greater lymphocyte proliferation response to PWM. This is consistent with non-significant lymphocyte proliferation responses to PWM in pigs fed supplemental Bio-Mos in two previous trials (Davis et al., 1999; Davis et al., 2000).

Implications

Bio-Mos supplementation resulted in improved performance at higher dietary Zn concentrations in this study than in the previous experiment. This discrepancy in response between the two studies suggests that the response of nursery pigs to Bio-Mos may be dependent on several factors such as environmental conditions, disease status, production facilities, or genetic diversity. Under certain management conditions, Bio-Mos may provide an effective alternative to the additions of pharmacological concentrations of Zn commonly added to nursery pig diets.

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Table 1. Composition of basal diets.[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 (Optipro)	6.75	–	–
Soybean meal, 48% CP	10.00	28.30	30.00
AP–301	2.00	2.00	–
AP–920	3.75	–	–
Select menhaden fish meal	8.50	4.00	–
Soybean oil	4.00	4.00	–
Fat	–	–	4.00
Ethoxyquin	0.03	0.03	0.03
Lysine HCl	–	–	0.16
Threonine	0.05	–	–
Methionine	0.15	0.12	0.07
Tylan–40	–	–	0.125
Neo-terromycin 10/5	1.00	1.00	–
Mineral premix (NB–8557B)[b]	0.15	0.15	0.15
Vitamin premix (NB–6157B)[b]	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
Methionine + cystine	0.90	0.82	0.72
Calcium	0.90	0.80	0.80
Phosphorus	0.80	0.70	0.70
Metabolizable energy, kcal/lb	1533	1542	1557
Lactose	14.53	8.3	–

[a] Basal diets were supplemented with 0.32% zinc oxide or with Bio–Mos added at 0.3% or 0.2% to provide six diets in each phase with each Bio–Mos level (0, 0.2%, and 0.3%) represented with and without 2300 ppm zinc as zinc oxide. Zinc oxide and Bio–Mos were added at the expense of corn.

[b] Vitamins and minerals met or exceeded NRC (1998) requirements.

Table 2. Main effect means showing Bio-Mos and zinc oxide addition to nursery pig diets.[a]

	Bio-Mos (%)				Zinc oxide (ppm)		
	0	0.2	0.3	SEM	165	2465	SEM
Phase 1 (days 0 to 10)							
ADG, lb[b]	0.36[y,z]	0.33[z]	0.40[y]	0.02	0.32	0.40	0.02
ADFI, lb[b]	0.44	0.43	0.45	0.02	0.41	0.47	0.02
F/G[b]	1.23[z]	1.35[y]	1.14[z]	0.05	1.30	1.19	0.04
Phase 2 (days 10 to 17)							
ADG, lb[b]	0.69	0.72	0.75	0.03	0.65	0.79	0.02
ADFI, lb[b]	0.95	0.97	1.00	0.03	0.92	1.02	0.02
F/G[b]	1.37	1.37	1.34	0.03	1.41	1.31	0.02
Phase 2 (days 17 to 24)							
ADFI, lb[b]	1.36	1.42	1.35	0.04	1.31	1.44	0.04
F/G	1.22	1.29	1.24	0.04	1.21	1.28	0.03
Phase 2 (days 10 to 24)							
ADFI, lb[b]	1.15	1.19	1.17	0.03	1.11	1.23	0.03
F/G	1.30	1.33	1.29	0.02	1.31	1.29	0.02
Phase 3 (days 24 to 31)							
ADG, lb	1.11	1.12	1.14	0.02	1.14	1.11	0.02
ADFI, lb	1.77	1.82	1.83	0.03	1.81	1.80	0.03
F/G	1.59	1.63	1.60	0.02	1.60	1.62	0.02
Phase 3 (days 31 to 38)							
ADG, lb	1.35	1.34	1.31	0.03	1.30	1.36	0.02
ADFI, lb	1.81	1.82	1.76	0.05	1.80	1.80	0.04
F/G	1.34	1.36	1.34	0.03	1.38	1.32	0.03
Phase 3 (days 24 to 38)							
ADG, lb	1.23	1.23	1.22	0.02	1.22	1.24	0.02
ADFI, lb	1.79	1.82	1.79	0.03	1.81	1.80	0.03
F/G	1.47	1.50	1.47	0.02	1.49	1.47	0.02
Overall trial (days 0 to 38)							
ADG, lb[b]	0.93	0.92	0.94	0.01	0.90	0.96	0.01
ADFI, lb[b]	1.26	1.29	1.28	0.02	1.25	1.31	0.02
F/G[b]	1.35[z]	1.40[y]	1.33[z]	0.02	1.38	1.34	0.01
Lymphocyte proliferation,[c] cpm							
Unstimulated	1169	716	1071	204	829	1142	166
PHA, 30 mg/ml	43046	50570	40549	6492	43593	45850	5301

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

[a] Data are means of six pens/treatment with six pigs/pen. Pigs were 15 to 21 d of age and averaged 10.1 ± 0.01 lb BW at the initiation of the study.

[b] Zinc oxide effect; $P < 0.05$.

[c] Data are means of six pens/treatment with one pig/pen. One blood sample was collected from each pig on one of 4 d beginning on day 24 and ending on day 29 of the trial. Data are expressed as counts per minute (cpm).

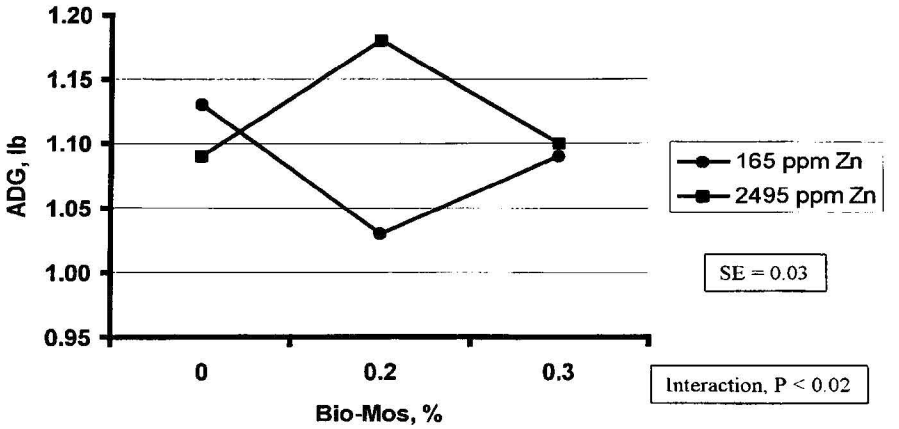

Figure. 1. Average daily gain response to Bio-Mos and zinc oxide addition in the diets of nursery pigs from days 17 to 24 (week 3).

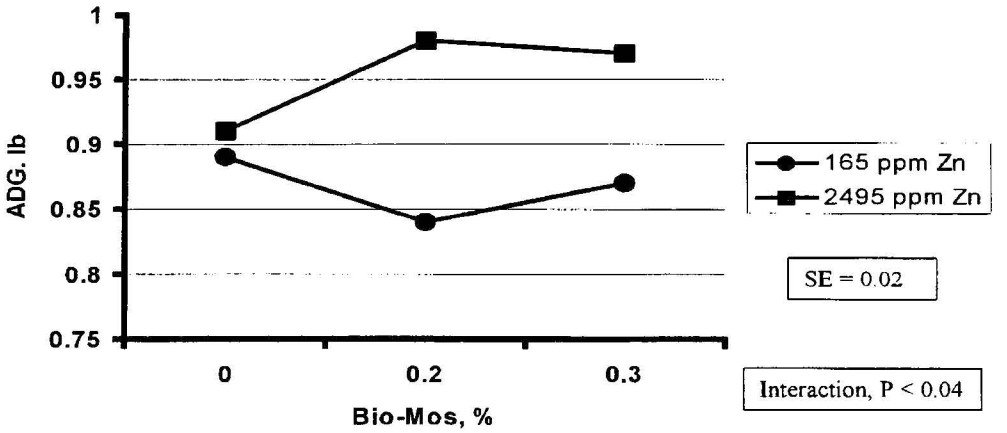

Figure. 2. Average daily gain response to Bio-Mos and zinc oxide addition in the diets of nursery pigs from days 10 to 24 (Phase 2).

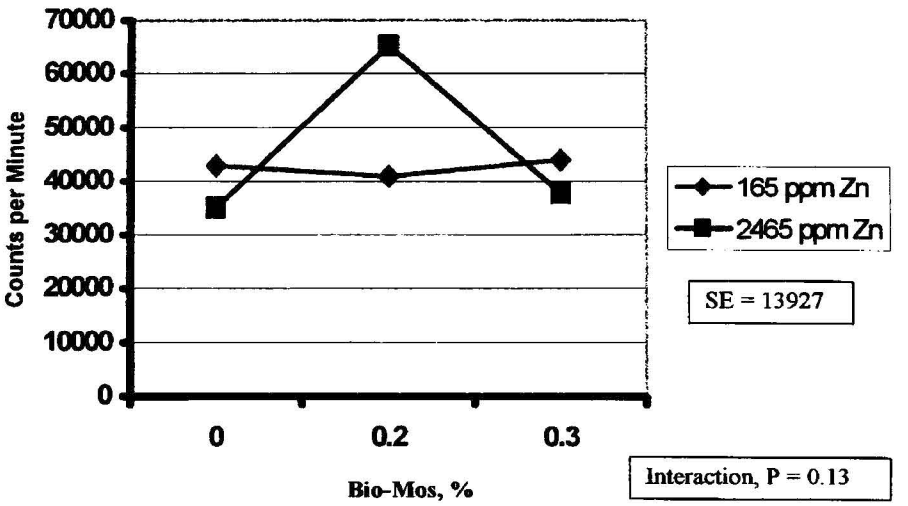

Figure. 3. Lymphocyte proliferation response to pokeweed mitogen in nursery pigs fed Bio-Mos and zinc oxide.

Potential for Profound (Multiple Protein Complex) as a Protein Source for Phase 1 Nursery Diets[a]

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Story in Brief

Protein sources for early-weaned pigs that will optimize performance are in limited supply and expensive. Egg protein has an excellent amino acid profile and should be an excellent protein source for young pigs, but the cost of processing has been prohibitive for eggs to be routinely utilized in swine Phase 1 nursery diets. American Dehydrated Foods, Inc., has recently developed an extrusion process using a combination of dry protein sources and liquid egg to produce a final multiple protein complex suitable for Phase 1 nursery diets. This new technology may provide an opportunity to produce a high-quality egg protein for use in diets for early-weaning pigs at costs lower than those associated with the currently available spray dried egg products. With use of this new process, egg protein can be incorporated with protein sources already used in young pig diets. This study was conducted to determine the potential for Profound, as a replacement for fish meal, in early-weaning pig diets. Results of this study indicate that Profound is an effective replacement for select menhaden fish meal in Phase 1 diets at either the 50 or 100% replacement level. Providing a processed soybean meal product (Optipro; Land O' Lakes, Inc) as the source of soybean meal in Profound did not improve performance.

Introduction

Pigs produced in conventional, intensively managed swine production systems are routinely weaned as early as 19 to 21 d of age and as early as 10 to 14 d of age for off-site segregated early weaning systems. At these early ages, pigs are very sensitive to the source of dietary protein. Many dietary proteins produce allergic reactions in which diarrhea, reduced growth, and increased mortality can occur (Bimbo and Crowther, 1992). Select-grade menhaden fish meal appears to be one of the most widely utilized protein sources because of a combination of consistent quality and competitive price. Inclusion levels of 8% to 9.3% have been shown to optimize gain and (or) feed intake (Stoner et al., 1990). However, its supply is limited, and therefore, this protein source is expensive.

Egg protein has an excellent amino acid profile (high in isoleucine) and should be an excellent protein source for young pigs. Several studies have suggested that heat-treated, spray-dried egg protein may replace a portion of the plasma protein without affecting performance (Owen et. al. 1993, Nessmith et. al. 1995). American Dehydrated Foods, Inc. (Springfield, MO) has developed an extrusion process using a combination of dry protein sources and liquid egg to produce a final multiple protein complex suitable for Phase 1 nursery diets. This may provide an opportunity to produce a high-quality, egg-containing protein source for use in diets for early-weaning pig at costs lower than those associated with spray-dried egg products. Using this process, egg protein can be co-produced with protein sources already used in young pig diets. Specific objectives of this study were to 1) determine the potential for Profound produced with Optipro (Land O' Lakes) as a protein source for Phase 1 nursery diets; 2) compare Optipro and soybean meal as the protein source in Profound; 3) determine the effect of level of Profound replacement of fish meal (50 and 100%) on performance; and 4) determine the effect of the experimental phase 1 diet on subsequent performance in phase 2 and 3.

Experimental Procedures

Allotment of Pigs. A total 216 weanling barrows (Line TT by line LL; 20 ± 2 d of age) were obtained from The Pork Group as a single source. Pigs were transported to University of Arkansas off-site nursery facilities, sorted by weight, and divided into six weight groups (blocks) with 36 pigs in each block. Pigs within each block were allotted into equal subgroups (six pigs/pen) with stratification based on weight.

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[a] Profound (multiple protein complex) was developed by ADF as a unique extruded product for use in swine nursery diets. This trial formula has been modified to include Optipro as a substitute for soybean meal.

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Treatments were then randomly assigned to pens (subgroups) within each of the weight groups.

Dietary Treatments. This study was conducted to determine the utility of Optipro or soybean meal in combination with poultry meal and egg protein as a replacement for fish meal in Phase 1 diets for pigs weaned at 20 ± 2 d of age and reared in an off-site nursery.

Diets during the first 10 d postweaning (Phase 1) consisted of the following, and are detailed in Table 1:

1. A negative control diet devoid of fish meal.
2. A positive control diet containing 8.00% fish meal with fish meal added at the expense of 48% soybean meal on an equal lysine basis (fish meal replaces 13.50% soybean meal).
3. The positive control diet with Profound w/Optipro replacing 50% of the fish meal on an equal lysine basis (Profound w/Optipro replaces 4.0% fish meal).
4. The positive control diet with Profound w/Optipro replacing 100% of the fish meal on an equal lysine basis (Profound w/Optipro replaces 8.0% fish meal).
5. The positive control diet with Profound w/soybean meal replacing 50% of the fish meal on an equal lysine basis (Profound w/soybean meal replaces 4.0% fish meal).
6. The positive control diet with Profound w/soybean meal replacing 100% of the fish meal on an equal lysine basis (Profound w/soybean meal replaces 8.0% fish meal).

Substitutions in all diets were made at the expense of corn. Dietary metabolizable energy was maintained constant by adding soybean oil. Diets were formulated to contain 1.60% lysine, 0.92% methionine plus cystine, 0.90% calcium, 0.80% phosphorus, and 14.70% lactose. Upon completion of the phase 1 diet, a common Phase 2 diet (Table 2, 1.35% lysine) was fed from day 10 to 24 postweaning. Upon completion of Phase 2, a common phase 3 diet (Table 2; 1.20% lysine) was fed from day 24 to 38 postweaning.

Housing. Pigs were housed in an off-site nursery facility in pens (20 ft^2) with two nipple waterers, a four-hole feeder, and Maxima nursery flooring (Double L Group, LTD.). Pigs had ad libitum access to feed and water. For the first week of the trial, the nursery was maintained at 84°F and decreased 2°F/wk.

Data Collection. Pig BW and feed intake was determined at initiation, at the end of phase 1, and weekly thereafter to evaluate ADG, ADFI, and F/G.

Statistical Analysis. 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 procedures of SAS (SAS Inst. Inc., Cary, NC). The effects of source of soybean protein, level of fish meal replacement, and the source x level of replacement interaction were evaluated. In addition, contrast statements were included to compare the negative control (treatment 1, 0% fish meal) vs. the positive control (treatment 2, 8.0% fish meal) and treatment 1 vs. the average of all Profound treatments (treatments 3, 4, 5, and 6).

Results and Discussion

Means of each dietary phase are presented in Table 3. During Phase 1, pigs fed fish meal tended to grow faster (20%, $P < 0.18$) and were more efficient ($P < 0.03$) than pigs receiving the negative control diet (treatment 1 vs. treatment 2). Average daily feed intake was similar between the two treatments ($P < 0.69$). During Phase 2, when pigs were fed a common diet, pigs previously fed the negative control diet (treatment 1) or the positive control fish meal diet had similar gain and feed intake, but pigs previously fed the negative control diet tended to have improved F/G ($P < 0.11$). Although differences were not significant, pigs fed the fish meal diets were consistently heavier than those fed the negative control diet and weighed 2.1 lb more at the completion of the study.

Performance, measured by ADG, ADFI, or F/G during Phase 1, 2, or 3 or for the overall experiment, was similar among pigs fed the Profound diets formulated with either Optipro or soybean meal (treatments 3 and 4 vs. treatments 5 and 6). Similarly, pigs fed either the 50% or 100% replacement of fish meal with either Profound formulated with Optipro or Profound formulated with soybean meal had similar performance (treatments 3 and 5 vs. treatments 4 and 6). This study suggests that performance among pigs fed the Profound diets with either formula or at the 50 or 100% replacement of fish meal produced similar performance throughout the nursery study.

A direct comparison of pigs fed the Profound diets (treatments 3, 4, 5, and 6) with those fed the positive control fish meal diet (treatment 2) indicates that ADG, ADFI, and F/G were similar during Phase 1 when the specific treatments were fed. During Phase 2, when a common diet was fed to all treatment groups, pigs previously fed the positive control fish meal diet (treatment 2) had lower F/G than those fed the four Profound diets (treatments 3, 4, 5,or 6). Neither ADG nor ADFI during Phase 2 was significantly affected by the previous feeding of the fish meal or Profound diets during Phase 1. Similarly, for Phase 3 and for the overall study, performance was similar among pigs fed the positive control fish meal diet (treatment 2) or those fed the four Profound treatments (treatments 3, 4, 5, and 6).

This study confirms the superior performance of pigs fed select-grade menhaden fish meal during Phase 1 when compared to those fed soybean meal (Stoner et al., 1990). In addition, results of this study indicate that Profound is an effective replacement for select-grade menhaden fish meal in Phase 1 diets at either 50% or 100% replacement. This study suggests that the transition to a Phase 2 diet may be improved in pigs fed the Profound diets when compared to those fed fish meal during Phase 1, as evidenced by the improved feed efficiency. Providing a processed (Optipro) soybean meal product as the source of soybean meal in Profound did not improve performance.

Implications

Results of this study indicate that Profound, a product developed utilizing extrusion to process a combination of dry protein sources and liquid egg, is an effective replacement for select-grade menhaden fish meal in Phase 1 diets at either the 50 or 100% replacement. Providing a processed (Optipro) soybean meal product as the source of soybean meal in Profound did not improve performance.

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Table 1. Composition of experimental phase 1 diets.

	Phase 1 diets					
	1	2	3	4	5	6
Item, %	Negative control	Positive fish meal control	50% Fish *meal rep.* Prfound w/Optipro	100% Fish *meal rep.* Profound w/Optipro	50% Fish *meal rep.* Profound w/soybean meal	100% Fish *meal rep.* Profound w/soybean meal
Yellow corn	31.22	39.16	36.35	33.48	36.26	33.35
Steam rolled oats	5.00	5.00	5.00	5.00	5.00	5.00
Lactose	15.00	15.00	15.00	15.00	15.00	15.00
AP-301	1.75	1.75	1.75	1.75	1.75	1.75
AP –920 (plasma protein)	3.00	3.00	3.00	3.00	3.00	3.00
Soybean meal, 48% CP	33.80	20.30	20.30	20.30	20.30	20.30
Select menhaden fish meal	**0.00**	**8.00**	**4.00**	**0.00**	**4.00**	**0.00**
Profound w/Optipro	**0.00**	**0.00**	**6.00**	**12.00**	**0.00**	**0.00**
Profound w/soybean meal	**0.00**	**0.00**	**0.00**	**0.00**	**6.00**	**12.00**
Soybean oil	4.56	3.45	3.90	4.40	3.90	4.40
Ethoxyquin	0.03	0.03	0.03	0.03	0.03	0.03
Neoterromycin 10/5	1.00	1.00	1.00	1.00	1.00	1.00
Zinc oxide	0.30	0.30	0.30	0.30	0.30	0.30
$CuSO_4$	0.07	0.07	0.07	0.07	0.07	0.07
Mineral premix (NB-8557B)	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix (NB-6157B)	0.25	0.25	0.25	0.25	0.25	0.25
Dicalcium phosphate	2.19	1.25	1.55	1.90	1.62	1.95
Calcium carbonate	0.74	0.30	0.40	0.46	0.40	0.51
Lysine	0.15	0.16	0.18	0.20	0.18	0.20
Methionine	0.19	0.16	0.15	0.12	0.16	0.14
Threonine	0.10	0.12	0.10	0.09	0.11	0.10
Tryptophan	0.00	0.01	0.00	0.00	0.00	0.00
Isoleucine, 85%	0.00	0.04	0.02	0.00	0.02	0.00
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Calculated composition						
Lysine	1.60	1.60	1.60	1.60	1.60	1.60
Threonine	1.04	1.04	1.04	1.04	1.04	1.04
Tryptophan	0.31	0.29	0.29	0.31	0.30	0.32
Met + Cys	0.92	0.92	0.92	0.92	0.92	0.92
Isoleucine	0.94	0.91	0.91	0.91	0.91	0.92
Calcium	0.90	0.90	0.90	0.90	0.90	0.90
Phosphorus	0.80	0.80	0.80	0.80	0.80	0.80
Metabolizable energy	1548	1548	1548	1548	1547	1546
Lactose	14.70	14.70	14.70	14.70	14.70	14.70

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

Item, %	Phase 2	Phase 3
Yellow corn	47.64	62.305
Soy meal, 48%	28.30	30.00
AP-301	2.00	0.00
Select menhaden fishmeal	4.00	0.00
Ethoxiquin	0.03	0.03
Lysine	0.00	0.16
Zinc oxide	0.30	0.00
Neoterramycin	1.00	0.00
Lactose	10.00	0.00
Methionine	0.08	0.02
$CuSO_4$	0.07	0.07
Mineral premix (NB-8557B)	0.15	0.15
Vitamin premix (NB-6157B)	0.25	0.25
Dicalcium phosphate	1.40	1.88
Fat	0.00	4.00
Soy oil	4.00	0.00
Calcium carbonate	0.38	0.61
Tylan 40	0.00	0.125
Salt	0.40	0.40
Calculated composition		
Lysine	1.35	1.20
Threonine	0.88	0.77
Tryptophan	0.26	0.24
Met + Cys	0.78	0.67
Calcium	0.80	0.80
Phosphorus	0.70	0.70
Metabolizable energy	1542.00	1557.00
Lactose	9.80	0.00

Table 3. Effect of Profound with Optipro or soybean meal at two levels of fish meal replacement on performance of nursery pigs (phase means).

	Treatment[a]						
	1	2	3	4	5	6	
Trait	Negative control	Positive fish meal control	50% Fish *meal rep.* Prfound w/Optipro	100% Fish *meal rep.* Profound w/Optipro	50% Fish *meal rep.* Profound w/soybean meal	100% Fish *meal rep.* Profound w/soybean meal	SE
ADG, lb							
Phase 1[b]	0.44	0.53	0.55	0.53	0.55	0.50	0.04
Phase 2	1.03	1.03	0.98	1.08	1.10	1.10	0.04
Phase 3	1.31	1.29	1.30	1.34	1.29	1.34	0.05
Overall (1–3)	1.01	1.07	1.00	1.04	1.03	1.03	0.03
ADFI, lb							
Phase 1	0.57	0.60	0.62	0.66	0.70	0.60	0.05
Phase 2	1.35	1.43	1.28	1.36	1.38	1.45	0.07
Phase 3	2.03	2.09	2.03	2.09	2.08	2.09	0.09
Overall (1–3)	1.39	1.45	1.58	1.44	1.46	1.46	0.06
F/G							
Phase 1[c]	0.761	0.891	0.898	0.819	0.792	0.835	0.039
Phase 2[d]	0.768	0.725	0.769	0.799	0.798	0.764	0.020
Phase 3	0.647	0.616	0.643	0.648	0.622	0.647	0.016
Overall (1–3)	0.732	0.739	0.729	0.728	0.703	0.710	0.016
Wt, lb							
Initial wt	13.76	13.76	13.76	13.79	13.76	13.76	0.013
Phase 1	18.14	19.00	19.29	19.14	19.25	18.76	0.450
Phase 2	33.11	34.61	32.96	34.22	34.68	34.19	0.996
Phase 3	52.25	54.34	51.68	53.26	52.78	53.02	1.283

[a] Six pigs per pen, six pens per treatment.

[b] Negative control vs. fish meal, $P < 0.18$.

[c] Negative control vs. fish meal, $P < 0.03$.

[d] Negative control vs. fish meal, $P < 0.15$, Positive control vs. treatments 3, 4, 5, and 6, $P < 0.02$.

Efficacy of Feather Meal for Improving Gain, Feed Efficiency and Carcass Composition in Growing Finishing Pigs

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Story in Brief

Crossbred barrows and gilts (n = 132; BW = 54.52 ± 0.18 lb) were used to assess the efficacy of hydrolyzed feather meal plus blood (FM) to improve performance and carcass composition in growing-finishing swine. Pigs were blocked by weight, segregated within blocks into subgroups based on sex and litter, and assigned randomly to 24 pens (five to six pigs/pen). Treatments were assigned randomly to pens and included 1) control corn-soybean meal (SBM) starter, grower, and finisher diets devoid of FM; 2) corn-SBM diet supplemented with 3% FM; and 3) corn-SBM diet supplemented with 6% FM. Feather meal plus blood was substituted for SBM on an equal lysine basis at the expense of corn. During the starter phase, there was a quadratic decrease in ADG ($P < 0.06$) and a quadratic increase in F/G ($P < 0.01$). However, during the grower phase, F/G decreased linearly ($P < 0.08$) as FM increased in the diet. Inclusion of FM had no effects ($P > 0.10$) on performance during the finisher phase, or the overall trial. Although carcasses from pigs fed 3% FM had greater average backfat (quadratic; $P < 0.02$) than carcasses from pigs fed control diets or diets containing 6% FM, dietary FM had no effect ($P > 0.10$) on lean carcass yield, lean ham yield, or ham fat yield. Substitution of FM for SBM in the diets of growing-finishing swine may improve feed efficiency during the grower phase with a potential to reduce diet cost, without dramatically affecting carcass composition.

Introduction

Feather meal plus blood (FM), a major byproduct of poultry processing, has been of interest to the swine and poultry industries because of its high protein content (80 to 85%). Feather meal is a relatively inexpensive protein source that has a higher concentration of valine, cystine, and threonine than soybean meal (SBM), and previous research has shown it to be a good source of extra dietary nitrogen (Chiba et al., 1995; Cabel et al., 1988). Feather meal has not been extensively used as a protein source in growing-finishing diets because of concerns about variability in quality and its low content of lysine. As a result of these concerns, FM is limited to about 5% of the diet for optimum performance (Chiba et al., 1996). Nevertheless, replacing SBM with up to 9% dietary FM enhanced leanness in finishing pigs (Chiba et al., 1995). However, Chiba and co-workers (1996) observed that feeding FM as the only source of protein in the diet, with lysine supplementation, reduced weight gain but had no effect on carcass cutability. This study was conducted to further assess the efficacy of hydrolyzed FM as a means of improving performance and carcass composition in growing-finishing pigs at reduced diet cost.

Experimental Procedures

Materials. Hydrolyzed FM containing 8% blood was obtained from Tyson's Foods, Inc. Protein Plant in Noel, MO, which was contributed by Tyson Specialty Products. 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 hydrolyzer to break 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 dryer (natural gas fire dryer), milled through a mesh screen and shipped to the producer.

Allotment of Pigs. A total of 132 crossbred gilts and barrows (offspring of Yorkshire x Landrace females mated with Duroc x Hampshire sires) were moved from nursery facilities, sorted by weight, and divided into four weight groups (blocks) with 36 pigs in blocks 1 and 2 and 30 pigs in blocks 3 and 4. Pigs within each weight group were allotted into pens with six pigs per pen in blocks 1 and 2 and five

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pigs per pen in blocks 3 and 4. Stratification across pens was based on sex and litter. Treatments were then randomly assigned to pens (subgroups) within each of the four weight groups. A total of eight pens were randomly allotted to each of the three treatments during the starter, grower and finisher periods.

Experimental Treatments. Three dietary treatments consisted of three levels of FM (0, 3, or 6 %) in the starter, grower, and finisher diets (Table 1). The specific diets consisted of the following:

1. Control corn-soybean meal (SBM) starter, grower and finisher diets devoid of FM.

2. Corn-SBM diet supplemented with 3% FM (FM was substituted for SBM on an equal lysine basis at the expense of corn).

3. Corn-SBM diet supplemented with 6% FM (FM was substituted for SBM on an equal lysine basis at the expense of corn).

Pigs were fed a three-phase dietary program with transition from starter to grower and from grower to finisher occurring when the mean weight of each block reached 80 and 200 lb, respectively. The control diets met, or exceeded, NRC (1998) requirements for all nutrients. Diets were formulated to contain 1.16% lysine during the starter phase, 0.90% lysine during the grower phase, and 0.53% lysine during the finisher phase.

Performance Data. The study was terminated when the lightest block reached an average weight of 240 lb. Data collected were ADG, feed intake, and F/G during each of the three phases.

Carcass Data. Pigs were transported to Brown Packing Co. (Little Rock, AR), and harvested following industry-accepted procedures. Carcass weight and fat depth opposite the first rib, last rib, and last lumbar vertebra were recorded at 24 h postmortem. Hams from the left sides were weighed, boxed, shipped to Louisiana State University, and analyzed for lean and fat composition using a TOBEC unit. Prediction equations were utilized to estimate carcass lean yield and fat content (Knowles et al., 1998).

Statistical Analysis. Performance data for each phase and carcass 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 procedures of SAS (SAS Inst. Inc., Cary, NC.). Linear and quadratic polynomials were used to detect the response of replacing SBM with FM in the diet on performance and carcass characteristics.

Results and Discussion

Performance. During the starter phase, there was a quadratic decrease in ADG ($P < 0.06$), and an quadratic increase in F/G ($P < 0.01$; Table 2) because of inclusion of FM. However, during the grower phase, F/G decreased linearly ($P < 0.08$) as FM increased in the diet. Inclusion of FM had no effects ($P > 0.10$) on performance during the finisher phase or for the overall trial. As observed in the current study, previous research has shown that supplementation of FM to swine diets up to 6% had no adverse effect on ADG, ADFI, or final BW (Chiba et al., 1995; 1996). This was also observed in turkey (Eissler and Firman, 1996) and broiler (Cabel et al., 1987; 1988) diets using FM as an alternative protein source. However, the results of the current study contradict previous research by showing improved feed efficiency when a portion of SBM was substituted with dietary FM.

Carcass. Carcasses from pigs fed 3% FM had greater average backfat (quadratic; $P < 0.02$) and carcass fat measurements (quadratic; $P < 0.05$) than those fed the control diets or the diets supplemented with 6% FM (Table 3). However, dietary FM had no effect on lean ham yield, ham fat yield, ham and carcass weight or lean carcass yield. These results contradict other studies that reported that supplementation of feather meal enhanced leanness in finishing pigs (Chiba et al., 1995) and reduced abdominal fat in broilers (Cabel et al., 1988). Lean carcass traits found in previous studies could be attributed to excess supplementation of lysine and protein in the diet.

Implications

The results from this study indicate that substitution of FM for SBM in the diets of growing-finishing swine may improve feed efficiency with a potential to reduce cost, especially during the grower phase. In addition, inclusion of FM to the diets had no dramatic effects on weight gain or carcass composition.

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Table 1: Composition of research diets.

Ingredient, %	Starter Control[a]	Grower Control[a]	Finisher Control[a]
Corn	66.64	71.26	79.24
Soybean meal, 48%	28.80	18.23	3.84
Animal fat	1.90	0.35	0.00
Dicalcium phosphate	0.85	0.80	0.28
Calcium carbonate	0.76	0.86	0.86
Salt	0.50	0.50	0.35
Tylan 40	0.05	0.05	0.025
Lysine	0.15	0.15	0.15
Threonine	0.05	0.02	0.00
Midds	0.00	7.50	15.00
Mineral premix(NB-557B)	0.10	0.10	0.10
Vitamin premix(NB-6157B)	0.15	0.15	0.125
Ethoxyquin	0.03	0.03	0.03
Feather meal	0.00	0.00	0.00
Composition calculated, total			
Protein, crude	19.40	15.90	10.90
Lysine	1.16	0.90	0.53
Methionine	0.33	0.26	0.20
Methionine & cystine	0.67	0.55	0.43
Valine	0.91	0.75	0.51
Threonine	0.78	0.60	0.38
Tryptophan	0.23	0.18	0.10
Calcium	0.60	0.60	0.45
Phosphorus, available	0.23	0.23	0.15
Energy	1545	1505	1500
Composition calculated, available			
Lysine	1.030	0.790	0.450
Methionine	0.30	0.24	0.18
Methionine & cystine	0.59	0.54	0.37
Threonine	0.67	0.57	0.32
Tryptophan	0.20	0.16	0.09

[a] Control diets from starter, grower and finisher phases were supplemented with 3% or 6% FM. Feather meal plus blood was substituted for SBM on an equal lysine basis at the expense of corn.

Table 2. The effects of feather meal plus blood on performance in growing-finishing swine.

	Feather meal plus blood, %			
Item	0.0	3.0	6.0	SE
Starter (40–80 lb)				
ADG, lb[c]	1.269	1.126	1.155	0.035
ADFI, lb	3.261	3.143	3.053	0.086
F/G[a]	2.571	2.804	2.654	0.056
Grower (80–200 lb)				
ADG, lb	2.025	2.104	2.077	0.031
ADFI, lb	6.039	6.004	5.963	0.117
F/G[b]	2.984	2.851	2.872	0.043
Finisher (200–240 lb)				
ADG, lb	2.189	2.180	2.150	0.104
ADFI, lb	8.097	7.946	7.748	0.205
F/G	3.733	3.689	3.646	0.148
Overall (18–109 lb)				
ADG, lb	1.872	1.877	1.863	0.026
ADFI, lb	5.721	5.649	5.573	0.113
F/G	3.054	3.000	2.989	0.052
Wt, lb				
Initial	54.570	54.351	54.634	0.184
Starter[c]	84.775	80.883	82.267	0.973
Grower	200.683	201.244	201.077	2.288
Finisher	243.658	243.904	242.798	2.738

[a] Quadratic effect of supplementing FM ($P < 0.01$).

[b] Linear effect of supplementing FM ($P < 0.08$).

[c] Quadratic effect of supplementing FM ($P < 0.06$).

Table 3. Effect of dietary feather meal plus blood on carcass characteristics.

Trait[a]	Control	3% FMI	6% FMI	SE
BF, in[b]	1.26	1.31	1.23	0.02
HCW, lb	171.67	175.80	173.12	1.93
LCCW, lb	84.55	86.58	85.26	0.95
HAM wt., lb	20.96	21.11	20.95	0.27
C LEAN, lb	75.76	76.55	76.43	1.07
CAR FAT, lb[c]	56.64	59.64	57.34	1.01
H LEAN, lb	11.84	11.93	11.95	0.14
HAM FAT, lb	5.85	5.87	5.73	0.12

[a] BF= average backfat; HCW = hot carcass weight; LCCW = left chilled carcass weight; C LEAN = carcass lean; CAR FAT = carcass fat; H LEAN = ham lean.

[b] Quadratic effect of supplementing FM ($P < 0.02$).

[c] Quadratic effect of supplementing FM ($P < 0.05$).

The Use of Inactivated *Propionibacterium acnes* as an Immunostimulant in Off-Site Reared Piglets Challenged With *Actinobacillus pleuropneumoniae*

J.B. Morris, D.H. Hellwig, S. Krumpelman, C. Maxwell, and Z. Johnson[1]

Story in Brief

Ten sows were bled and antibody titers for *Actinobacillus pleuropneumoniae* were measured. Seventy-two pigs (12.8 ± 0.2 lb and 18 ± 2.5 d of age) were weaned from the 10 sows and were blocked by sow antibody titer. Treatment and pen were assigned randomly to each pig within a block. Treatment consisted of inactivated *P. acnes* injected i.m. (1 mg/animal) or the same volume (2.5 ml) of a 0.9% saline solution i.m. Twenty-four hours later, all pig were challenged with 4.12 x 10^8 colony forming units of *A. pleuropneumoniae* intranasally. Pig mortality was recorded. On day 8 postweaning, lungs were harvested from all remaining pigs and were ranked according to lesions on the lungs. The use of inactivated *P.acnes* approached significance (P = 0.14) for improved survival rate compared to controls. There was no significant difference in the lung lesion scores by treatment.

Introduction

Weaned pigs are challenged by many external factors, including the stress of being weaned and exposure to any pathogens in their environment. These challenges coupled with the pigs' immature immune system have a negative effect on growth performance. One way of helping these animals in stressful periods, while keeping an optimum performance level, has been through the use of immunostimulants (Blecha, 1988). Injectable immunostimulants may be used to activate the immune system during this time period by providing enhanced protection, while improving performance of the animal.

Actinobacillus pleuropneumoniae serotype 1 is a bacterium that can be characterized as highly virulent. In most cases, gross lung lesions are characteristic and, in chronic infections, nodular abscesses can form. *A. pleuropneumoniae* can lead to death within 6 to12 h when pigs are challenged with as many as 10^8 to 10^9 bacteria (Leman et al., 1986). Evaluation of *P. acnes* as a nonspecific immunostimulant in weaned pigs will include a challenge with *A. pleuropneumoniae* to measure morbidity and mortality.

The objective of this experiment was to assess the protective effects of inactivated *P. acnes* against an infectious pathogen (*A. pleuropneumoniae*).

Experimental Procedures

Ten sows with litters from the University of Arkansas swine farm were bled (approximately 24 h postpartum) for measuring antibody levels to *A. pleuropneumoniae* serotypes 1, 5, 9, 10, 11. Blood was collected via vena cava puncture into 6 mL serum separating Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ). Serum was separated through centrifugation and stored at -20°C. Serum was tested by hemolysin neutralization test (HNT-titer) at the Department of Diagnostic Medicine/Pathobiology, Kansas State University, Manhattan.

A total of 72 crossbred (Tyson line TT and TT/York crossbred boars x Yorkshire, Landrace, Duroc crossbred sows) mixed sex weanling pigs (initial weight 12.8 ± 0.2 lb and average age 18 ± 2.5 d of age) were obtained from these ten sows. Animals were blocked by sow antibody titer for *A. pleuropneumoniae* (10 blocks) and randomly assigned to treatment and pen within a block. Treatment consisted of inactivated *P. acnes* (Eqstim, ImmunoVet Tampa, FL) injected i.m. (1 mg/pig) at weaning. The control group received an equal volume (2.5 ml) of a 0.9% saline solution i.m. at weaning. Pigs were transported 7.5 miles to the University of Arkansas Physiology farm and housed two pigs per pen with animal as the experimental unit. Pigs were housed in a nursery with elevated pens (30 in long x 32 in wide) with one nipple waterer, a three-hole feeder, and wire flooring. Pigs were allowed ad libitum access to feed and water. For the duration of the trial, the facility was maintained at 28°C. Pigs were fed a diet which contained 1.5% lysine, 0.90% methionine plus cystine, 0.92% calcium, 0.80% phosphorus, and 14.5% lactose.

The *A. pleuropneumoniae* (strain 4074) was supplied by and prepared in liquid culture according to a protocol from Dr. B. Fenwick, Department of Diagnostic Medicine/ Pathobiology, Kansas State University. Cultures were grown

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in RPMI 1640 medium (Sigma Chemical Co., St. Louis, MO, R-8758) with 2.5% fetal bovine serum and 0.25 g/mL NAD (Sigma Chemical Co. St. Louis, MO, N-1511) overnight at 7.5% CO_2 and 37°C. To check for purity, cultures were streaked for isolation on chocolate agar (Remel 0-01300). The initial *A. pleuropneumoniae* culture streaked pure after 20 h of incubation. The initial seed culture was diluted in a 1:10 solution of fresh culture medium and cultured for 4 h at 7.5% CO_2 and 37°C. At 4 h the final culture was put on ice and aliquoted into 4-ml syringes. The culture was kept agitated during the aliquoting procedure. Concentration of the final culture was checked by serial dilutions and was found to be 4.12×10^8 cfu per 4-ml dose.

Each pig was infected intranasally with 4-ml of the final bacterial culture on day 1 (24 h postweaning). Animals were monitored for signs of pneumonia twice a day. If severe distress, characterized by labored or difficulty breathing, was observed the animal was humanely euthanized through lethal injection of Euthansol (90 mg sodium pentobarbital and 12 mg phenytoin/kg BW). Animals that were killed or that died were necropsied by a veterinarian and examined for signs of pneumonia. Morbidity and mortality were recorded.

On day 8 postweaning, all remaining pigs were sacrificed through lethal injection of Euthansol and lungs were harvested. The lungs were scored according to severity of lung lesions. There was no knowledge of treatment groups during the scoring process. The scores were defined as 1 = no apparent lesions or abscesses, 2 = less than 25% of the lung was infected or no apparent abscesses, 3 = less than 50% but greater than 25% of the lung was affected or abscesses were present, and 4 = greater that 50% of the lung was affected and abscesses were present with severe necrosis of the lung tissue (Table 1).

Lung lesion scores and pig survival were analyzed using analysis of variance procedures with maternal antibody as the block. Age and treatment were included in the model in JMP (SAS Inst. Inc., Cary, NC).

Results and Discussion

Of the 72 piglets challenged with *A. pleuropneumoniae,* 28 died within the first 4 d. One-third of the *P. acnes* treated pigs died while the control group lost almost half of the pigs (17/36) (Table 2). This difference in mortality rate approached significance ($P = 0.14$). *Streptococcus suis* was isolated, and clinical signs were consistent with *S. suis* infection in one pig that was killed during the study period. That animal was excluded from the study. There were no significant differences in lung lesion scores (Table 3). *A. pleuropneumoniae* was re-isolated from harvested lungs to verify *A. pleuropneumoniae* infection.

Sow antibody titer affected both mortality ($P < 0.01$) and lung lesion scores ($P < 0.05$). More pigs survived that had a higher maternal antibody titer; however, those pigs had more severe lung lesion scores at 8 d postinfection than pigs with lower maternal antibody titers.

These differences in the way sow antibody titer influenced morbidity and mortality may be a result of individual pig antibody titers, which were not measured. By measuring the sow antibody titer only, an assumption was made that each pig within the block would have approximately the same degree of immunity. However, maternal antibodies found in the serum are not transferred through the placenta, but rather are selectively concentrated in colostrum towards the end of gestation (Gaskins and Kelly, 1995). The pig is limited to the quality and quantity of antibodies absorbed, which is dependent on the amount of colostrum it is able to consume and absorb. It would be necessary to measure pig antibody titers at weaning to evaluate this observation more effectively. Based on the observed mortality, inactivated *P. acnes* appeared to provide some protection ($P = 0.14$) for weaned pigs when challenged with *A. pleuropneumoniae.*

Implications

An immunostimulant that could be applied once at the time of weaning has potential to maximize growth while minimizing the labor associated with treating sick animals under certain environmental conditions. Inactivated *P. acnes* appeared to provide some protection for weaned piglets when challenged with *A. pleuropneumoniae.* More studies are needed to examine this product's efficacy as an immunostimulant. This product is marketed for companion animal use and would not be cost effective for swine production uses unless the price is reduced. Currently, this product is not approved by the Food and Drug Administration for use in food animals. However, with proper testing, inactivated *P. acnes* could be approved. This product is similar to other inactivated bacterial vaccines and adjuvants that are currently on the market and are used in domestic food animals.

Acknowledgments

The authors would like to thank Dr. B. Fenwick for testing the sows, providing the *A. pleuropneumoniae* and the protocol for the challenge; and Alex Stelzleni, Troy Wistuba, Mike Nihsen, and Ashley Hayes for their assistance in data collection for this trial.

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Table 1. Definitions of lung lesion scores in piglet lungs that were harvested 7 d after challenge with *A. peuropneumoniae*.

Score	Description
1	No apparent lesions or abscesses
2	<25% of lung affected with no abscesses
3	<50% of lung affected with abscesses present
4	>50% of lung affected with abscesses present and severe necrosis of the lung tissue

Table 2. Mortality of crossbred pigs treated with either inactivated *P. acnes* or saline at weaning then challenged 24 h later with *A. pleuropneumoniae*.[a]

Treatment	Live	Dead	Total
P. acnes	24	11	35[b]
Control	19	17	36
Total	43	28	71

[a] Treatment consisted of commercially available *P. acnes* (Eqstim®) injected i.m. (1mg/animal) or the control group received an i.m. saline injection. *A. pleuropneumoniae* was administered intranasally at a concentration of 4.12×10^8 cfu per animal 24 h after *P.acnes*/saline injection.

[b] One pig from the *P. acnes* group died. *Streptococcus suis* was isolated and clinical symptoms were consistent with *S. suis*.

Table 3. Lung lesion scores of crossbred pigs treated with either inactivated *P. acnes* or saline at weaning then challenged 24 h later with *A. pleuropneumoniae*.[a]

Treatment	1 No Lesion	2 Low	3 Med	4 High	Total
P.acnes	*7*	*7*	*7*	*3*	*24*
Control	6	3	5	5	19
Total	13	10	12	8	43

No statistical differences were found.

[a] Treatment consisted of commercially available *P. acnes* (Eqstim) injected i.m. (1mg/animal) or the control group received an i.m. saline injection. *A. pleuropneumoniae* was administered intranasally at a concentration of 4.12×10^8 cfu per animal 24 h after *P.acnes*/saline injection. The scores were defined as 1 = no apparent lesions or abscesses, 2 = less than 25 percent of the lung was infected with no apparent abscesses, 3 = less than 50 percent but greater than 25 percent of the lung was affected with abscesses present, and 4 = greater that 50 percent of the lung was affected with abscesses present and severe necrosis of the lung tissue.

Enhancement of Ovulation Rate and Litter Size in Swine

D. Kreider,[1] R. Rorie,[1] D. Brown,[1] F. Miller,[2] and S. Wright[1]

Story in Brief

Two experiments were conducted to evaluate the effects of the immunization against ovarian steroids on ovulation rate and litter size in gilts. In Experiment 1, gilts at 165 ± 1.6 d of age were immunized against carrier (control), androstenedione (ANDRO), or 17α-hydroxyprogesterone (PROG17). Age at puberty and estrous cycle length averaged 208 ± 5.5 and 20.3 ± 2.8 d, respectively, and were not affected by treatment. The ANDRO- and PROG17-treated gilts had higher ($P < 0.05$) ovulation rates than controls (14.25 ± 0.82, 14.20 ± 0.73, and 11.40 ± 0.83, respectively). Total pigs born tended to be higher ($P = 0.15$) in the PROG17 group (11.75 ± 1.19) than in the controls (9.35 ± 1.15), suggesting the increased ovulation rate in the PROG17-immunized group resulted in an increased number of pigs born. Total pigs born for the ANDRO group was not different from controls. The number of pigs born alive tended to be higher ($P = 0.18$) in the PROG17 group compared to controls (11.3 ± 1.2 vs. 9.0 ± 1.2, respectively). Gestation length was not different between any of the treatments and the controls, averaging 115 ± 0.9 d overall. Immunization procedures used in Experiment 2 were identical to those in Experiment 1, except that only control and PROG17 treatments were included and only litter size at farrowing was measured. Total number of pigs and number of live pigs born were higher in the PROG17 treatment vs. controls (12.4 + 0.6 vs. 10.5 + 0.5; $P < 0.02$ and 11.3 + 0.6 vs. 9.2 + 0.5; $P < 0.01$, respectively). Data from this study indicate that litter size in gilts can be increased by immunization against PROG17.

Introduction

Litter size in swine is the most important factor contributing to the economic efficiency of swine production and is the primary measure of reproductive performance (Tess, 1981). Ovulation rate and thus litter size are influenced by a number of factors including breed, age at breeding, weight at breeding, and nutritional status at or near the time of breeding. Ovulation rate can be increased by the injection of superovulatory drugs, but results are variable, and such treatments frequently lead to reproductive problems such as decreased cycle length, increased duration of estrus, and cystic follicles. Genetic selection and conventional crossbreeding programs maintained for a period of several years have resulted in relatively small increases in litter size (Legault, 1985). Crossbreeding programs using prolific Chinese breeds of swine can lead to increases in litter size; however, the progeny of such exotic crosses may typically have poor carcass and growth characteristics (Legault et al., 1985). As a result of these problems, only limited success has been achieved in increasing litter size in swine.

Immunization of sheep against androstenedione, an estrogen precursor, increases ovulation rate and number of follicles > 4 mm in size (Scaramuzzi and Hoskinson, 1984). This procedure is thought to increase ovulation rate by reducing the negative feedback effects of estradiol on gonadotropin release from the pituitary, thus increasing gonadotropin stimulation of the developing follicles.

The immunization of gilts against androstenedione has been shown to increase ovulation rate but to have no effect on litter size (McKinnie, 1987; McKinnie et al., 1988). Gilts immunized against androstenedione had more follicles 5 to 10 mm in diameter, more total ovarian follicles, and more total ovarian structures than controls.

The effects of immunization against other androgen precursors on ovulation rate and litter size in gilts has not been studied. Therefore, two experiments were conducted to determine whether active immunization of gilts against androstenedione (ANDRO) or 17α-hydroxyprogesterone (PROG17) affects ovulation rate and litter size in gilts and to evaluate the effects of immunization upon other reproductive parameters.

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Experimental Procedures
Experiment 1

In Experiment 1, 15 prepubertal crossbred gilts averaging 165 ± 1.6 d of age were randomly assigned to three treatment groups of five animals each. Gilts were ranked by age and were randomly assigned to the following treatments: control (adjuvant + carrier only), ANDRO (1.0 mg of androstenedione 3-CMO:BSA), and PROG17 (1.0 mg of 17α-hydroxyprogesterone 3-CMO:BSA). Steroids coupled with bovine serum albumin were used in order to elicite an immune response in gilts. As an additional stimulus for immune response, all treatments were dissolved in 1.5 ml of 5% DEAE dextran (5% w/v in 0.45% saline), and this solution was then emulsified with an equal volume of mineral oil. Gilts received an initial 0.6-ml injection divided equally between two subcutaneous sites in the loose skin at the base of each ear, followed by a single booster injection 4 wk later. Animals in all groups received booster injections equal to one-half the original injection.

Following the booster immunization, gilts were moved to outside pens and checked for estrus twice daily. Gilts were observed through two normal periods of estrus to determine whether treatments affected age at puberty or estrous cycle length. Gilts were bred at 12 and 24 h after the second observed estrus to boars of known fertility. At 7 to 10 d after breeding, gilts were examined surgically to determine ovulation rate by counting the number of corpora lutea present on each ovary.

Following surgery, gilts were allowed to continue through pregnancy in order to determine the number of pigs born at term for each treatment. Serum samples were collected by anterior vena cava puncture immediately prior to immunization, at the booster immunization, at first estrus and at 0, 10, 12, 14, and 21 d of pregnancy (day 0 = day of first breeding). Serum was analyzed for progesterone and estradiol 17β radioimmunoassay. Serum antibody response against the antigen used in each treatment group was determined by measuring the percentage of counts bound by a 1:100 dilution of serum when 30,000 cpm of the appropriate tritium labeled antigen was added (Scaramuzzi et al., 1975).

Experiment 2

In Experiment 2, a group of 59 gilts that had previously been identified as potential replacement gilts were ranked by age and then randomly assigned to either control (n = 30) or PROG17 (n = 29) treatment groups. Immunization procedures were identical to those used in Experiment 1 except that only the control and PROG17 groups were included. In the control group, 12 gilts were removed from the study for the following reasons: four gilts did not show estrus; two were detected open after breeding; and six were culled for reasons unrelated to reproduction. In a similar manner, 12 gilts were removed from the PROG17 group as follows: two gilts did not cycle, three were detected not pregnant after breeding, two were injured, and five were culled for reasons not related to reproduction. The only measurements recorded were the total number of pigs born and the total number of pigs born live at term. Gilts that were retained in the herd for a second litter were not boosted, and reproductive parameters were assessed at the subsequent farrowing in order to determine the long-term effects of immunization on subsequent litter size.

Data Analysis

Data for reproductive performance were analyzed by analysis of variance, and means for each treatment were contrasted with the means for the control group. Hormone and antibody binding data were analyzed as a split-plot analysis using the repeated measures option of the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion
Experiment 1

One gilt from the control group and one from the PROG17 group had to be reanesthetized at 14 to 17 d after breeding to correct surgical hernia problems, and both were subsequently removed from the study.

The immunization of gilts against androgenic steroid precursors did not significantly influence age at first estrus or estrous cycle length, but it did cause a significant ($P < 0.05$) increase in ovulation rate in the PROG17 and ANDRO groups compared to controls (Table 1). Mean ovulation rate was 14.25 ± 0.82, 14.20 ± 0.73, and 11.40 ± 0.83 for the ANDRO, PROG17, and control groups, respectively.

Gestation length, and average weight of pigs at birth were not significantly influenced by immunization (Table 2). Immunization did, however, tend to increase the total number of pigs born ($P = 0.15$) and the number of live pigs born per litter ($P = 0.18$). Total pigs born at term averaged 11.8 ± 1.2 in the PROG17 group and 9.4 ± 1.2 in the control group, suggesting that the increased ovulation rate in the group immunized against PROG17 translated into an increased number of pigs born at term. Average total number of pigs born in the ANDRO groups was not different from controls. The number of pigs born alive averaged 11.3 ± 1.2 in the PROG17 group compared to 9.0 ± 1.2 in control gilts.

Antibody response for each treatment compared to controls is illustrated in Figures 1A and 1B. Antibody response of the PROG17 and the ANDRO groups was different ($P < 0.05$) from the response in control gilts and was also affected ($P < 0.05$) by time after immunization.

Serum progesterone and estradiol response for each treatment is shown in Figures 2A and 2B. Serum progesterone and estradiol were not changed by immunization against any of the steroids evaluated in this study. However, both progesterone and estradiol were affected ($P < 0.01$) by day of pregnancy.

Experiment 2

Farrowing data for gilts in Experiment 2 are summarized in Table 3. Gilts immunized against PROG17 had 1.9 more total pigs born per litter than control gilts ($P < 0.02$). Similarly, gilts in the PROG17-immunized group had 2.1 more live pigs born per litter than control gilts ($P < 0.01$). When gilts were held for a second farrowing without a booster immunization, total pigs born and live pigs born were numerically higher for PROG17-immunized gilts than for controls (Table 4) but were not statistically different (10.9 ± 1.2 vs. 8.5 ± 1.1; $P = 0.17$, and 9.9 ± 1.2 vs. 8.0 ± 1.1; $P = 0.26$, respectively).

The immunization of gilts against PROG17 in this study increased ovulation rate and the number of pigs born at term. Similar to this study, McKinnie (1987) observed a significant increase in ovulation rate in gilts immunized against androstenedione but found no effect on litter size. Data in that study also indicated no significant effects on age at puberty or length of the first estrus cycle. There was no significant effect of immunization against any steroid on serum progesterone levels in the current study. In contrast, McKinnie (1987) observed significantly higher levels of progesterone at days 2, 6, 9, and 12 after mating in androstenedione-immunized gilts.

Results of these experiments indicate that immunization of gilts against androstenedione, and 17α-hydroxyprogesterone can effectively increase the ovulation rate in gilts. In addition, immunization of gilts against 17α-hydroxyprogesterone results in a significant and substantial increase in litter size.

Further studies in gilts are needed to determine whether additional booster immunizations can further improve litter size; what response is elicited when immunized gilts are boosted prior to rebreeding; what effects occur in mature sows; and what physiological changes are associated with the increase in litter size.

Implications

An increase of two pigs per litter in gilts would have a very significant impact on the economic efficiency of swine production. This product would have to be approved by the USDA and FDA prior to use in food animals, but the benefits would likely justify this expense. If this treatment would also benefit litter size in mature sows (which has not been determined), the benefits would substantially increase. In addition, an understanding of the physiological changes induced by this treatment could yield other approaches to enhancing the reproductive performance of swine.

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Table 1. Reproductive variables (mean ± SE) of immunized gilts by treatment.

Treatment[a]	Age at puberty	Estrus cycle length	Ovulation rate
Control	209 ± 3.3	22.8 ± 3.3	11.40 ± 0.83
ANDRO	210 ± 3.3	19.3 ± 3.6	14.25 ± 0.82[b]
PROG17	211 ± 3.3	20.0 ± 3.3	14.20 ± 0.73[b]

[a] Control (adjuvant + carrier only); ANDRO (1.0 mg of androstenedione 3-CMO:BSA); and PROG17 (1.0 mg of 17α-hydroxyprogesterone 3-CMO:BSA).

[b] Ovulation rate in these groups was ($P < 0.05$) higher than in the control group.

Table 2. Reproductive performance (mean ± SE) of immunized gilts by treatment.

Treatment[a]	Gestation length, d	Total pigs	Live pigs	Avg wt, lb
Control	116.0 ± 2.2	9.4 ± 1.2	9.0 ± 1.2	3.52 ± 0.44
ANDRO	115.0 ± 2.5	10.0 ± 1.2	9.8 ± 1.2	2.86 ± 0.44
PROG17	115.8 ± 2.2	11.8 ± 1.2[b]	11.3 ± 1.2[c]	2.86 ± 0.44

[a] Control (adjuvant + carrier only); ANDRO (1.0 mg of androstenedione 3-CMO:BSA); and PROG17 (1.0 mg of 17α-hydroxyprogesterone 3-CMO:BSA).

[b] Total number of pigs born tended to be higher (P = 0.15) in the PROG17 group than in the control group.

[c] Number of pigs born alive tended to be higher (P = 0.18) in the PROG17 group than in the control group.

Table 3. Summary of farrowing data (mean ± SE) for PROG17 and control gilts for Experiment 2.

Treatment[a]	Number of litters	Total pigs born	P value	Live pigs born	P value
Control	18	10.5 ± 0.5	—	9.20 ± 0.5	—
PROG17	15	12.4 ± 0.6	< 0.022	11.30 ± 0.6	< 0.01

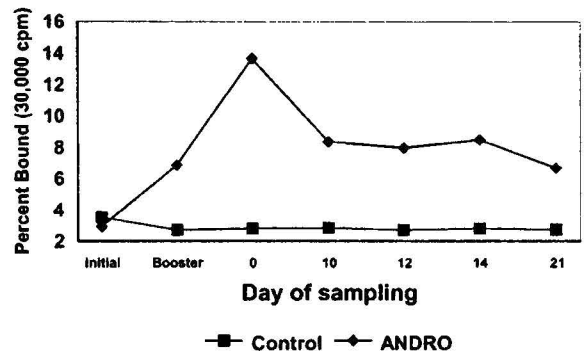
[a] Control (adjuvant + carrier only); ANDRO (1.0 mg of androstenedione 3-CMO:BSA); and PROG17 (1.0 mg of 17α-hydroxyprogesterone 3-CMO:BSA). One control litter with only three pigs born and one treatment litter in which all pigs were born dead due to an unassisted farrowing were deleted from the analysis.

Table 4. Summary of second farrowing data (mean ± SE) for PROG17 and control gilts for Experiment 2.

Treatment[a]	Number of litters	Total pigs born	P value	Live pigs born	P value
Control	13	8.5 ± 1.1	—	8.0 ± 1.1	—
PROG17	10	10.9 ± 1.2	< 0.166	9.9 ± 1.1	< 0.26

[a] Control (adjuvant + carrier only); ANDRO (1.0 mg of androstenedione 3-CMO:BSA); and PROG17 (1.0 mg of 17α-hydroxyprogesterone 3-CMO:BSA).

A



B

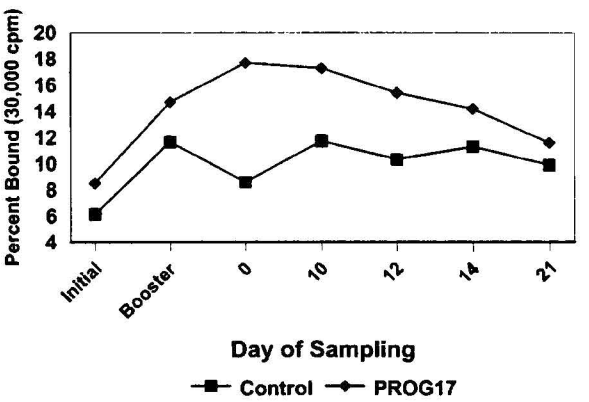
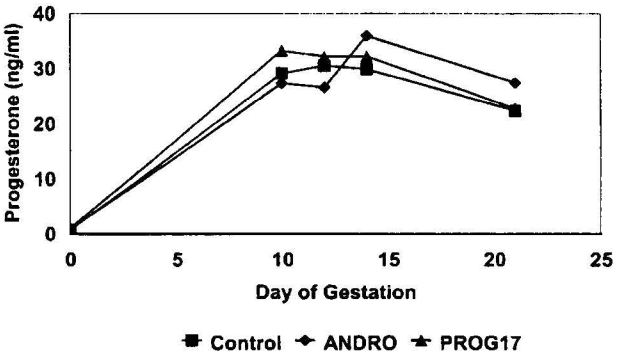


Figure 1A. Serum binding of androstenedione.
1B. Serum binding of 17-OH progesterone.

A



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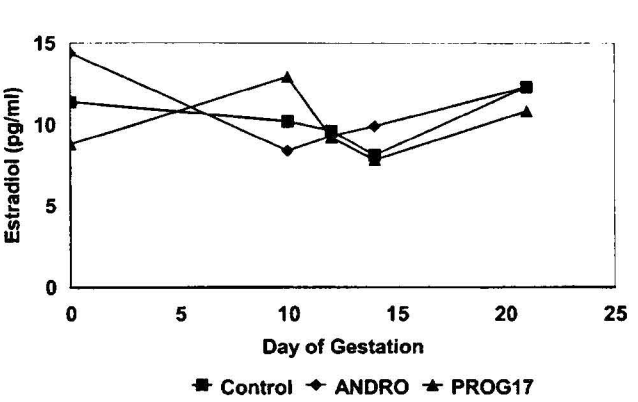

Figure 2A. Serum progesterone concentration.
2B. Serum estradiol concentration.

A Canonical Correlation Analysis of Production Traits of Large White Swine

Z. Johnson[1] and R. Nugent, III[2]

Story in Brief

A canonical correlation analysis was used to examine relationships between two sets of production traits for purebred Large White boars. Data consisted of performance test records of 7,529 boars collected in a commercial swine operation from 1990 to 1997. Boars were individually pen-tested for approximately 77 d (100 to 177 d of age). They were weighed at the beginning (WT100) and end of the test (WT177), and feed intake was recorded. Average daily feed intake and F/G were computed. Backfat (BF) and loin eye area (LEA) were measured at the 10th rib at the end of the test by ultrasound. Body length (LEN) was measured at that time. The traits WT100, ADFI, and F/G were adjusted to a beginning age of 100 d. Likewise WT177, BF, LEA, and LEN were adjusted to an ending age of 177 d. For the canonical correlation analysis, WT100, WT177, and LEN were one set of measurements needing less labor and expense to obtain (LLE traits), and ADFI, F/G, BF, and LEA were the second set of measurements, requiring more labor and expense to obtain (MLE traits). Three significant ($P < 0.01$) canonical correlations were obtained. Among the traits in the LLE set, WT177 had the highest correlation to canonical variate 1, and among the traits in the MLE set, ADFI had the highest correlation to canonical variate 1. The trait WT100 in the LLE set and F/G in the MLE set of traits had the highest correlations to canonical variate 2. Length in the LLE set and BF in the MLE set of traits had the highest correlations to canonical variate 3. Results of this analysis indicate strong relationships between the LLE and MLE traits that may be useful to producers in selection programs.

Introduction

It is well known that gain in swine is genetically related to feed efficiency, and selection for gain has been used quite effectively to indirectly improve feed efficiency. This approach has been taken because measuring individual feed intake is time-consuming and expensive. Emphasis is currently being placed on producing lean pigs. It is time-consuming to measure backfat and loin eye area on individual pigs. Therefore, it would be advantageous to find a trait or combination of traits related to measures of leanness that is also easier to measure. The objective of this study was to examine relationships between two sets of production traits in Large White swine through a canonical correlation analysis. One set of traits is less labor-intensive and less expensive to obtain (LLE), while the other set of traits requires more labor and expense to obtain (MLE).

Materials and Methods

Data evaluated were performance test records from 7,529 Large White boars collected in a commercial swine operation from 1990 to 1997. Boars born to approximately 60% of the litters were culled at weaning on the basis of a maternal breeding value (index) for the dam. These index values were based on the number born alive, farrowing interval, and weaning weight. Boars that were not culled were grown to 100 d of age. At this time, boars to be individually pen tested were selected primarily on the basis of phenotypic weight, with some consideration given to the maternal index.

Boars were individually penned in 2.79 m^2 pens on slatted concrete floors at approximately 100 d of age (79 to 134 d; mean = 100.4 d) for approximately 77 d. A pelleted corn-soybean meal diet that was 1.14% lysine, 19% protein, and 3,344 mcal/kg ME was offered ad libitum. Exact

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composition of the diet varied because of ingredient cost. Ending test age ranged from 152 to 211 d, with a mean of 176.2 d. Boars were weighed at the beginning and end of the test, and feed intake was recorded. Boars were typically fed three to four times a week; however, feed was only weighed back at the end of the test. Backfat (BF) and loin eye area (LEA) were measured at the 10th rib at the end of the test using B-mode ultrasound equipment. Backfat was measured 4 cm off the midline with skin excluded. Body length (LEN), measured from the top of the tail (tailset) to the point of the shoulder when the head is down, was obtained at this time. Average daily gain, ADFI, and F/G were calculated. The traits WT100, ADFI, and F/G were adjusted to a beginning age of 100 d using regression coefficients obtained from previous analyses. Likewise, WT177, BF, LEA, and LEN were adjusted to an ending age of 177 d.

A canonical correlation analysis was used to examine relationships between two sets of production traits using PROC CANCORR of SAS (SAS Inst. Inc., Cary, NC). A canonical correlation analysis is a generalization of multiple correlation analysis with more than one y variable. Thus there are two sets of variables — a set of x variables that possess some common feature and a set of y variables that are characterized in some other way. The objective is to find a linear combination of the first set of variables (x) that has maximum correlation with a linear combination of the second set of variables (y). This is called the first canonical correlation. A second canonical correlation can be found that is greatest for all linear combinations uncorrelated with the first linear combinations. There can be as many canonical correlations as variables in the smallest data set. Thus, all the correlation between the sets of the original variables has been channeled through the canonical correlations. It provides a way of considering overall test performance as a composite evaluation, rather than using one performance trait at a time, as in traditional regression analysis. For the canonical correlation analysis in this study, WT100, WT177, and LEN were considered to be one set of measurements (LLE traits) and DFI, F/G, BF, and LEA were considered to be the second set of measurements (MLE traits).

Results and Discussion

Simple phenotypic correlations among traits examined in this study are presented in Table 1. All correlations were different from zero ($P < 0.01$), with the exception of body length with F/G.

Results of the canonical correlation analysis are presented in Table 2. Three canonical correlations were obtained (0.96, 0.41, and 0.15). All were different from zero ($P < 0.01$). Interpretation of results is often done through examination of correlations of derived variables for each set of traits (canonical variates) with the original measured variables. This is the approach taken here (Table 2). Among the traits in the LLE set, WT177 had the highest correlation ($r = 0.90$) with canonical variate 1, and among the traits in the MLE set, ADFI had the highest correlation ($r = 0.70$) with canonical variate 1. This indicates that a major portion of the variation observed contrasted boars that ate more and were heavier at the end of the test with boars that ate less and were lighter at the end of the test. Canonical variate 2 had the highest correlation to WT100 ($r = 0.95$) in the LLE set and to F/G ($r = 0.73$) in the MLE set of traits. Thus, selecting for high values of this variate would choose boars that were heavier at 100 d and had poorer F/G values on test. Canonical variate 3 was negatively correlated with LEN ($r = -0.70$) in the LLE set and positively with BF ($r = 0.82$) in the MLE set; therefore, selecting for high values of this variate would select shorter, fatter boars, and selecting for low values of this variate would select for longer, leaner boars. Results of this analysis indicate strong relationships between the LLE and MLE traits that may be useful to producers in selection programs.

Implications

Relationships between the two sets of production traits (one set that is less labor-intensive and less expensive to measure and the other set more labor-intensive and more expensive to measure) examined in this study could be useful to producers in selection programs.

Table 1. Phenotypic correlations among traits[a] examined.

Trait	WT177	Length	F/G	ADFI	Backfat	LEA
WT100	0.58**	0.41**	0.25**	0.32**	0.21**	0.26**
WT177		0.56**	–0.13**	0.70**	0.46**	0.39**
Length			0.01	0.40**	0.17**	0.32**
F/G				0.47**	0.16**	–0.13**
ADFI					0.55**	0.18**
Backfat						0.08**

[a] WT100 = weight at 100 d of age; WT177 = weight at 177 d of age; Length = body length measured at the end of the test; F/G = feed-to-gain ratio on performance test; ADFI = average daily feed intake on performance test; Backfat = backfat at 10th rib measured at the end of the test; LEA = loin eye area measured at end of the test.

** $P < 0.01$.

Table 2. Correlations of canonical variates with observed variables.

Trait[a]	Variate 1	Variate 2	Variate 3
Set 1 (LLE)			
WT100	0.17	0.95	0.27
WT177	0.90	0.42	0.11
Length	0.45	0.55	–0.70
Set 2 (MLE)			
F/G	–0.30	0.73	0.26
ADFI	0.70	0.51	0.21
Backfat	0.47	0.26	0.82
LEA	0.34	0.58	–0.43
Canonical correlation	0.96**	0.41**	0.15**

[a] WT100 = weight at 100 d of age; WT177 = weight at 177 d of age; Length = body length measured at the end of the test; F/G = feed-to-gain ratio on performance test; ADFI = average daily feed intake on performance test; Backfat = backfat at 10th rib measured at the end of the test; LEA = loin eye area measured at end of the test.

** $P < 0.01$.

1999 Dairy Herd Improvement Herds in Arkansas

J.A. Pennington[1]

Story in Brief

In December 1999, 107 of the 440 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. Seventy-three herds completed at least eight DHI tests, with 97 cows/herd averaging 15,613 lb milk, 552 lb fat, and 517 lb protein and 82.5% days in milk. Raw somatic cell count averaged 464,000. The income over feed costs was $1,541/cow per year. The Arkansas average for milk/cow was 12,381 lb/yr on all cows in 1999. Herds not on DHI records averaged less than 12,000 lb milk/yr compared to the 15,613 lb milk/yr for herds on DHI. This difference of almost 4,000 lb/cow per year affected income per cow by over $600/cow, or approximately $60,000/herd per year. The quartile data of milk production for the Holsteins with DHI records also showed 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 per cow. It was surprising that four times as many cattle left the herd because of death, injury, or disease as were culled for low production. Since less than 25% of the state's herds were enrolled in the DHI record-keeping program, opportunities exist for raising the level of milk production in Arkansas 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 in the DHI program produce 3,500 to 4,500 lb more milk per year than herds not in the program. This difference in production has a significant effect on net income for the dairies, as greater income over feed costs is associated with greater milk production per cow. The herd summaries also allow a dairy producer to compare production, health, reproduction, and financial aspects of his/her dairy to those of other dairies, so areas of management that need improvement can be detected. Therefore, the purpose of this study was to summarize the production and management data for DHI herds in Arkansas.

Experimental Procedures

Dairy cattle herds on test (n = 107) were used to report production and management data for DHI herds. The test milking (or day) for each cow included weighing milk, taking a sample of milk to be analyzed for percentage of fat and protein and to determine 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 Laboratory in Manhattan, KS. Records were processed at Dairy Records Management Systems (DRMS), Raleigh, NC.

Results and Discussion

Rolling herd averages for all DHI herds with at least eight test dates are in Table 1. The weighted average milk/cow for the 73 herds was 15,613 lb/yr.

Table 2 shows the DHI averages for various quartile data of milk production for the Holstein breed. The quartile data for Holsteins illustrate the relationship of higher milk production to higher income over feed costs. However, the higher producing herds did tend to have more services per conception, but the improved management resulted in a greater percentage of cows detected in heat.

Table 3 shows that 27.4% of Holstein cows left the herd

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last year. Only 7.5% of the cows leaving the herd left because of low production. This compares to 20.2% of the cows leaving because they died and another 11.0% of cows left because of injury or disease. These data are similar to results from all states included in the Heart of America DHIA Summary for 1999.

The 73 dairy cattle herds reported here are less than the 107 cattle herds that have been reported on DHI through other summaries. The primary reason for the difference in numbers is that herds reported here have undergone at least eight test periods. Still, less than 25% of the 440 herds in 1999 were involved in the DHI program. Herds on DHI averaged 15,613 lb milk/cow per year compared to the Arkansas average of 12,381 lb/yr. Omitting DHI herds from the state average indicates that the non-DHI herds averaged less than 12,000 lb milk/yr. The difference of almost 4,000 lb/cow per year affects income by over $600/cow per year, or $60,000/yr in a 100-cow herd.

Implications

DHI program participation affords dairy producers an opportunity to maintain milk production records on individual cows and other management practices. Because herds utilizing DHI records averaged substantially more milk/cow per year than herds not in DHI program, we should continue to encourage producers to enroll in the DHI testing program.

Table 1. 1999 Dairy cow herds in DHI test in Arkansas.

Rolling herd averages	All herds (n = 73)	Standard deviation
Milk, lb	15,613	320
% Fat	3.6	0.3
Fat, lb	552	109
% Protein	3.4	0.2
Protein, lb	517	101
% in Milk	82.5	7.1
Number cows/herd	97	61
Days dry	77	23
1st Lactation, lb	54	17
2nd Lactation and over, lb	72	15
Projected calving interval, mon	15.2	2.1
Raw SCC (x 1,000)	464	214
Linear SCC	3.5	0.7
Services/conception - pregnant cows	2.6	1.9
Days to 1st service	86.3	40.9
Days open	183.8	63.5
AIPL - PTA $		
All cows	38	28
All sires	65	42
1st Lactating cows	75	59
2nd Lactating cows and over	57	40
Milk price/cwt, $	$15.13	$0.98
Income over feed costs, $/cow	$1541.00	$302.00

Table 2. 1999 Arkansas DHI comparisons—Holstein herds.

	Rolling herd averages—Arkansas Holstein herds			
No./herd	115	92	101	89
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Milk, lb	19,991	17,561	15,256	12,002
% Fat	3.5	3.5	3.5	3.5
Fat, lb	694	617	534	423
% Protein	3.3	3.3	3.3	3.2
% Protein, lb	656	571	499	385
Days in milk	193	200	194	184
% Cows in milk	90.3	85.5	84.9	78.3
Days dry	67.9	83.7	74.3	93.1
Standardized 150-d milk, lb	68.2	62.5	54.5	45.0
Peak milk - All, lb	80.3	77.0	67.8	57.4
1st Lactation, lb	69.0	62.9	56.0	57.8
2nd Lactation, lb	83.4	80.4	69.6	47.9
3rd Lactation, lb	89.0	86.2	74.6	61.9
305-d ME projected milk, lb	21,393	19,478	17,122	13,938
% Cows left herd	33.0	26.2	32.7	24.2
Raw SCC (x 1,000)	405	383	523	492
Days open	174	181	183	185
Freshening interval, mon	15.0	15.2	15.2	15.3
Services/conception - all cows	3.5	2.6	2.8	2.4
Services/conception - pregnant cows	1.9	2.0	1.8	1.7
% Heat observed	37.8	32.5	31.0	22.6
AIPL PTA $ - cows	$59	$42	$42	$36
AIPL PTA $ - sires	$94	$85	$84	$70
Income over feed costs, $/cow	$1947	$1699	$1598	$1127

Table 3. Cows leaving herds in last 12 mo, January 2000.[1]

Reason for leaving	%[2]
Udder	1.4
Injury	7.0
Disease	4.0
Low production	7.5
Mastitis	12.0
Reproductive problems	16.5
Feet and legs	3.5
Died	20.2
Sold for dairy reproduction	6.5
Other	21.5

[1] Averages in Arkansas for Holstein herds on DHI from Dairy Records Management Systems.

[2] Total left herd = 27.4%.

Growth of Calves Fed Milk Replacer Containing Dried Egg Product

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Story in Brief

An experiment was conducted to use an egg protein product in a milk replacer for young dairy calves as a partial replacement for protein and fat from dried milk or whey products. Eighteen young Holstein calves were fed either a commercial milk replacer (control) or a milk replacer containing 30% spray-dried, feed-grade egg product for 28 d. There was no difference between BW gains of calves fed the control milk replacer and the replacer containing 30% egg protein. Average daily gains were approximately 0.5 lb for calves. Control calves tended to consume more grain during week 1 and did consume more grain during the second and fourth weeks than calves fed milk replacer containing 30% dried egg product.

Introduction

The nutritional quality of egg protein has been recognized for years. However, this source of protein has not been tested extensively as a feed for dairy calves, partially because milk proteins are the accepted standard. However, a reasonably priced dry egg-protein product should serve as a high-quality protein source for young dairy calves. The price of dried skim milk has varied tremendously in recent years, and it at times has often been too expensive to purchase for inclusion in a milk replacer designed for young dairy calves. Dried whey can replace some of the dried skim milk, but it has only 14% protein compared to 35.8% in dried skim milk. The calf's requirement is 22% protein, and more important, specific amino acids must be provided in the correct proportions. Soy protein and other plant protein sources have been fed to calves but are generally inferior to milk protein for calves. Heat-treated, soy protein isolates have promise as a calf feed, but extensive processing is required. Therefore, the need exists to find economical, suitable products that will replace milk protein. The products must be soluble enough to mix with warm water, remain in solution to pass through a nipple bottle or bucket, support adequate growth of calves, and foster good health. Dried egg product appears to meet or surpass those concerns and might provide a replacement for at least part of the protein in dried skim milk. Whole milk contains about 25% fat on a dry basis. Specialty fat products must be purchased for combination with dried skim milk or dried whey. It would seem probable that the 33% fat in dried egg product would be a suitable replacement for at least part of the fat in milk. Dried egg product has been used successfully as an alternative protein and fat source in milk replacers designed with soy flour and a dextrin carbohydrate source for young dairy calves (Kellogg and Hatfield, 1992). In a preliminary experiment, the milk replacers mixed well, and calves consumed the milk replacers readily (Kellogg, 1999). Research is needed to determine whether the dried egg product results in calf performance that is equivalent to performance with dried skim milk and to decide upon the level of dried egg product that can be used to replace dried skim milk in formulation of a milk replacer.

For these reasons, it was proposed to use differing amounts of dried egg product to formulate milk replacers and to feed the milk replacer to young calves.

Experimental Procedures

A milk replacer was prepared by replacing dried skim milk and dried whey with dried egg product (Table 1) for comparison with a commercially available milk replacer. Nutrient requirements (NRC, 1989) were met or exceeded, including protein and specific amino acid requirements. Fat content was formulated at 14.9%, but the actual analysis of a sample that was taken during mixing was 11.6% fat. The commercial milk replacer contained 20% fat.

The experiment was initiated by purchasing two groups of 10 male Holstein calves from cattle auctions in the Northwest Arkansas area. Calves were from 4 to 7 d old, and the second group arrived 2 wk after the first group. The buyer confirmed with previous owners, who owned local dairy farms, that each calf had received colostrum. All calves were weighed and housed in individual wooden hutches with an exercise area for the 4-wk trial. Hutches were enclosed except for a 2-ft vertical opening to the south. Calves had access to

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an exercise area created by bending an 8-ft wire panel attached to front corners of each hutch. Straw was used as bedding material inside hutches, and new bedding was added as needed. Fresh water was offered daily in pails attached to the wire panels.

Soon after arrival, calves were fed a commercial milk replacer (Merrick's Gold Star, Merrick's Co., Madison, WI) that contained 20% crude protein, 20% fat, and Neo-terramycin (Table 2). Each group of calves was placed in the trial after a 4- to 5-d adjustment period. Fecal consistency (scours) was recorded on a scale of 1 to 9 (see description below). At onset of scours (fecal consistency score 7) each calf was given an electrolyte solution 1 h before feeding milk replacer. This continued until the scouring stopped (fecal score 6). Records were kept of the number of days that the electrolyte solution was fed and the number of times antibiotic treatment was necessary (fecal scores 8 and 9 or elevated body temperature). The scale of 1 to 9 used to measure fecal consistency was defined as follows:

1 = feces so firm the calf is constipated

2 = feces more firm than is typical for calves

3 = feces firm, but not as hard as scores 1 and 2

4 = feces clumpy with liquid present

5 = feces consistently loose and typical for young calves fed liquid feeds

6 = feces loose and some of the material is running on the ground

7 = feces definitely running on the ground (scours)

8 = feces very runny on the ground (severe scours)

9 = feces extremely liquid or bloody (extreme scours).

Calves were placed in a randomized block design with initial body weight as the block for both replications of 10 calves each. Dietary treatments were assigned randomly within pairs of calves with similar BWs. Initial (day 0) BWs were taken in the morning, and treatment calves received an egg-protein milk replacer for the evening feeding. One calf in each replication was ill with scours on day 0, and the illness persisted so both were removed before the data were analyzed. Calves were fed milk replacer twice daily. Milk replacers were reconstituted (1 lb/gal warm water) and mixed thoroughly. Two quarts of the mixture (0.5 lb of dry feed) were fed in a nipple bottle at each feeding.

All calves were offered 0.25 lb/d of a calf starter grain mixture in an enclosed bottle fitted with a specialized nipple. Remaining grain was weighed daily and recorded as orts. The amount of calf starter grain offered was increased to 0.50 lb/d on day 7, to 0.75 lb/d on day 14, and to 1.0 lb/d on day 21. Orts that were removed daily were weighed and subtracted from the amount of grain provided to determine actual intake.

Calves were weighed on days 7, 14, 21, and 28. The BWs were used to calculate ADG and feed efficiency.

Results and Discussion

There was no difference ($P > 0.05$) between BW gains of calves fed the control (commercial) milk replacer and the milk replacer containing 30% egg protein (Table 3). Weight gains of calves were similar for both replications, so one mean per treatment is presented. This should be the case, since the second replication began only 2 wk later than the first and both were conducted under the similar conditions. Weather was mild with warm days and cool nights during the experimental period. The temperature remained warm during the single rainy day.

The pattern of growth was similar, and weekly BW gains did not vary ($P > 0.05$) by dietary treatment (Figure 1). Treatment groups were blocked by initial BW, which was very similar, so there was no need for an analysis of covariance in this trial. It is important to note that calves in an earlier experiment had difficulty competing with control calves when dried egg products were included in the milk replacer (Scott et al., 1999). That experiment tested a different source of dried egg product than this experiment, so that may explain the different results. However, in a preliminary trial that included this dried egg product, weight gains declined later in the trial compared to controls (Kellogg, 1999). For those reasons, the levels of vitamin A, zinc, and copper were increased in this trial. These dietary changes were designed to counter the high iron in egg yolk because that iron is probably very soluble for calves. There is no evidence that high iron is a problem; in fact, milk is low in both iron and copper. However, when there is a bacterial infection, part of the body's defense mechanism is to reduce iron in blood, apparently to prevent invading bacteria from using the iron. While speculative, it may be logical to infer that disease bacteria causing infectious scours in calves may benefit from highly soluble iron in egg products. It was thought that high vitamin A, zinc, and copper would help counter the iron levels, but this hypothesis was not tested in this experiment.

Calves in this experiment may have been older than in other trials, since the calves were purchased at sale barns and allowed a few days to adjust to the University farm. Calves in this trial were offered a grain mixture in bottles with a specialized nipple, which corresponds to the management on farms that raise heifers, whereas some researchers offer only the liquid feeds being tested, which is the typical management for veal calves. Control calves tended to consume more grain during week 1 (Figure 2) and did consume more grain ($P < 0.05$) during the second and fourth weeks than calves fed milk replacer containing 30% dried egg product. During the third week, the means were not different ($P = 0.13$). This effect was also noted in the preliminary experiment last spring (Kellogg, 1999). It does not seem reasonable that the milk replacer containing egg protein would have reduced appetite of calves for grain unless the level of protein fed satisfied the calves. The energy provided by fat content (20% vs. 15%) of the commercial replacer should have offset the lower protein (22% vs. 27%). Milk replacers in this experiment were formulated to demonstrate that it is possible to include 30% dried egg product. Another experiment is needed to compare milk replacers that are isocaloric and isonitrogenous. That formulation is possible if more ingredients are available. The

lower voluntary feed intake associated with inclusion of 30% dried egg protein is of concern, since a major goal of dairy heifer growers is to establish grain intake to initiate development of the rumen and to permit early weaning of dairy heifer calves.

Average fecal scores (Figure 3) and the number of days of treatment for scours was similar for both dietary treatments. The incidence of disease was low for all calves.

Implications

This experiment demonstrated that 30% dried egg product was successfully used to raise dairy calves, and BW gains were similar to that of calves receiving an excellent commercial milk replacer.

Acknowledgement

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Table 1. Components of milk replacer designed with 30% spray-dried, feed-grade egg product[a] to meet or exceed nutrient requirements.

Ingredient	Egg protein,%, as fed basis
Dried egg product	30
Dried whey	36
Dried skim milk	20
Lactose	10.7
Poultry fat	3
Artificial flavoring	0.1
Availa-Zn[b]	0.075
Availa-Cu[b]	0.011
Manganese oxide	0.007
Vitamin ADE premix[c]	0.08
Vitamin E premix[d]	0.2
Neo-Terra, 10/5[e]	0.1
Selenium premix[f]	0.0005
Analysis*	
Crude protein	26.2
Crude fat	14.9
Calcium	0.75
Phosphorus	0.69
Vitamin A, IU/lb	121,284
Vitamin D, IU/lb	7999
Vitamin E, IU/lb	657

[a] Spray-dried, feed-grade egg product (American Dehydrated Foods, Inc., Springfield, MO) contained 49.07% protein, 37.82% fat, 6% ash, 0.63% calcium, 0.71% phosphorus, 0.61% sodium, 0.58% potassium, 0.08% magnesium, 98 mg/kg iron, 5 mg/kg copper, 5 mg/kg manganese, 46 mg/kg zinc, 0.85 mg/kg selenium, 1.56 mg/lb thiamine hydrochloride, 18.28 mg/kg riboflavin, 2.009 mg/kg vitamin B_6, 115 mcg/kg vitamin B_{12}, 72.4 mg/kg pantothenic acid, 22.4 mg/kg niacin, 0.865 mg/kg folic acid, 3.542 mg/kg biotin, 2,110 IU vitamin A, 15.2 IU/kg vitamin E, 2.16% threonine, 0.68% tryptophan, 2.61% phenylalanine, 1.12% histidine, 2.82% arginine, 4.40% lysine, 4.22% leucine, 2.54% isoleucine, 1.81% methionine, 3.39% valine, 3.13% alanine, 1.23% cystine, 3.90% serine, 2.41% proline, and 1.92% glycine.

[b] Zinpro Availa-Zn[7] contained 10% zinc; Zinpro Availa-Cu contained 10% Cu.

[c] Vitamin ADE premix contained 4,000,000 IU/lb of vitamin A, 800,000 IU/lb of vitamin D, and 500 IU/lb of vitamin E.

[d] Vitamin E premix contained 20,000 IU of vitamin E.

[e] Neo-Terra 10/5 contained oxytetracycline, 5 g/lb, and neomycin sulfate, 7g/lb.

[f] Selenium premix contained 0.06% selenium and 35 to 40% calcium.

* Calculated values, as fed basis.

Table 2. Composition of commercial milk replacer[a] used as control treatment.

Analysis	Milk protein, %, as fed basis
Crude protein	≥20.0
Crude fat	≥20.0
Calcium	≥0.5
Calcium	≥1.0
Phosphorus	≥0.6
Vitamin A, IU/lb	≥35,000
Vitamin D_3, IU/lb	≥7,500
Vitamin E, IU/lb	≥150

[a] Merrrick's medicated calf milk replacer lists ingredients as follows: dried skimmed milk, dried whey, dried whey product, dried milk protein, animal fat (preserved with BHT), lecithin, dicalcium phosphate, vitamin A acetate, D-activated animal sterol (source of vitamin D3), vitamin E supplement, riboflavin, calcium pantothenate, niacin supplement, vitamin B_{12} supplement, biotin, folic acid, ascorbic acid, magnesium sulfate, manganese sulfate, sodium selenite, ferrous sulfate, zinc sulfate, cobalt sulfate, copper sulfate, calcium iodate, sodium silico aluminate, and natural & artificial flavors. Active drug ingredients are oxytetracycline, 200 g/ton, and neomycin base (from neomycin sulfate), 400 g/ton.

Table 3. Mean body weights and accumulative weight gains (losses) of calves by week of trial.

	Day				
Replacer	0	7	14	21	28
Control[a]					
Body weight, lb	94.4	93.2	96.1	102.3	108.1
Egg protein[a]					
Body weight, lb	93.2	93.4	95.4	102.8	106.7

[a] Means from control and egg-protein treatments did not differ ($P > 0.10$).

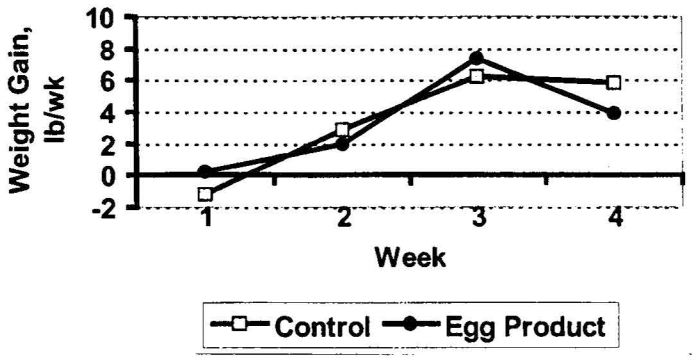

Figure 1. Weekly weight gains of calves.

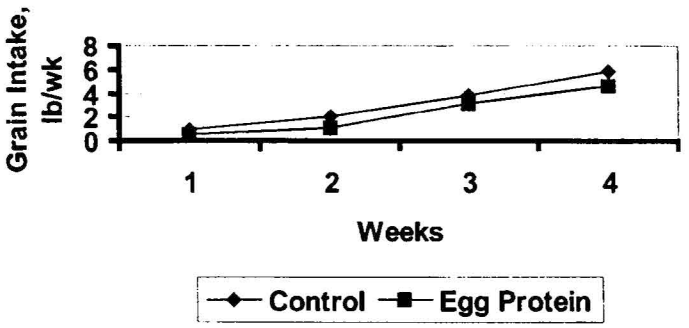

Figure 2. Weekly grain intake by calves.

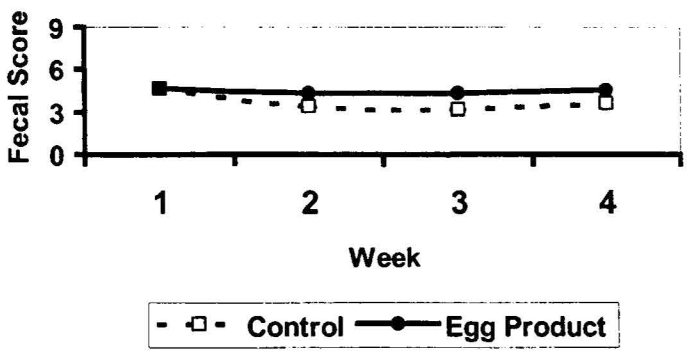

Figure 3. Fecal consistency scores.

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