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Arkansas Animal Science Department Report 2008

Zelpha B. Johnson
University of Arkansas, Fayetteville

D. Wayne Kellogg
University of Arkansas, Fayetteville

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Animal Science
Department Report • 2008

Zelpha B. Johnson
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Editors

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ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT • 2008

JOHNSON AND KELLOGG

AAES

UNIVERSITY OF ARKANSAS

DIVISION OF AGRICULTURE

ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT 2008

Edited by

Zelpha B. Johnson
Professor

and

D. Wayne Kellogg
Professor

Department of Animal Science
University of Arkansas

University of Arkansas Division of Agriculture
Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72701

INTRODUCTION

Welcome to the 11th edition of *Arkansas Animal Science*. Once again, we owe a great debt to Drs. Zelpha Johnson and Wayne Kellogg who devoted valuable time to making this a quality publication. We believe Arkansas Animal Science is an essential publication for our program. While peer-reviewed journals are the ultimate goal for quality research, the time-lines for publication and the frequent necessity to combine several trials limit the utility of journals for early dissemination of results. Stakeholders, researchers, extension faculty, and industry professionals need results as quickly as the data are statistically analyzed and prepared in a professional publication such as *Arkansas Animal Science*. The capacity to present this year's publication for the first time in only electronic format on the departmental, Division of Agriculture, and University of Arkansas Web sites further increases its impact.

The research described in this report was conducted at the four main experiment stations used by the Department of Animal Science, including the Arkansas Research and Extension Center at Fayetteville, the Southwest Research and Extension Center at Hope, the Southeast Research and Extension Center at Monticello, and the Livestock and Forestry Branch Station at Batesville. Other valuable research and extension work was conducted at numerous private farms across the state. In the modern world of animal science, the traditional lines between research and extension programs are increasingly disappearing. This should be apparent as one looks at the authorship of the articles in this publication.

Readers are invited to view all programs of the Department of Animal Science at the departmental Web site at *animalscience.uark.edu* and the Livestock and Forestry Branch Station Web site at *www.Batesvillestation.org*.

This was a challenging year for the department as we have been faced with the same escalating costs experienced by our stakeholders. Many of our research and extension programs reflect these challenges. Members of our faculty have quickly developed new projects and programs to give stakeholders answers and at the same time adapt our operations as efficiently as possible. In this respect, the challenges have made our programs more relevant. The Animal Science Extension Section developed a new emphasis program titled 300 Days of Grazing designed to make the most effective use of fuel, equipment, and fertilizer inputs, and to optimize cattle management and marketing. This program will be set up and demonstrated on livestock operations across Arkansas and on our research station at Batesville.

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

Sincerely,

Keith Lusby
Department Head

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 0.1%, respectively. Using the example of $P < 0.05$, there is less than a 5% chance that two treatment averages are really the same. Statistical differences among means are often indicated in tables by use of superscript letters. Treatments with any letter in common are not different, while treatments with no letters in common are. Another way to report means is as mean ± standard error (e.g. 9.1 ± 1.2). The standard error of the mean (designated SE or SEM) is a measure of the amount of variation present in the data – the larger the SE, the more variation. If the difference between two means is less than two times the SE, then the treatments are usually not statistically different from one another. Other authors may report an LSD (least significant difference) value. When the difference between any two means is greater than or equal to the LSD value, then they are statistically different from one another. Another estimate of the amount of variation in a data set that may be used is the coefficient of variation (CV) which is the standard error expressed as a percentage of the mean. Orthogonal contrasts may be used when the interest is in reporting differences between specific combinations of treatments or to determine the type of response to the treatment (i.e. linear, quadratic, cubic, etc.).

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

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

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

COMMON ABBREVIATIONS

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

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Effects of Forage Type and Anabolic Implantation of Steers on Growth and Subsequent Carcass Characteristics[1]

C.R. Bailey[3], M.L. Looper[2], A.H. Brown, Jr.[3], and C.F. Rosenkrans, Jr.[3]

Story in Brief

A 2 x 2 factorial treatment arrangement was used in a multi-year study to examine the effects of forage type and implant status during the stocker phase on performance (3 yr; n = 142 steers) and carcass characteristics (2 yr; n = 88) of crossbred steers. Steers were randomly assigned to receive no implant or a Synovex S implant (20 mg estradiol benzoate; 200 mg progesterone) on d 0 and 56, 63, or 50 for yr 1, 2, and 3, respectively, and graze either common bermudagrass (CB; 4 pastures/yr) or pearl millet (PM; 4 pastures/yr) for 97, 84, or 92 d for yr 1, 2, and 3, respectively. Intermediate (d 56, 63, and 50 of grazing for yr 1, 2, and 3, respectively) and final (d 97, 84, and 92 of grazing for yr 1, 2, and 3, respectively) ADG was calculated, and following a finishing phase in a commercial feedlot, cattle were slaughtered and hot carcass weight (HCW) was recorded immediately. Following a 48 h chill, 12th rib backfat (BF) and *longissimus* muscle (LM) area were measured, kidney-pelvic-heart (% KPH) fat and marbling score were visually estimated, and yield grade (YG) was calculated. No forage x implant interaction ($P > 0.13$) was observed for any variables. Neither final BW nor ADG was affected ($P > 0.41$) by implant or forage type ($P > 0.77$). Implant treatment did not influence ($P > 0.22$) HCW, BF, LM area, KPH or YG. Forage type did not affect ($P > 0.19$) HCW, BF, LM area, KPH, or MS, but YG was reduced ($P = 0.06$) in CB compared to PM grazed calves. Stocker producers in Arkansas may utilize pearl millet to increase ADG early in the grazing season and summer carrying capacity; however, the economic feasibility of annual establishment of pearl millet should be considered.

Introduction

It is well known that stocker cattle gains decline during midsummer grazing. This is likely due, in part, to low pasture productivity and reduced quality of perennial forage grasses. Alternative forages are needed to increase stocker performance and thereby increase profitability. One of the options to increase forage production is the use of warm season annuals. Warm season annuals provide a fast growing, high yielding, and high quality forage; however, they require more intense management and have an increased establishment cost. Pearl millet, a warm season annual, has been shown to enhance ADG during a relatively short grazing season (Franzluebbers and Stuedemann, 2005).

Utilization of anabolic implants typically increases performance of stocker cattle. Duckett and Andrae (2001) indicated that implants could improve ADG by up to 15% in stocker cattle with minimal effect on feedlot performance and carcass quality. Therefore, our objective was to investigate forage type and implant status during the stocker phase on performance and carcass characteristics of crossbred steers.

Experimental Procedures

A 2 x 2 factorial treatment arrangement was used in a multi-year study to examine the effects of forage type and implant status during the stocker phase on performance (3 yr; n = 142 steers) and carcass characteristics (2 yr; n = 88) of crossbred steers. Steers were stratified by weight and randomly assigned to receive no implant or a Synovex S implant (20 mg estradiol benzoate; 200 mg progesterone) on d 0 of each year, and re-implanted on d 56, 63, or 50 for yr 1, 2, and 3, respectively, and graze either common bermudagrass (CB; 4 pastures/yr) at a stocking rate of 2.4 steers/acre or pearl millet (PM; 4 pastures/yr) at a stocking rate of 3.2 steers/acre, for 97, 84, or 92 d for yr 1, 2, and 3, respectively. Initial stocking rates of PM pastures were greater than CB pastures due to higher yields and more rapid growth rates of PM compared with CB (McCartor and Rouquette, 1977). Common bermudagrass pastures were 20 year old stands and pearl millet was planted annually at 28 lb/acre when soil temperatures reached 60°F, which was usually the first week in May. Intermediate ADG was calculated using the BW at 56, 63, and 50 d for yr 1, 2, and 3, respectively; overall ADG for the grazing period was calculated using BW at 97, 84, and 92 d for yr 1, 2, and 3, respectively, and, following a finishing phase in a commercial feedlot, cattle were slaughtered and hot carcass weight (HCW) was recorded immediately. Following a 48-h chill, 12th rib backfat (BF) and *longissimus* muscle (LM) area were measured, kidney-pelvic-heart (% KPH) and marbling score (MS; 30 = slight; 40 = small) were visually estimated, and yield grade (YG) was calculated.

Statistical analysis was performed using the PROC MIXED procedures of SAS (SAS Inst., Inc., Cary, N.C.) with the model consisting of forage type (CB and PM), implant status (yes or no), and the interaction with both year and pasture considered random effects.

Results and Discussion

All performance results are listed in Table 1. Initial BW (d 0) was similar across treatments (647 ± 35 lb). No forage x implant

[1] Names are necessary to report factually on available data; however, the USDA does not guarantee or warrant the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that also may be suitable.

[2] USDA-ARS, Dale Bumpers Small Farms Research Center, Booneville

[3] Department of Animal Science, Fayetteville

interaction ($P > 0.13$) was observed for any variables. Intermediate ADG was greater ($P = 0.05$) in steers grazing PM than CB, which is in agreement with previous research that indicated PM enhanced ADG during a relatively short grazing season (Franzluebbers and Stuedemann, 2005). This also could be due to the fact that forage availability was greater ($P < 0.01$; data not shown) for PM in all months of the study. Pearl millet has high yields and rapid growth rates (McCartor and Rouquette, 1977) and was why PM pastures were initially stocked at higher rates than CB pastures. Total BW gain/acre was greater for PM ($P = 0.01$) than CB, which is likely due to the fact that steer grazing days were increased ($P < 0.01$) on PM (total grazing days = 649) compared to CB (total grazing days = 510). Intermediate ADG tended ($P = 0.11$) to be greater in implanted than non-implanted steers; however, this increase did not equal that demonstrated by Duckett and Andrae (2001) which indicated that implants could improve ADG by up to 15%. Neither final BW nor ADG was affected ($P > 0.41$) by implant or forage type ($P > 0.77$). Implant treatment did not influence ($P > 0.16$) HCW, BF, LM area, KPH, MS, or YG in stocker cattle with minimal effect on feedlot performance and carcass quality. Similarly, Duckett and Andrae (2001) reported implanting stocker cattle had only minimal effects on carcass quality. Forage type did not affect ($P > 0.19$) HCW, BF, LM area, KPH, or MS, but YG was reduced ($P = 0.06$) in CB (2.7 ± 0.24) compared to PM (3.1 ± 0.24) grazed calves.

With final BW and ADG of steers not different between forages, annual establishment costs (i.e., seed costs, seed-bed preparation, etc.) of PM compared with perennial CB pastures would be cost prohibitive. Future studies investigating the economic feasibility of warm season annuals in stocker cattle production is warranted.

Implications

Stocker producers in Arkansas may utilize pearl millet to increase ADG early in the grazing season and summer carrying capacity; the economic feasibility of annual establishment of pearl millet should be considered. Anabolic implants during the stocker phase may not improve steer performance or carcass characteristics of cattle grazing pearl millet or common bermudagrass.

Literature Cited

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Duckett, S.K., and J.G. Andrae. 2001. J. Anim. Sci. 79:(E. Suppl.) E110-E117.

McCartor, M.M., and F.M. Rouquette, Jr. 1977. Agron. J. 69:983.

Table 1: Effects of forage type and implant status on BW, ADG, BW gain/acre and carcass characteristics in beef steers.

	Forage type						
	Bermuda		Pearl Millet		*P* Value		
Item	Implant +	Implant -	Implant +	Implant -	F[1]	I[1]	F x I[1]
No. of steers	31	32	40	40	-	-	-
BW, lb							
Initial	645 ± 35	642 ± 35	651 ± 35	649 ± 35	0.53	0.77	0.96
Final	812 ± 40	805 ± 40	812 ± 40	801 ± 40	0.78	0.42	0.85
ADG, lb							
Intermediate[2]	2.3 ± 0.15	2.2 ± 0.15	2.5 ± 0.13	2.31 ± 0.15	0.05	0.11	0.79
Final[3]	1.8 ± 0.22	1.8 ± 0.22	1.8 ± 0.22	1.8 ± 0.22	0.95	0.56	0.9
Total BW gain/acre	384 ± 21.5	366 ± 21.5	463 ± 21.5	443 ± 21.5	0.01	0.23	0.95
Carcass							
No. of steers	20	20	24	24	-	-	-
HCW, lb	849 ± 39.6	865 ± 39.6	858 ± 37.4	871 ± 39.6	0.69	0.42	0.96
BF, in	0.51 ± 0.16	0.43 ± 0.16	0.51 ± 0.16	0.55 ± 0.16	0.20	0.94	0.17
LM area, sq in	14.4 ± 0.78	14.57 ± 0.78	14.10 ± 0.78	14.10 ± 0.78	0.21	0.97	0.81
KPH, %	2.8 ± 0.5	2.5 ± 0.5	2.6 ± 0.5	2.5 ± 0.5	0.53	0.23	0.56
MS[4]	37.9 ± 2.2	42.9 ± 2.3	39.7 ± 2.1	29.5 ± 2.2	0.66	0.17	0.13
YG	2.8 ± 0.3	2.6 ± 0.3	3.1 ± 0.3	3.1 ± 0.3	0.06	0.78	0.68

[1] F = forage; I = implant; F x I = forage x implant interaction.
[2] Yr 1 calculated on a 56 d basis, yr 2 calculated on a 63 d basis and yr 3 calculated on a 50 d basis.
[3] Yr 1 calculated on a 97 d basis, yr 2 calculated on an 84 d basis and yr 3 calculated on a 92 d basis.
[4] 30 = slight marbling; 40 = small marbling.

Comparison of Bloat Potential between Soft-Red and Hard-Red Winter Wheat Forages[1]

M.S. Akins[2], E.B. Kegley[3], K.P. Coffey[3], J.D. Caldwell[3], K.S. Lusby[3], J.C. Moore[3], and W.K. Coblentz[4]

Story in Brief

Some aspects of wheat pasture bloat in cattle have been researched extensively, but few studies have evaluated the effect of wheat type on occurrence of bloat. Eight Gelbvieh × Angus ruminally cannulated heifers (1,135 ± 108 lb BW) and 48 Angus heifers (525 ± 26 lb BW) grazed 2.5-acre pastures of either hard-red or soft-red winter wheat. In Exp. 1, cattle grazed from November 11 to 22 and from November 26 to December 7, 2006 in a crossover design. In Exp. 2, cattle were shrunk for 20 h and then grazed from December 19 to 20, 2006 and from January 19 to 20, 2007. In both experiments, bloat was scored at 1000 and 1600 daily. In Exp. 1, cannulated heifers grazing soft-red had a greater ($P < 0.01$) percentage of observed bloat (21.9 vs. 5.6%) than those grazing hard-red winter wheat, but bloat incidence was low (2.1%) for the stocker cattle with no difference between hard-red and soft-red winter wheat. In Exp. 1, rumen fluid was collected 3 times/d from the cannulated heifers during the last 2 d of each period. Rumen fluid from cattle grazing soft-red wheat at 1200 and 1800 was more viscous than rumen fluid collected at 0600 and hard-red at all times (wheat type × time interaction, $P = 0.03$). In Exp. 2, no bloat was observed. Therefore, soft-red winter wheat had a greater bloat potential than hard-red winter wheat based on results from the cannulated heifers, but no differences were observed in the frequency of bloat in stocker cattle.

Introduction

Cattle graze hard-red winter wheat pastures throughout the Southern Plains. Stocker cattle can have high rates of gain while grazing winter wheat, but wheat pasture bloat can be a major problem. On average, annual death losses of 2% are expected from wheat-pasture bloat, but losses can be as high as 20% with serious outbreaks. In these reports, cattle were probably grazing hard-red winter wheat; however in Arkansas, stocker cattle graze soft-red winter wheat and the incidence of bloat appears to be lower. Daniels et al. (2002) conducted a 3-yr study grazing cattle on soft-red winter wheat and reported no incidences of bloat.

Wheat pasture bloat is a type of frothy or foamy bloat where gases produced by microbial fermentation become trapped in a polysaccharide slime layer and cannot be eructated. If untreated, rumen pressure builds and interferes with respiration, thereby causing suffocation. Frothy bloat is caused by an interaction of plant, animal, and environmental factors. There has been no research that evaluates wheat types [soft-red (SR) or hard-red (HR)] for bloat-causing potential. Determining if a wheat type is more or less apt to cause bloat would assist stocker cattle producers in calculating the risk of encountering this production problem.

Therefore our objectives were to determine if SR and HR winter wheat have different bloat-causing potentials in 2 distinct production situations. These included: (i) cattle allowed to graze wheat pastures normally during the late fall, and (ii) the initial response of grazing cattle to bloat-provocative wheat during cold, dry conditions.

Experimental Procedures

Exp. 1

Forage Establishment. This study was conducted at the Arkansas Agriculture Research and Extension Center in Fayetteville, Ark. Nitrogen was applied at a rate of 50 1b/acre as ammonium nitrate (34-0-0), and P and K were applied to meet requirements specified by the Ark. Coop. Ext. Ser. soil test guidelines. Eight 2.5-acre pastures were assigned randomly to a forage treatment of either HR (OK 101) or SR (GR 9108) winter wheat. Forages were established on September 15 and 16, 2006 at a rate of 123 lb/acre using a 7-ft-wide no-till drill with 7-in row spacings.

Animals and Sampling Procedures. Eight Angus × Gelbvieh ruminally cannulated heifers (1,135 ± 108 lb) and 48 primarily Angus stocker heifers (525 ± 26 lb) were received at the facility on November 7. Before and between periods, animals were fed medium quality warm-season grass hay at ad libitum intake. A free choice mineral without ionophores or surfactants also was offered (Sweet Mag, Ragland Mills, Neosho, Mo.).

Animals were stratified by weight and allocated randomly to the 2.5-acre pastures of either SR or HR winter wheat. Two pastures with cannulated heifers had 4 heifers, and 6 pastures with stocker cattle had 8 animals. Two periods of 10 d were arranged in a crossover design. Periods 1 and 2 began on November 12 and 27, respectively, with 8 d of adaptation and observation and 2 d of rumen fluid sample collection and observation. Bloat was scored twice daily (1000 and 1600), where 0 = normal animal; 1 = slight distention of left side of animal; 2 = marked distention of the left side with rumen distended upward toward the top of the back, cre-

[1] We gratefully acknowledge the assistance of R. K. Bacon, and J. V. Skinner, Jr. in conducting these projects, and the donation of seed from Delta King, McCrory, Ark.

[2] Present address: University of Wisconsin Department of Dairy Science, Madison, Wis.

[3] Department of Animal Science, Fayetteville.

[4] Present address: USDA-ARS, Marshfield, Wis.

ating an asymmetrical (egg shape) appearance from the rear; and 3 = marked distention on the left and right sides of the animal with distention above the top of the back.

Forage availability was measured on d 0 and 10 of each period to establish initial and final forage mass. Daily forage samples were taken to assess nutritive value. On d 9 and 10, rumen fluid from cannulated heifers was sampled at 0600, 12 noon, and 1800

Rumen Fluid Analysis. Upon arrival in the laboratory, rumen fluid viscosity was measured using a Bostwick consistometer (Christison Particle Technologies, Inc., Gateshead, UK). Rumen fluid foam production and strength were measured by pouring rumen fluid into a graduated cylinder, then bubbling CO_2 at 1 psi from a bottom inlet through the rumen fluid for 30 s. Maximum foam height (cm) was measured and foam strength was calculated as the percentage of the initial foam height remaining after 5 min.

Forage Nutritive Value Analyses. Forage samples were freeze-dried, and kept at -4°F between all laboratory procedures. Samples were analyzed for total N by the rapid combustion procedure. Neutral detergent fiber was determined by batch procedures using the ANKOM 200 Fiber Analyzer (ANKOM Technology Corp., Fairport, NY). In vitro organic matter disappearance (IVOMD) was determined using the batch culture method described by ANKOM Technology Corporation. Neutral detergent insoluble N was determined by quantifying N within NDF residues by the combustion procedure. Non-protein N and buffer-soluble N were determined according to Licitra et al. (1996). Soluble true protein was calculated by difference of buffer soluble N (% of total N) minus NPN (% of total N). Protein degradability was measured using the Streptomyces griseus protease method.

Exp. 2

The same pastures and animals were used in this experiment as in Exp. 1. This study used a similar design with 2 periods in a crossover design, but the length of the periods was 2 d, and the cattle were withheld from feed and water for 20 h prior to each period. The intent was to mimic a situation where new cattle were turned onto bloat-provocative wheat. Periods 1 and 2 began on December 19, 2006 and January 19, 2007, respectively. Due to a lack of wheat forage, animals were removed from the wheat pastures between periods and fed the same hay as in Exp. 1, but the diet also included a grain mix offered at 0.5% of BW (91% cracked corn, 4% molasses, and 5% trace mineral salt). Prior to assignment of treatment, cattle were stratified by bloat scores from Exp. 1; and assigned randomly to treatments to minimize variation in bloat potential of the cattle. For each period, on d -1 cattle were placed in a corral with no access to feed or water until 0800 on d 0. On d 0, rumen fluid samples were taken from the ruminally-cannulated heifers at 0600 and all of the cattle were placed on wheat at approximately 0900. Daily bloat scoring and rumen fluid collections were done on d 0 and 1 at the same times and using the same methods as described for Exp. 1. Forage availability was measured on d 1 of each period, and forage samples were obtained on d 0 and 1 for subsequent analysis of nutritive value.

Statistical Analysis. Forage data obtained from the stocker cattle pastures were analyzed as a completely randomized design with pasture being the experimental unit using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.). Means were obtained for forage data taken from the pastures assigned to cannulated heifers with the MEANS procedure; however, means could not be subjected to mean separation procedures because HR and SR were not replicated. Daily bloat score data were analyzed independently for cannulated and stocker cattle by Chi-square analysis using the FREQ procedure. Correlations between mean bloat scores and nutritive value analyses and environmental temperatures were conducted using the CORR procedure of SAS. Rumen fluid data were analyzed using the MIXED procedure. Differences were determined using least square means with the PDIFF option.

Results and Discussion

Exp. 1

Forage Availability and Nutritive Value. Forage availability (Table 1) did not differ between SR and HR for the stocker cattle pastures. Initial and final forage availability differed ($P < 0.01$) due to the cattle grazing; however, there was no wheat type × day interaction. The initial and final forage availability for pastures stocked with cannulated heifers also is shown in Table 1. No differences were found between wheat types for DM, NDF, N, IVOMD, and soluble N fractions where stocker cattle grazed. Protein degradability was greater ($P = 0.04$) for SR than HR, but the small magnitude of this difference suggests limited biological relevance. Soft-red wheat tended to be lower in NDIN than HR ($P = 0.08$). Soluble N fractions were relatively high and were within a range between bloat provocative and non-bloat provocative wheat pastures reported by Horn et al. (1977). Nitrogen concentrations also were high (4.3%) and were identical across wheat types.

Bloat Observations. Cannulated heifers exhibited bloat during 13.8% of all observations, which was more frequent than observed for stocker cattle (Table 2). Soft-red wheat had a higher percentage of bloat observations than HR ($P < 0.01$). Mean bloat score also was greater for cattle grazing SR vs. HR ($P = 0.02$). The number of bloating incidents for stocker cattle was low, occurring in only 2% of all observations. Also, severity of bloat was low, with only 3 cases of a bloat score of 2 and no scores of 3. Both wheat types had mean bloat scores of ≤ 0.05. Wheat type had no effect on percentage of bloat observed, and there was no effect of observation time (am vs. pm) on bloat score.

No correlations between bloat and any soluble N or NDIN fractions were observed. For the cannulated heifers, IVOMD was positively correlated with bloat (r = 0.32, $P = 0.04$). For the stocker cattle, IVOMD tended to be positively correlated with bloat (r = 0.28, $P = 0.08$), while NDF tended to be negatively correlated (r = -0.30, $P = 0.06$). Environmental temperature was negatively correlated with bloat for both cannulated heifers (r = -0.38, $P = 0.01$) and stockers (r = -0.40, $P = 0.01$). Lower temperatures and frost increased bloat scores perhaps due to increased fragility of leaves that caused a more rapid release of cell contents in the rumen.

Rumen Fluid Analysis. Rumen fluid pH (Figure 1A) decreased throughout the day ($P < 0.01$), but was not affected by wheat type. Rumen fluid from cattle on SR had greater foam production than HR (3.6 vs. 2.3 ± 0.33 in, $P = 0.04$). Rumen fluid foam strength (Figure 1B) was not different between wheat types at 0600, but foam strength from heifers grazing SR was greater than that from HR at 1200and 1800 (wheat type × time, $P = 0.02$). In addition, rumen fluid from cattle on HR did not change in viscosity throughout the day (Figure 1C), while that from cattle on SR flowed a shorter distance at each subsequent sampling time (wheat type × time, $P < 0.01$), thereby indicating increased viscosity. Highly viscous rumen fluid does not permit gas to escape easily, thereby trapping it in the fluid (Meyer and Bartley, 1971).

Exp. 2

Forage Availability and Nutritive Value. In the stocker cattle pastures, no differences between wheat types were found for forage availability, or concentrations of DM, total N, NDF, IVOMD, or

NPN (Table 3). Soluble N (% of DM and of total N) concentrations were greater ($P < 0.05$) for HR than for SR. Concentrations of NDIN (% of total N) and protein degradability tended to be higher for SR ($P < 0.10$). Observed nutritive values for pastures with cannulated heifers also are shown in Table 3.

Bloat Observations. No cases of bloat were observed during this experiment for either the cannulated or the stocker cattle. This might be explained by the design of the experiment, in which cattle were removed from hay and grain prior to shrinking rather than allowing the cattle to first graze wheat to adapt the rumen to the wheat forage and then shrinking the cattle. When sampled at 0600 on d 1, the rumen still had large amounts of digesta that may have slowed digestion of the wheat forage and lessened the potential for bloat. Feeding of hay prior to putting cattle on pasture has effectively reduced bloat in other studies (Colvin et al., 1958).

Rumen Fluid Analysis. On d 1, as observed in Exp. 1, rumen pH decreased with sampling time; however, on d 2 rumen pH at all 3 sampling times did not differ from the 1800 sampling time on d 1 (day × time, $P < 0.01$). Wheat type did not affect rumen pH; the average pH for both wheat types was 6.1. On d 1, both wheat types were similar in foam production (Figure 2) at 0600 At 12 noon, foam production from both wheat types increased, but SR had greater ($P < 0.07$) foam production than HR. Then at 1800 on d 1 foam production from both wheat types decreased to 0600 levels. On d 2, foam height for both wheat types did not change (wheat type × day × time; $P = 0.07$). This interaction indicates that when first put onto pastures, foam production increased, but by the end of the day there were only small amounts of foam produced. Cattle are most at risk for bloat the first few hours after consuming large amounts of wheat forage. Even with no apparent bloat, the current study shows that foam production did increase after initiation of grazing.

Implications

Soft-red wheat had greater bloat causing potential than hard-red wheat when grazed by cannulated heifers, but no differences were observed with stocker cattle. This result is in contrast to anecdotal accounts suggesting very low bloat incidence on soft-red winter wheat. Hard-red winter wheat may have produced less bloat in this study, but since bloat is unpredictable and associated with several factors, more research would be needed before concluding that particular wheat types are likely to be lower or higher in bloat potential.

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Table 1. Forage availability and nutritive values of soft-red and hard-red winter wheat forages in Exp. 1.

	Cannulated heifers[1]		Stocker cattle[2]		
Item	Hard red	Soft red	Hard red	Soft red	SEM
Available forage, lb/acre					
Initial	1,511	1,076	1,205	1,276	
Final	1,358	835	1,018	960	93.6
DM, %	22.8	22.6	19.6	19.3	0.19
NDF, % of DM	38.9	38.6	39.0	38.4	0.29
N, % of DM	4.0	4.5	4.3	4.3	0.06
IVOMD[3], % of DM	93.3	94.6	91.9	92.6	0.55
NDIN, % of N	21.8	24.9	24.0^{x}	22.5^{y}	0.46
NDSN[4], % of N	78.1	75.1	76.0^{y}	77.5^{x}	0.46
NDIN, % of DM	0.9	1.2	1.0	1.0	0.03
NDSN, % of DM	3.1	3.4	3.3	3.4	0.04
Soluble N, % of N	51.6	46.7	47.2	46.8	0.86
Soluble protein, % of N	34.4	31.2	30.9	30.9	1.06
Soluble N, % of DM	2.1	2.1	2.0	2.0	0.04
Soluble protein, % of DM	1.4	1.4	1.4	1.4	0.05
Soluble NPN, % of N	17.1	15.5	16.3	16.0	0.35
Soluble NPN, % of DM	0.7	0.7	0.7	0.7	0.01
Protein degradability % of N	83.8	84.3	84.1^{b}	85.1^{a}	0.26

$^{a-b}$Means in a row within a cattle group without a common superscript differ ($P = 0.04$).
$^{x-y}$Means in a row within a cattle group without a common superscript differ ($P \leq 0.10$).
[1]Nutritive values of forage from mean of last 4 d of each period to relate with rumen sampling. Values for each forage type represent 1 pasture; therefore, means cannot be compared statistically.
[2]Nutritive values of forage obtained by analyzing composite samples for each pasture for each period.
[3]IVOMD = in vitro organic matter digestibility.
[4]NDSN = neutral detergent soluble N.

Table 2. Percentage of bloated stocker calves or cannulated heifers and mean bloat scores for cattle grazing either soft-red or hard-red winter wheat forage in Exp. 1.

	Cannulated heifers		Stocker calves	
Item	Hard red	Soft red	Hard red	Soft red
Bloated, %[1]	5.6[b]	21.9[a]	1.9	2.3
Bloat score of 1, %	5.6[b]	20.0[a]	1.9	2.0
Bloat score of 2, %	0[b]	1.9[a]	0	0.3
Mean bloat score	0.08[b]	0.32[a]	0.04	0.05

[a-b]Means in a row within a cattle group without a common superscript differ ($P \leq 0.05$).
[1]Bloated, % = (observed bloat scores of > 0 / total animal observations) × 100.

Table 3. Forage availability and nutritive values of soft-red and hard-red winter wheat forages in Exp. 2.

	Cannulated heifers[1]		Stocker cattle[2]		
Item	Hard red	Soft red	Hard red	Soft red	SEM
Available forage, kg/ha[3]	1,526	1,105	1,180	1,070	73.3
DM, %	22.7	20.7	21.4	20.4	0.46
NDF, % of DM	43.5	42.6	43.0	43.0	0.55
N, % of DM	4.1	5.2	4.6	4.6	0.12
IVOMD[4], % of DM	91.6	92.8	92.0	92.6	0.52
NDIN, % of N	27.0	26.4	26.7[y]	28.3[x]	0.47
NDSN[5], % of N	73.0	73.6	73.3[x]	71.7[y]	0.47
NDIN, % of DM	1.1	1.4	1.2	1.3	0.05
NDSN, % of DM	3.0	3.8	3.3	3.2	0.08
Soluble N, % of N	49.4	45.3	48.6[a]	44.7[b]	0.33
Soluble protein, % of N	32.3	32.3	27.2	23.6	2.17
Soluble N, % of DM	2.0	2.3	2.2[a]	2.0[b]	0.05
Soluble protein, % of DM	1.3	1.7	1.2	1.1	0.07
Soluble NPN, % of N	17.1	13.0	21.4	21.1	2.00
Soluble NPN, % of DM	0.69	0.67	1.00	1.00	0.11
Protein degradability % of N	80.3	85.0	81.6[y]	83.7[x]	0.58

[a-b]Means in a row within a cattle group without a common superscript differ ($P \leq 0.05$).
[x-y]Means in a row within a cattle group without a common superscript differ ($P \leq 0.10$).
[1]Values for each forage represent 1 pasture; therefore, means cannot be compared statistically.
[2]Nutritive values of forage obtained by analyzing composite samples for each pasture for each period.
[3]Period effect for stocker cattle pastures ($P < 0.05$); 1,247 and 1,003 kg/ha for Periods 1 and 2 (SE = 106.1), respectively.
[4]IVOMD = in vitro organic matter digestibility.
[5]NDSN = neutral detergent soluble N.

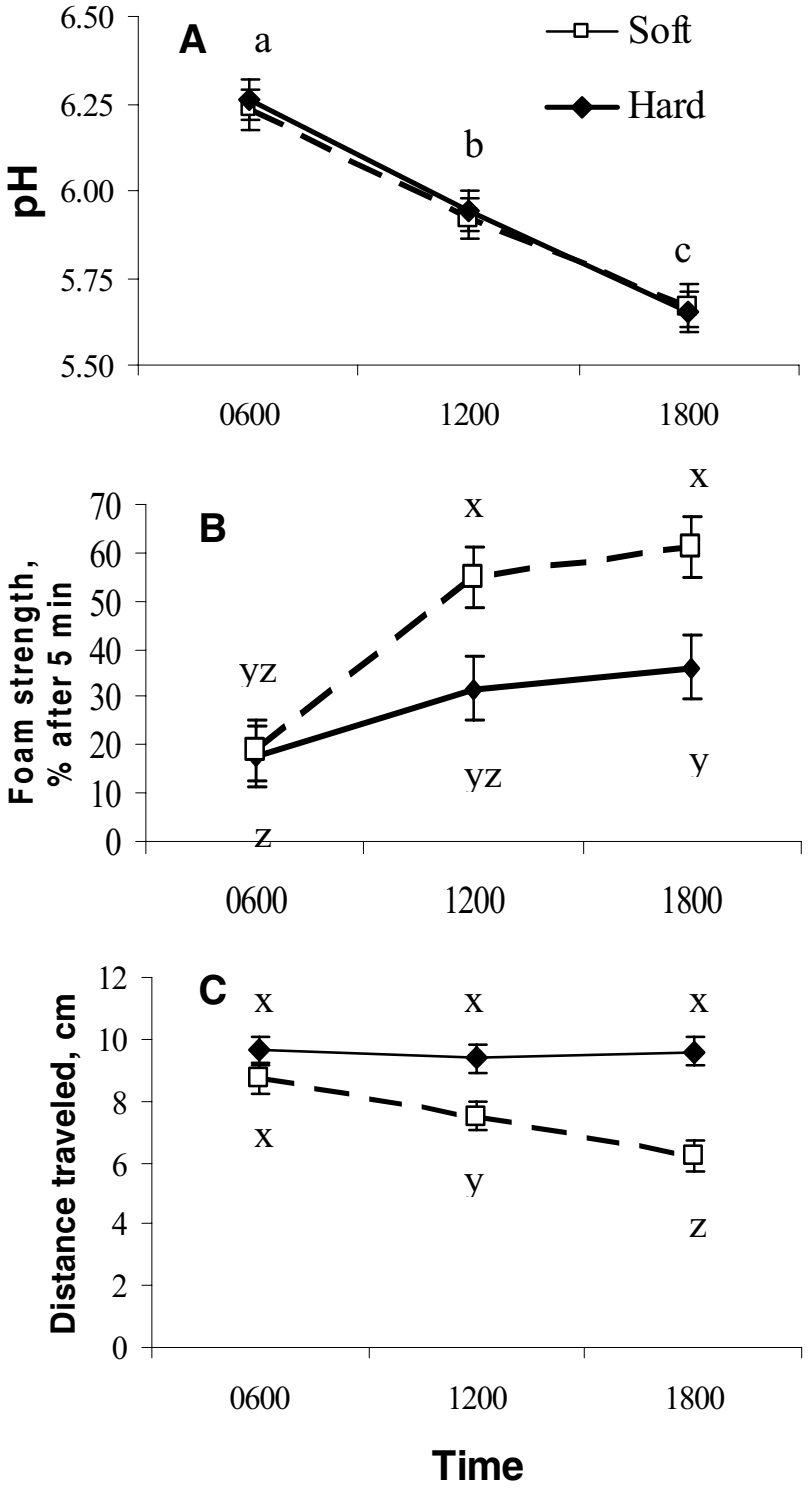

Fig. 1. Rumen fluid pH (A), foam strength (B), and viscosity (C) over time for cattle grazing soft-red and hard-red winter wheat in Exp.1. [a-c]Effect of time $P < 0.001$. [x-z]Wheat type × time interaction ($P < 0.05$), means without a common letter differ ($P < 0.05$).

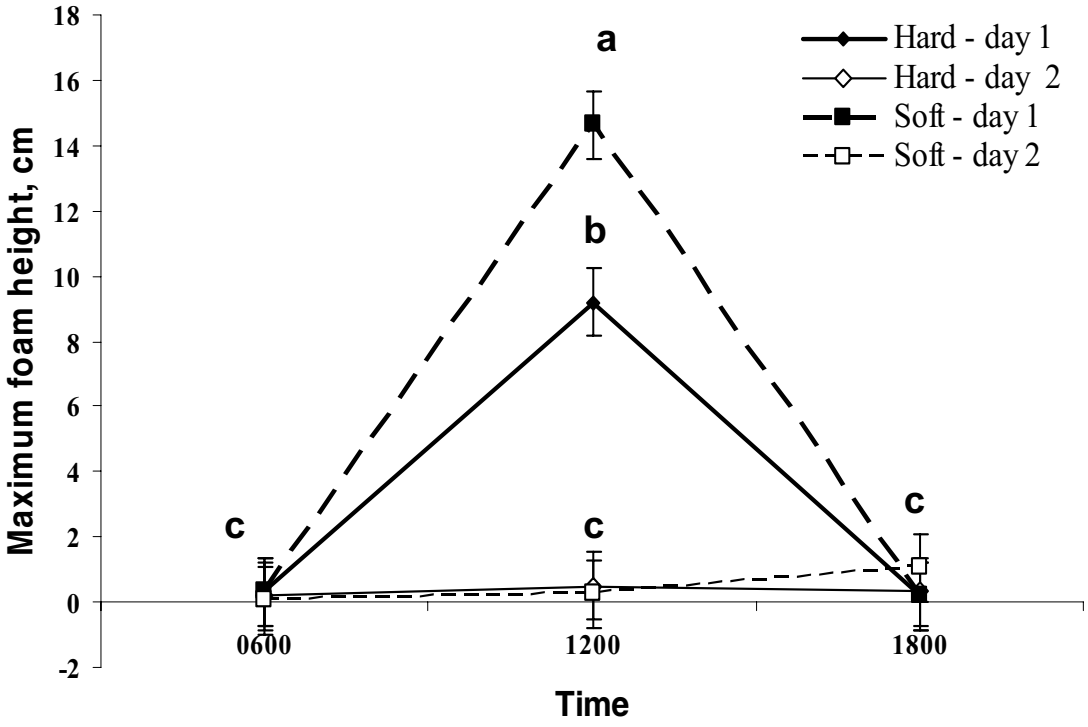

Fig. 2. Maximum foam height from rumen fluid at different times on d 1 and 2 for cattle grazing soft-red and hard-red winter wheat during Exp. 2. Day × time interaction, $P < 0.001$.
[a-c]Means without a common letter differ ($P < 0.05$).

Extension Demonstrations Begin Studying the Effect of Grazing Wheat on Potential Grain Yield

S. Gadberry[1], J. Vestal[1], J. Hawkins[1], E. Brown[1], B. Dodgen[1], A. Beuerman[1], K. Lawson[1], P. Beck[2] and J. Richeson[3]

Story in Brief

Three farm demonstration sites in Lafayette, Pulaski, and Perry counties were selected in 2007 to initiate a project evaluating tillage methods and grazing on wheat yield. Only 1 of 3 sites produced a harvestable grain crop in 2007 due to a late spring freeze that severely damaged the Arkansas wheat crop. The only harvestable wheat was grown in southern Ark. (Lafayette County) on bermudagrass pasture over-seeded with wheat for grazing. The plots averaged 42.5 bushel/acre wheat yield, and there was no difference between grazed and non-grazed wheat plots ($P = 0.22$). In lieu of harvest, plant heads per square foot were determined at the other locations. At the Perry County site, plots averaged 54.5 heads per square foot with no difference between grazed and non-grazed plots ($P = 0.92$). At the Pulaski County site, however, grazed plots exhibited a significant reduction in heads per square foot compared to non-grazed in both aerially applied wheat prior to soybean harvest and drilled wheat following soybean harvest. Grazing wheat may be an opportunity to capture additional value from a wheat production system through grazing cattle. In Arkansas, this system needs further investigation into soil types, tillage methods, and varieties that are most compatible to a dual purpose (grazing and grain) system for wheat.

Introduction

According to the National Agriculture Statistics Service, Arkansas averaged 800 thousand acres of wheat planted annually over the past 10 years. The bulk of Arkansas's wheat production is found in the eastern delta areas of the state where it is grown as a secondary crop in rice and cotton production areas. There are not many farmers in Arkansas taking advantage of the wheat's potential to provide income in the form of cattle weight gain as the traditional case in Oklahoma, Kansas, and Texas. This may be attributed to the fact in Arkansas wheat is grown primarily in the eastern part of the state while counties with the greatest number of cattle are located in the western half of the state. Where the two populations do co-exist, such as along the Arkansas and Red River valleys, most wheat farmers are fearful of the impact of grazing wheat on wheat yield because of damage that may be caused by trampling associated with clean tillage and inherent soil drainage properties. The objective of this project was to evaluate the impact of grazing on wheat yield under various management conditions where both cattle and wheat co-exist.

Experimental Procedures

Lafayette County (33°26'N, 93°36'W). On October 17, 2006, wheat seed (Terral LA841) was no-till drilled into bermudagrass sod at a rate of 150 lb/acre. The site soil type was composed of 42% Bowie fine sandy loam with a 1 to 3 percent slope and 58% Smithdale fine sandy loam with a 5 to 8 percent slope. Poultry litter was applied (2 ton/acre) after plant emergence. On November 14, 3 grazing exclosures (8' x 16') were assembled for control plots. On December 1, crossbred beef calves (450 lb) were turned onto the pasture for winter grazing at a stocking rate of 2.9 head/acre. Cattle continued to graze until May, 2007. Hay was provided when forage availability was limiting. A second set of grazing exclosure cages, prior to first hollow stem, were assembled adjacent to the initial exclosures on February 21 to simulate spring restriction. At this time, 70 lb/acre N was applied within all restricted areas. In early March, Osprey (Bayer CropScience, Research Triangle PK, N.C.) was applied at a rate of 4.75 oz/acre for ryegrass suppression within the cages and an additional 50 lb/acre N was applied. The replicated non-grazed and grazed plots were harvested using a plot combine on June 14 and moisture corrected test weights were used to determine yield per acre.

Pulaski County (34°47'N, 92°05'W). On September 16, 2006, wheat seed (Delta Grow 4500) was broadcast spread over soybeans by aerial application into one-half of the test field. The field was primarily Perry clay with some Rilla silt loam and a 0 to 1 percent slope; however, the field had been precision leveled. On October 6, following soybean harvest, the remainder of the field was no-till drilled with the same variety at a rate of 120 lb/acre. Replicated grazing restriction cages were assembled representing both establishment methods. In the fall, 140 lb/acre of K_20 equivalent fertilizer was applied, and plots were sprayed with Osprey at 4.75 oz/acre for ryegrass suppression. Mature, calving beef cows grazed the wheat pasture through mid-April. Cattle weighed approximately 1,200 lb and were stocked at approximately 0.4 head/acre. In late February, a second set of restriction cages was assembled, prior to first hollow stem, to simulate spring restriction. Seventy pounds per acre N was applied, an additional 50 lbs/acre N were applied in mid-March. The number of plant heads per square foot was determined in place of grain harvest because of freeze damage to the wheat crop.

Perry County (35°03'N, 92°33'W). In mid-September, 2006, wheat seed (Coker 9663) was broadcast seeded into a twice-disked seed bed. Soil type represented a Gallion silt loam and Roxana fine sandy loam soil with 0 to 1 percent slope. Calves were turned out after weaning, weighing approximately 400 lb and stocked at a rate

[1] Cooperative Extension Service, Little Rock
[2] Southwest Research and Extension Center, Hope
[3] Department of Animal Science, Fayetteville

of 2 head/acre. Calves grazed the wheat for 90 days prior to removal for wheat crop management for grain harvest. Thirty lb/acre N were applied in the fall and an additional 90 lb of N were applied in the spring. The number of plant heads per square foot was determined in place of grain harvest because of freeze damage to the wheat crop.

Data Analysis. Data (wheat yield per acre or heads per square foot) were analyzed within farm as a completely randomized design with plot as the experimental unit. Analysis of variance was performed using JMP 7.0 statistical package (SAS Inst., Inc., Cary, N.C.).

Results and Discussion

The objective of these demonstrations was to assess the impact of grazing on wheat yields in Arkansas. The sites studied have traditionally been managed for purposes other than wheat grain production. The Perry County site is a cropping and livestock enterprise that traditionally harvested wheat at this particular location to re-plant for grazing weaned calves held over for spring marketing. The Pulaski County site is a cropping and livestock enterprise, which at this particular site utilized the wheat for a winter cover crop behind grain sorghum or soybeans and utilized the cover crop to minimize hay feeding. The Lafayette site was the only sole livestock enterprise. This site over-seeds wheat into bermudagrass sod for winter pasture with the intention to graze-out the wheat.

Production of wheat for grain in Arkansas can generally be described as a prepared seed bed followed by drilling for establishment. The Perry County site was the only location where the ground was prepared prior to planting by twice disking. In addition, some locations may not be suitable for grazing under clean-till conditions because of inherent soil drainage properties. The Pulaski site was the only site that consisted of a soil series that was a poorly drained clay formation; however, this site had been precision leveled in the past to support poly pipe irrigation of summer crops.

Yield and plant count data are summarized in Table 1. In April, 2007, a late-spring freeze damaged most of the wheat crop in Arkansas. The Lafayette County site was the only site with a viable wheat crop. All of the Pulaski County plants were sterilized by the freeze. Approximately 90% of the Perry County grazed plots contained viable plants; whereas, the non-grazed plants were more mature when the freeze occurred and resulted in a total crop loss.

The yield of the grazed plots at the Lafayette County site was 7 bushel/acre less than the non-grazed plots (Table 1) but this was not statistically significant ($P = 0.22$). Overall, the Lafayette County plots averaged 42.5 bushel/acre. In comparison, the 2007 Arkansas Wheat Research Verification Program fields averaged 52.7 bushel/acre. It is interesting to note the plot yield at Lafayette site was surprisingly comparable to the 2007 estimated state average (41 bushel/acre) considering half of these plots were heavily grazed and the site was managed atypical to conventional wheat production.

In lieu of the freeze, wheat head counts were conducted at the 2 other sites where freeze had destroyed the crop. There was no difference ($P = 0.92$) in the number of heads per square foot between the grazed and non-grazed plots in Perry County. However, at the Pulaski County site, the grazed plots had 37% fewer heads per square foot compared to the non-grazed plots for both the no-till drilled ($P = 0.03$) and aerially broadcast ($P = 0.01$) seeding methods. This yield affect may be an impact response associated with soil type. In 2006, however, no-till drilled wheat grazed (37 bushel/acre) at the Pulaski County site did not differ in yield compared to non-grazed wheat (40 bushel/acre, $P = 0.72$).

Implications

Arkansas producers that have land suitable for crop and livestock production have the potential to capture additional income by adopting complimentary practices such as managing wheat for grazing and grain production. The impact of grazing wheat on grain production in Arkansas is limited and needs further investigation.

Acknowledgments

The authors express appreciation to Bo Dougan, Chris Schafer, and Jon Bennett for demonstration sites. The authors also express appreciation to Dr. Jason Kelly and Steven Sheets for plot management recommendations and grain harvest. This demonstration was supported by USDA-CSREES Agreement 2006-55101-17440.

Table 1. Wheat yield and wheat head counts for sites enrolled in a project to determine the impact of grazing on wheat harvest yield.

	Reps/trt	Non-grazed	Grazed	P-value
Lafayette County, 2007				
(no-till into bermudagrass sod)				
Yield, bushel/acre	6	46	39	0.22
Perry County, 2007				
(light disk, broadcast)				
Percent viable heads	3	0	90	
Heads per square foot	3	54	55	0.92
Pulaski County, 2007				
(aerial applied into pre-harvest soybeans)				
Percent viable heads	2	0	0	
Heads per square foot	2	56	32	0.01
Pulaski County, 2007				
(no-till drilled following soybean harvest)				
Percent viable heads	3	0	0	
Heads per square foot	3	57	39	0.03

Establishment and Survival of Red, White, and Berseem Clover on a Sandy Soil

C.B. Stewart, P.A. Beck, and P.K. Capps[1]

Story in Brief

This small plot demonstration was conducted to determine the establishment and production of 3 clover types (berseem, white, and red clovers) on a sandy loam soil. The berseem clover (28.4% cover) did not establish or survive well during this study ($P < 0.0001$). The white clover varieties cover ranged from 54.6% for 'Tripoli' to 95.8% for 'Patriot' with an average of 85%. The red clovers flourished on this type soil averaging a 98.5% cover. The 'Start' red clover had the highest stand of all clovers with a 100% stand. When yields were collected, berseem clover was omitted due to the lack of the legume. There were no observed differences in DM percent (mean = 20.1%) ($P = 0.90$) or yield (mean = 4,453 lb/acre) ($P = 0.98$) across red and white clover varieties. The white clovers averaged 4,160 lb an acre with 'Barblanca' producing the greatest amount at 4,648 lb DM/acre and 'Tripoli' producing only 3,358 lb DM/acre. The red clovers averaged 4,893 lb/acre with 'Freedom' producing 5,949 lb DM/acre and 'Start' producing 4,278 lb DM/acre. No differences were found ($P > 0.42$) in chemical composition between red and white clover.

Introduction

Legumes can be a very important part of grasslands. Legumes can fix from 50 up to 200 lb of nitrogen a year and this nitrogen becomes available to other forages when the legume plants decay. Nitrogen fixation and availability can reduce the need for other N fertilization, which reduces fertilization cost. Legumes can also increase the nutritional value of pasture and hays.

Legume species can be difficult to establish and maintain in a grass sod. Factors influencing a successful establishment include adequate nutrient requirements, proper pH, matching your legume to your soil characteristics, removal of grass competition (whether by disking or mowing), and seed inoculation. Sandy soils are droughty soils that pose particular problems to legume establishment and maintenance. Most sandy soils are medium to strongly acidic; therefore lime should be applied to raise the soil pH. Some species of legumes, such as a red clover, are more tolerant to droughty and acidic conditions, while others, such as white clover, are less tolerant.

Red clover (*Trifolium pretense*) is a short lived perennial (usually 2 years in the South) that is an erect growing, leafy plant 2 to 3 feet tall. It is fairly drought tolerant and can persist in soils with a pH as low as 5.5. Seedling vigor is better than for any other clover. White clover (*Trifolium repens*) is a short lived perennial in the lower South that is leafy, grows to a height of 8 to 12 inches, and spreads by stolons. Seeds are extremely small and do not reseed well. It is not productive on droughty soils, but will survive considerable dry weather. Berseem clover (*Trifolium alexandrinum*) is a winter annual that grows erect to a height of about 2 feet. The winter hardy variety produces hard seed and will often reseed. It is adapted to loamy soils of pH 6 or above (Ball et al., 2002). The objective of this study was to determine the establishment and production of berseem, white, and red clovers on a sandy loam soil.

Experimental Procedures

Replicated plots (10 x 40 ft) were mowed to a 2-inch stubble and sown on November 1, 2006 into a Savannah fine sandy loam soil using a no-till planter. Savannah soils are deep, moderately well drained, moderately to moderately slowly permeable, nearly level to gently sloping soils that formed in thick beds of loamy, marine sediment (Hoelscher and Laurent, 1979). Six varieties of white clover, three varieties of red clover, and berseem clover were used in this study. White clover was planted at 3 lb/acre, red clover at 8 lb/acre, and berseem clover at 15 lb/acre. All legumes, whether pre-inoculated or not, were inoculated with appropriate rhizobia before planting. The legumes were seeded into a dallisgrass/bermudagrass mixed sod. Plots were limed with 1 ton lime/acre on the 7th of November. Previously collected soil test showed adequate phosphorus and potassium levels.

A 30-inch by 30-inch square quadrant equally divided into 25 (6 inch x 6 inch) squares was used to collect stand counts on June 7, 2007. Ten squares were visually scored from each plot. Dry matter yields in lb/acre were collected on plots with a substantial legume percentage (75% or higher). Three 1-foot square quadrants were clipped, weighed, and dried in a forced air oven at 120°C to determine DM content, which was used to determine dry forage yield (lb/acre).

Samples were ground to pass a 2-mm screen (Thomas A. Wiley Laboratory Mill; Model 4; Thomas Scientific, Swedesboro, N.J.). Forage CP, NDF, ADF, and TDN were estimated using near infrared reflectance spectroscopy (Feed and Forage Analyzer, Model 6500, FOSS North America, Eden Prairie, Minn.).

Data were analyzed using PROC GLM of SAS (SAS Inst. Inc., Cary, N.C.). Response variables included percent cover, DM percentage, DM yield (lb/acre), and chemical composition. Legume species was analyzed using the residual error mean square as the error term.

[1] University of Arkansas Division of Agriculture Southwest Research and Extension Center, Hope.

Results and Discussion

Table 1 shows that berseem clover (28.4 % cover) did not establish or survive well during this study ($P < 0.0001$). The white clover cover ranged from 54.6% for 'Tripoli' to 95.8% for 'Patriot' with an average of 85%. The red clovers flourished on this type soil averaging a 98.5 % cover. 'Start' red clover had the highest of all clovers with a 100% stand. As clover percentages increased, a decrease in the amount of grass was observed..

When yields were collected, berseem clover was omitted due to the lack of the legume. Table 2 shows that there were no observed differences in DM% (mean = 20.1%) ($P = 0.90$) or yield (mean = 4,453 lb/acre) ($P = 0.98$) across red and white clover varieties. The white clovers averaged 4,160 lb an acre with ' Barblanca' producing the greatest amount at 4,648 lb DM/acre and 'Tripoli' producing only 3,358 lb DM//acre. The red clovers averaged 4,893 lb/acre with 'Freedom' producing 5,949 lb DM/acre and 'Start' producing only 4,278 lb DM/acre.

Table 3 shows chemical constituents of the red and white clovers. There were no ($P > 0.42$) observed differences in crude protein (average 15.6%), NDF (57.0%), ADF (39.4%), and TDN (58.2%). All were above the daily requirements of a lactating beef cow.

Implications

Berseem clover did not establish or survive well during this study. However, the red and white clover varieties performed very well on this soil type under proper growing conditions. Wider drill spacing's or a lower planting rate could be used to help reduce the impact on grass growth.

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Table 1. Observed percent cover across varieties.

Variety	Species	% Cover
Start	Red	100.0 a
Freedom	Red	99.4 a
FLMD	Red	96.2 a
Patriot	White	95.8 a
Durana	White	94.2 a
Ladino	White	93.6 a
Regalgraze	White	90.2 a
Barblanca	White	81.6 ab
Tripoli	White	54.6 bc
Bigbee	Berseem	28.4 c
	SE	19.00

a,b,c Means within column with no letters in common differ ($P < 0.05$).

Table 2. Observed dry matter % and yields across varieties of red and white clovers[a].

Variety	Species	DM %	Yield, lb/acre
Freedom	Red	20.0	5,949
Barblanca	White	20.0	4,648
FLMD	Red	21.0	4,454
Patriot	White	21.8	4,406
Start	Red	19.8	4,278
Ladino	White	19.3	4,190
Durana	White	18.7	4,030
Regalgraze	White	19.3	3,976
Tripoli	White	21.0	3,358
	SE	0.03	2,442.7

[a]No differences were observed among DM % and yields among varieties ($P > 0.05$).

Table 3. Observed chemical composition constituents by species[a].

	Red		White	
	Mean	SE	Mean	SE
Crude protein	15.1	1.92	16.1	2.89
Neutral detergent fiber	58.5	6.95	55.4	6.78
Acid detergent fiber	41.9	4.93	36.9	6.10
Total digestible nutrients	55.4	5.46	60.9	6.85
Relative feed value	91.0	17.58	103.1	19.78

[a]No differences were found between red and white clover means ($P > 0.05$).

Productivity of "Pensacola" Bahiagrass at Different Fertilizer Treatments and Cutting Intervals

C.B. Stewart, P.A. Beck, and P.K. Capps[1]

Story in Brief

A small-plot demonstration study was conducted to determine the productivity of common bahiagrass at different fertilizer treatments and cutting intervals. Plots received 1 of 7 fertilizer treatments supplying 0, 50, 100, and 150 lb N/acre from ammonium nitrate and ammonium sulfate and were harvested at 1 of 3 harvesting intervals (2, 4, and 6 wk). Dry matter (DM) yield/harvest was not affected by N rate or source of N ($P = 0.17$), but there were linear ($P < 0.0001$) and quadratic ($P = 0.015$) harvest interval effects. Cumulative yields were greater ($P < 0.0001$) at 4 weeks than at 6 or 2 weeks (5,229, 4,769, and 4,045 lb DM/acre, respectively), and ammonium sulfate tended ($P = 0.06$) to produce more forage than ammonium nitrate (4,927 vs 4,555 lb DM/acre). There was a rate of N by source of N ($P = 0.03$) interaction where at the lowest nitrogen level, ammonium sulfate produced more cumulative yield than ammonium nitrate.

Introduction

Bahiagrass (*Paspalum notatum*) is a hardy perennial forage that is productive throughout Florida and along the Gulf Coast. Bahia is tolerant of most soil conditions, but it is best adapted to sandy soils. A deep root system allows it to thrive on drought-prone soils; however, it can also survive on poorly drained soils. It is more tolerant to acidic soils than most other warm season grass species.

Bahiagrass can spread by rhizomes or by seed. It is very aggressive and can grow to a height of 12 to 20 inches. It is mainly productive from April until October and can be used for pasture or hay production. Bahiagrass is tolerant of low soil fertility and acidic soils. It responds well to nitrogen and potassium fertilization. One concern with fertilization is sulfur (S) concentrations available for the plant. Research by Mitchell and Blue (1989) has shown that bahiagrass will deplete available soil S quite rapidly in an Aeric Haplaquod under high N fertilization. Most soils in the southeast are highly leached soils. This allows for soils to become deficient when S is not added as fertilizer. Soils deficient in S not only results in reduced forage growth, but also reduced cattle productivity because low levels of S may reduce forage protein concentrations, dry matter (DM) intake, fiber digestion, and N and S retention (Rees et al., 1974).

The purpose of this study was to determine if fertilization at different levels of N and S and harvesting at different maturities has an effect on forage dry matter production in bahiagrass. The study was also conducted to determine if split applications of N would be beneficial to forage growth during the later parts of the summer.

Experimental Procedures

A field demonstration was conducted at Stewart Farms near Patmos, Ark., on Pensacola bahiagrass growing on a Kirvin fine sandy loam. These soils are deep, well drained, and gently sloping and are low in native fertility, with low soil pH and organic matter (Hoelscher and Laurent, 1979). On May 20, 2004, twenty-eight (10 ft X 15 ft) plots were cleared to a 2-inch stubble height using a sickle bar mower (Jari "Monarch" model "C", Mankato, Minn.). Soil test results required for lime was applied at a rate of 1 ton/acre to amend a pH of 5.3. Due to nutrient concentrations of 60 lb/acre for P_2O_5 and 186 lb/acre for K_2O, phosphorus and potash were applied at a rate of 100 lb/acre for each, respectively. Plots were replicated 4 times to receive 1 of 7 (N) and/or (S) treatments: (0N-0S, 50N-0S, 100N-0S, 150N-0S, 50N-24S, 100N-48S, or 150N-72S). Nitrogen was applied at 50 lb/N/acre, so split applications (4-wk intervals) were used for treatments containing 100 and 150 lb N/acre.

Plots were divided into 3 strips each 3 ft wide and randomly assigned to be harvested at 1 of 3 maturity dates (2, 4, or 6 week intervals). At each harvest, strips were scored by collecting 10 canopy heights and maturities. Maturities were based on the numerical scheme for bermudagrass growth stages (West, 1990). Strips were harvested to a 2-inch stubble height using a sickle bar mower. All (wet) clipped forage was weighed, and a subsample was collected and dried at 120°C to determine DM yield.

Field data were sorted by (N) treatment and harvest interval, and analyzed independently as a randomized complete block design with 4 replications using PROC GLM of SAS (SAS Inst. Inc., Cary, N.C.). Dry matter yield/harvest (lb/acre) and maturity were the response variables. When significant rate X interval interactions occurred ($P < 0.05$), data were sorted by harvest interval and reanalyzed. Cumulative yield data were sorted by N treatment and harvest interval and analyzed using PROC GLM of SAS.

Results and Discussion

Rainfall. Figure 1 shows the actual and normal precipitation collected during the trial for the Patmos (Hope) area. Rainfall was close to average for the early to mid part of this trial, but was below average for the later part of this trial. The last 2-week harvest had to be abandoned due to the lack of forage growth. Mitchell and Blue (1989) reported that bahiagrass responds to rates as high 350 lb N/acre, but the degree of response is dependent on the amount and distribution of rainfall during the growing season.

[1] University of Arkansas Division of Agriculture Southwest Research and Extension Center, Hope.

Yield. Dry matter yield per harvest (DM) was not affected by N rate ($P = 0.63$) or the source ($P = 0.17$) of N (average 1,277 lb DM/acre). Yields were linearly ($P < 0.0001$) and quadratically ($P = 0.02$) greater at the 6-week harvest interval than at the 4- and 2-week intervals (2,384, 1,742, and 674 lb DM/acre, respectively). Forage maturity was not affected ($P = 0.99$) by N rate or source of N ($P = 0.58$). Maturity stages were early emergence, mid anthesis, and early seed maturation for 2, 4, and 6 week intervals, respectively.

Cumulative results are shown in Figures 2, 3, and 4. Rate of N ($P = 0.35$) had no significant effect on cumulative yield data (average 4,681 lb DM/acre) (Figure 2). Ammonium sulfate tended ($P = 0.06$) to produce more forage than ammonium nitrate (4,927 vs. 4,555 lb DM/acre) (Figure 3). Kalmbacher et al. (2005) found that N increased bahiagrass yield at all levels of S fertilization when grown on a Pomona fine sand. Cumulative yields were greater ($P < 0.0001$) at 4 weeks than at 6 or 2 weeks (5,229, 4,769, and 4,045 lb DM/acre, respectively) (Figure 4). There was also a rate of N by source of N ($P = 0.03$) interaction where at the lowest N level of ammonium sulfate produced more yield than ammonium nitrate (Table 1).

Implications

This trial showed that when common bahiagrass was grown on a sandy soil, nitrogen rate had no effect on bahiagrass growth; however, ammonium sulfate tended to produce more forage when compared to ammonium nitrate over the entire summer. Cumulative yields were greater for the 4-week cutting interval when compared to the 2- and 6-week intervals.

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Table 1. Interaction in cumulative yield between rate of N and source of N.

	Source of nitrogen		
Rate, lb N/acre	Ammonium nitrate	Ammonium sulfate	SE
50	4,168 [b]	4,902 [a]	623.5
100	4,499 [a]	5,299 [a]	1,292.5
150	4,999 [a]	4,579 [a]	821.3

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

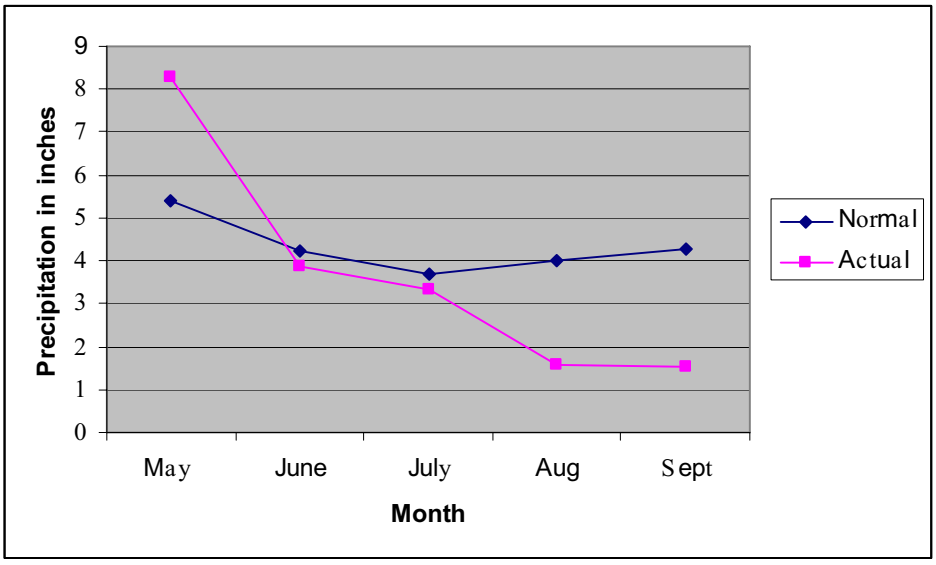

Fig. 1. Normal and actual monthly rainfall during trial.

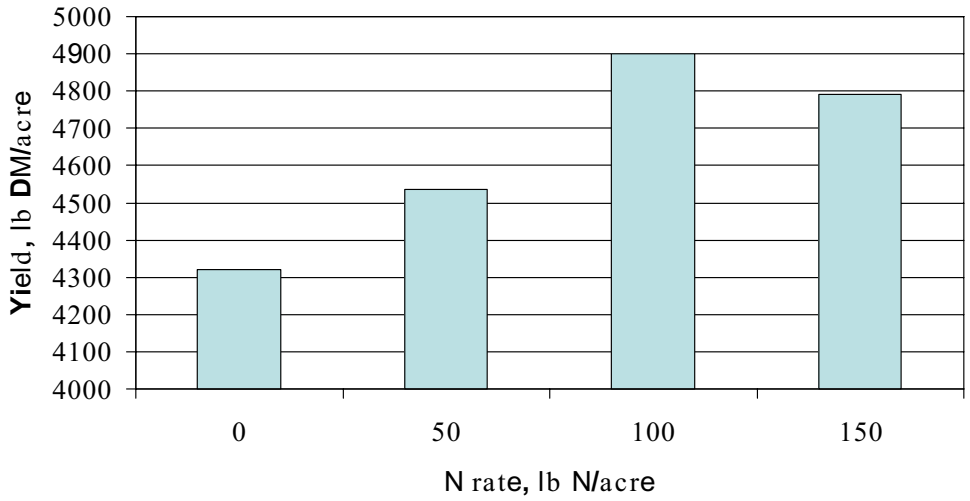

Fig. 2. The cumulative effect of rate of N (lb N/acre) on 'Pensacola' bahiagrass harvested at Patmos, Ark. No difference found (*P* = 0.35).

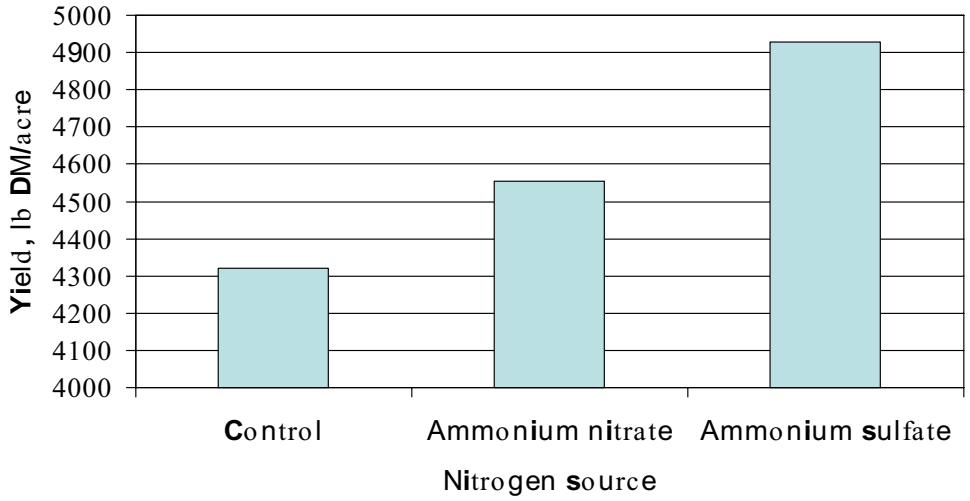

Fig. 3. The cumulative effect of source of N on 'Pensacola' bahiagrass harvested at Patmos, Ark. Nitrogen source effect on dry matter yield (*P* = 0.06).

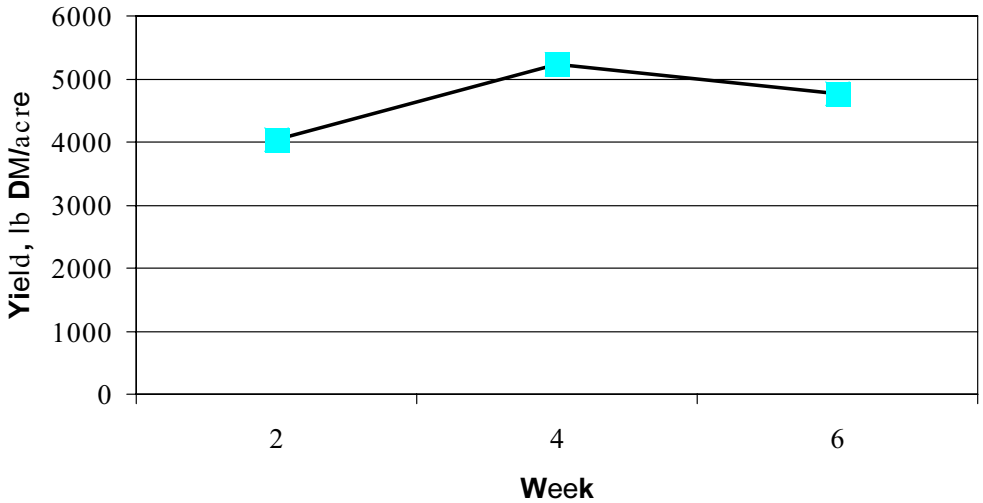

Fig. 4. Effect of harvest interval on cumulative yield of 'Pensacola' bahiagrass harvested at Patmos, Ark. * Four-week harvest interval yield significantly higher than 2 or 6 wk.

Performance by Spring- and Fall-Calving Cows Grazing with Full Access, Limited Access, or No Access to Endophtye-Infected Fescue

J. Caldwell[1], K. Coffey[1], J. Jennings[2], D. Hubbell, III[3], T. Hess[3], D. Kreider[1], M. Looper[4], M. Popp[5], M. Savin[6], D. Philipp[1] and C.F. Rosenkrans, Jr.[1]

Story in Brief

Although cow performance is improved when grazing non-toxic endophyte-infected fescue (NE+) instead of wild-type toxic endophyte-infected tall fescue (E+), acceptance of NE+ by producers is slow. Our objective of this study was to compare performance of spring (S) and fall-calving (F) cows grazing E+ or NE+ at different percentages of the total pasture areas to determine to what extent having limited access to NE+ will enhance cow/calf performance. Gelbvieh × Angus crossbred cows (n = 177) were stratified by weight and age within calving season and allocated randomly to 1 of 14 groups representing 5 treatments: 1) F on 100% E+ (F100); 2) S on 100% E+ (S100); 3) F on 75% E+ and 25% NE+ (F75); 4) S on 75% E+ and 25% NE+ (S75); 5) S on 100% NE+ (NE100; 2 replications). Cow BW and BCS at breeding and BCS at weaning were greater ($P < 0.05$) for F vs S. Cow BCS at breeding and BW at weaning were greater ($P < 0.05$) for NE100 vs S75, and cow BCS at weaning was higher ($P < 0.05$) for F75 and S75 vs F100 and S100. Calving rates were higher ($P < 0.05$) from NE100 vs S75, and from S75 vs S100. Calf BW gain, actual and adjusted weaning weight, ADG, sale price, and calf value at weaning were higher ($P < 0.05$) from F vs S. Therefore, a fall calving season may be desirable for overall cow/calf performance while grazing E+ pasture, and limited use of NE+ may improve overall cow BW and spring-calving rates.

Introduction

Tall fescue is commonly grown in pastures in northern Arkansas because it is highly persistent. This ability to persist is attributed to the fungus *Neotyphodium coenophialum* that is beneficial to the plant but produces toxins that reduce animal performance (Nihsen et al., 2004). "Friendly" type endophyte - tall fescue associations (NE+) have been developed and resulted in improvements in performance by spring-calving cows compared with endophyte-infected tall fescue (E+) (Coffey et al., 2007), but plant persistence declined (Parish et al., 2003). This decline in plant persistence is a contributing factor causing producer acceptability of NE+ to be slow. Therefore, the objective of this study was to compare performance of spring (S) and fall-calving (F) cows grazing E+ or NE+ at different percentages of total pasture areas to determine to what extent having limited access to NE+ will enhance cow/calf performance.

Experimental Procedures

This study was conducted at the University of Arkansas Livestock and Forestry Branch Experimental Station near Batesville, Ark. Gelbvieh × Angus crossbred cows (n = 177) were stratified by weight and age within calving season and allocated randomly to 1 of 14 groups representing 5 treatments: 1) F on 100% E+ (F100); 2) S on 100% E+ (S100); 3) F on 75% E+ and 25% NE+ (F75); 4) S on 75% E+ and 25% NE+ (S75); 5) S on 100% NE+ (NE100; 2 replications) starting January 1, 2007. Groups were assigned randomly to 1 of 14, 24-acre pastures that were blocked based on previous forage production as either low (4 replicates), medium (5 replicates), or high-producing (5 replicates). Two separate 24-acre NE+ pastures were divided into 3, 8-acre pastures each. Each of these 8-acre pastures was assigned randomly to one of either the S75 or F75 replicates. This combination resulted in 24 acres of E+ and 8 acres of NE+ for the S75 and F75 groups. Cows assigned to S75 and F75 treatments grazed E+ until approximately 28 d prior to the start of the breeding season (May 9, 2007, S75; November 27, 2007, F75) and 28 d prior to weaning (October 18, 2007, S75; May 9, 2007, F75; weaning dates). At this time, the cows were given access to NE+ pasture. The S75 and F75 groups remained on NE+ pasture until available forage was limiting (< 1,000 lb/acre), and then were returned to their original E+ pasture (late May or early June). Cows assigned to F100, S100, or NE100 treatments stayed on their assigned pasture throughout the year. All cows were grazed using a rotational grazing system. Each E+ and the NE100 pastures were subdivided into 6, 4-acre paddocks and stocked at one cow/2.5 acres. Each 8-acre portion of NE+ was divided in half and cows rotated within those cells. Hay was harvested from approximately 8 acres from each pasture. This hay was offered during adverse weather conditions or when available forage was limiting. No supplemental concentrate was offered to any treatment, and trace mineralized salt was available free choice.

Cow BW and BCS were evaluated at the start of the trial (data not presented), at the start of the breeding season, and at weaning. Calving rates were determined for the spring-calving cows only.

[1] Department of Animal Science, Fayetteville
[2] Department of Animal Science, Little Rock
[3] Department of Animal Science, Batesville
[4] USDA-ARS, Booneville
[5] Department of Agricultural Economics and Agribusiness, Fayetteville
[6] Department of Crop, Soil, and Environmental Sciences, Fayetteville

Calf BW was obtained at birth and at weaning. At weaning the calves were gathered, vaccinated against 7 clostridial strains, infectious bovine rhinotraceitis (IBR), bovine virus diarrhea (BVD), parainfluenza, bovine respiratory syncytial virus (BRSV), *Haemophilus somnus*, and 5 strains of *Leptospira,* and separated from their dams. Calf value was assigned by first estimating the price per pound of each calf. This price per pound was derived using a sliding price scale within calf sex based on Arkansas state average price ranges for the day the calves were weaned. The weaning weight of each calf was then multiplied by the derived market price per pound at weaning to obtain calf value.

Cow and calf performance measurements were analyzed using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.) with each group of animals in a specific pasture considered the experimental unit. Planned orthogonal contrasts were used to compare 1) mean of F with the mean of the S, 2) mean of S75 and F75 with the mean of S100 and F100, 3) S75 with NE100, and 4) interaction between S and F in their response to having 25% of their pasture area as NE+. Calf weaning weights were analyzed both as actual and adjusted 205-d weaning weights. Weaning weights were adjusted for calf age but not for age of cow. Calving rate was analyzed by Chi-square using PROC FREC. Treatment means are reported as least squares means.

Results and Discussion

Cow and calf performance measurements are shown in Table 1. Cow BW at the start of the breeding season was higher ($P < 0.05$) from F compared with S, and cow BW at weaning tended to be lower ($P = 0.05$) from 100% E+ compared with 75% E+. Cow BCS at the start of the breeding season was greater ($P < 0.05$) from F compared with S. Cow BCS at weaning was also greater ($P < 0.05$) from NE100 compared with S75 and was higher ($P < 0.05$) from 75% E+ compared with 100% E+. There was a calving season by NE+ % interaction tendency ($P = 0.10$) for cow BCS at weaning. Calving rates were higher ($P < 0.05$) from NE100 compared with S75 and were higher ($P < 0.05$) for S75 compared with S100.

A calving date difference ($P < 0.05$) was detected from F vs S, but was expected based on the different calving seasons. Calf weaning age did not differ ($P \geq 0.18$) across treatments. Calf birth weight, actual and adjusted weaning weight, calf gain, ADG, sale price at weaning, and calf value at weaning were higher ($P < 0.05$) from F compared with S. When compared with S75, NE100 calves tended ($P < 0.10$) to have higher actual and adjusted weaning weight, ADG, and calf value. Calves grazing NE100 also had higher ($P < 0.05$) preweaning gain compared with S75. Daily gains by calves in this study were comparable across treatments with that previously reported on spring-born calves grazing E+ or NE+ (Coffey et al., 2007).

Therefore, after one year of the study, it appears that fall-calving cows may perform more favorably when grazing E+ compared with spring-calving cows. The performance difference between fall and spring-calving cows may be attributed to lower environmental temperatures and(or) toxin concentrations during critical times of the year when cow nutrient requirements are highest. Furthermore, limited use of NE+ during the grazing season may improve cow BW and calving rates on spring-calving cows by offsetting some of the negative impacts associated with grazing E+ during times of the year when tall fescue toxicosis is more severely manifested.

Implications

Based on these results, grazing fall-calving cows on E+ may be more desirable than grazing spring-calving cows, resulting in better cow performance and heavier calves with higher value at weaning which would benefit producers selling to a cash market. Limited use of novel endophyte infected tall fescue may likewise benefit performance by cows grazing toxic fescue pastures.

Acknowledgments

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Table 1. Performance by spring- and fall-calving cows grazing with full access (S100 or F100), limited access (S75 or F75), or no access (NE100) to toxic wild-type endophyte-infected tall fescue.

	Treatments						
Item	F100	F75	NE100	S100	S75	SEM[a]	Contrasts[b]
Cow weights, lb							
Start of breeding	1179	1176	1112	963	1048	26.4	W
At weaning	1016	1099	1161	1010	1036	25.2	x,Y
Cow body condition score							
Start of breeding	5.7	5.7	5.8	5.0	5.0	0.09	W,Y
At weaning	5.3	5.8	5.4	4.8	4.9	0.14	W,X,Y,z
Calving rates, %	—	—	94[c]	36[e]	66[d]	—	
Avg. birth date	9/29	10/1	3/2	3/6	3/10	3.6	W
Age at weaning, d	223	221	230	226	222	3.6	ns
Calf BW, lb							
Birth weight	82	79	87	84	88	2.6	W
At weaning	507	515	542	444	477	17.6	W,y
Adj. weaning weight[f]	473	483	495	410	447	15.7	W,y
BW gain, lb	424	435	456	359	389	16.4	W,Y
Daily gain, lb	1.90	1.96	1.99	1.58	1.75	0.069	W,y
Sale price, $/lb[g]	1.15	1.15	1.06	1.13	1.11	0.013	W,y
Value at weaning, $[h]	583	587	571	499	526	14.0	W,y

[a]SEM = Pooled standard error of the mean.

[b]Contrasts:

W = mean of F compared with the mean of S

X = mean of S75 and F75 compared with the mean of S100 and F100

Y = mean of NE100 compared with the mean of S75

Z = the interaction between F and S response to having 25% of their pasture area as NE+ ($P < 0.05$)

lower case letters represent statistical tendency ($P \leq 0.10$)

ns = no significant difference.

[c-e] Percentages within a row without a common superscript letter differ ($P < 0.05$).

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

[g]Sale price/lb was determined using a sliding scale within calf sex based on the Arkansas average sale price on the actual date calves were weaned.

[h]Weaning value = actual calf price multiplied by the sale price determined for each individual calf.

Effects of Dexamethasone on the Metabolism of Ergot Alkaloids in Endophyte-infected Fescue Seed Diet in Rat Liver Microsomal Cytochrome P450

A.S. Moubarak[1], M.L. Poole[1], Z.B. Johnson[1], M.L. Looper[2], and C.F. Rosenkrans, Jr.[1]

Story in Brief

Animals ingesting ergot alkaloids found in tall fescue grass display a variety of toxicological conditions. Dexamethasone (DXM) is a synthetic glucocorticoid that has been shown to induce enzymatic degradation of ergot alkaloids in liver microsomes. The objective of this study was to determine if DXM induces catabolism or clearance of ergot alkaloids in diets containing such compounds in endophyte-infected tall fescue seed. Sprague-Dawley rats (n = 36; ~ 250 g BW) were randomly assigned to 1 of 6 treatments arranged in a 2 x 3 factorial design. Main effects were diets containing 50% endophyte-infected ground tall fescue seed or 50% uninfected ground seed (3 vs 0 mg/kg of ergovaline and ergotamine) and DXM at 0, 30, and 60 micrograms/kg BW spread equally over 3 days. Intraperitoneal injections of corn oil carrier (with and without DXM) were given to all rats on d 15, 16, and 17. On d 21, rats were given anaesthesia, exsanguinated, and eviscerated. Livers were weighed and microsomes prepared from liver tissue. Microsomes were assayed for metabolism of ergotamine and its isomer using high-performance liquid chromatography (HPLC) methodology. Body weight gain and ADG were decreased ($P < 0.01$) by increasing doses of DXM. Gross liver weight was affected ($P < 0.01$) by an interaction of DXM and diet. Infected seed diets increased ($P < 0.05$) the metabolism of ergotamine and ergotamine isomer across DXM concentrations. Comparison of amounts of P450 proteins by immunoassay suggests induction is affected by diet and DXM ($P < 0.05$), and that this influences metabolic activity in vitro.

Introduction

The symbiosis between tall fescue grass (*Festuca arundinacea* Schreb.) and endophytic fungus (*Neotyphodium coenophialum*) is responsible for drought and pest resistance and is related to production by the fungus of a variety of ergot alkaloids (Porter, 1995; West, 2000). These ergot alkaloids have a wide variety of physiological effects when ingested in small quantities, most of them detrimental to commercial agriculture. These effects are greatest at environmental extremes, and can prove deadly in either the hottest part of summer or the coldest part of winter. Beef cattle grazing infected fescue may gain half as much as those grazing non-infected, and they may have one-third to one-half lower pregnancy rates.

A wide variety of management practices have been explored to prevent the toxic effects of grazing fescue grass. Under common pasture conditions, ergovaline concentrations can range from 2 to 6 µg/g (Porter, 1995). Due to the variety of similar compounds under suspicion, it is difficult to relate precise symptoms to precise alkaloids. Animals have evolved a variety of methods of coping with the chemical defense systems that plants use to discourage predation (Cheeke, 1995). Unavoidable toxins, like ergot alkaloids, must be detoxified by other means. Based on the known metabolic pathways of ergot alkaloids, the P450 CYP3A4 enzyme is the human isoform responsible for their breakdown. Similar genes are evident in rats [CYP3A23] and cattle [CYP3A28]. In beef cattle, ergotamine undergoes a sequence of hydroxylations to four metabolites and their isomers, with similar activity occurring in rats (Moubarak and Rosenkrans, 2000).

This study was conducted to monitor other physiological changes and to characterize the dose-dependent responses in metabolism and catabolism of ergotamine to dexamethasone and dietary ergot alkaloids, and to see if diets containing ergot alkaloids modify dexamethasone induced P450 metabolism of alkaloids.

Experimental Procedures

Dexamethasone, ergotamine, nicotinamide adenine dinucleotide phosphate (NADP+), D-glucose-6-phosphate, glucose-6-phosphate dehydrogenase, and other chemicals were obtained from Sigma-Aldrich, St. Louis, Mo. Experimental animals were from Harlan Teklad, Madison, Wis. Metabolite analysis was performed using a high-performance liquid chromatography (HPLC) system from Gilson Inc., Middleton, Wis. Monoclonal antibodies were obtained from GENTEST Corporation, Woburn, Mass. Six-week old male rats (n = 36, ~250 g body weight) were housed in the small animal facility at University of Arkansas. Water and formulated diets were available ad libitum. Temperature was maintained at 24°C (76°F) and lights were on 18 hours and off 6 to simulate summertime conditions. Dietary treatment was pelleted food containing 50 percent Harlan Teklad lab chow and either 50 percent endophyte infected ground seed or noninfected ground fescue grass seed. Ergot alkaloids ergovaline and ergotamine in this diet were assayed by HPLC to be 0 and 3 ppm by the method of Moubarak et al. (1996). After 14 days of acclimation to cages and fescue diet the dexamethasone (DXM) treatment was administered. Dexamethasone treatments were doses of 0, 30, or 60 µg drug per kg body weight. This was divided into 3 injections on days 15, 16, and 17 of the study. Per animal dose was calibrated by variable injection of 100 µg/cc dexamethasone suspended in corn oil. Animal weights and feed consumption were monitored for 1 week, at which point animals were sacrificed. Livers were frozen, and then

[1] Department of Animal Science, Fayetteville
[2] USDA-ARS, Booneville, Ark.

prepared by the method of Kremers et al. (1981). Sodium phosphate was omitted to maintain microsome activity. During the preparation, frozen liver tissue was ground at 1 g per 5 ml of buffer (250 mM sucrose, 100 mM Tris-HCl, 1 mM ethylenediaminetetraacetic acid (EDTA), pH 7.4,) with Tissue-Tearor homogenizer. This slurry was then centrifuged at 800 g for 10 min. The pellet was discarded, and supernatant centrifuged at 13,500 g for 20 min. The supernatant from this was then spun at 105,000 g for 1 hour. The pellet was then suspended in storage buffer (100 mM sodium phosphate, 20% glycerol) and frozen in 50 µl aliquots. Microsome activity assay was performed in cofactor generating system by the method of Peyronneau et al. (1994). Microsomal protein (0.5 mg) was suspended in 500 µl cofactor generating buffer (100 mM Tris-HCl pH 7.5, 0.1 mM EDTA, 26 mM NADP+, 66 mM D-glucose-6-phosphate, 66 mM magnesium chloride, 1 U glucose-6-phosphate dehydrogenase in sodium citrate) along with 1 µg ergotamine. After 30 min, activity was stopped using concentrated acetic acid, and samples were centrifuged to remove particulate contaminants.

Metabolic activity of the microsomes was tracked by the conversion of ergotamine and its isomer into various metabolites. Separation was performed using a Gilson 714 HPLC system with gradients of acetonitrile and 2.6 mM ammonium carbonate in 10% methanol over a 3 * 3 CR C18 column. Detection was performed with Gilson 121 fluorescence detector with excitation at 250 nm and emission at 370 long pass filter (Moubarak and Rosenkrans, 2000).

Liver microsome P450 concentrations were compared by dot-blots performed using standard procedures obtained from Bio-Rad protocols and GENTEST monoclonal antibody product instructions. Total microsomal protein was measured by method of Lowry et al. (1951) and equalized at 7 µg per sample. Samples were then loaded into vacuum filtration system and transferred to nitrocellulose. Primary antibody was GENTEST's WB-MAB-3 against human P450 at 1:500 concentration, followed by secondary antibody of horseradish-peroxidase conjugated rabbit anti-mouse at 1:500 concentration. Nonspecific binding was blocked with 1% BSA. Color was developed with Sigma NBT-BCIP liquid substrate system, and analysis of color development was performed using Kodak 1D densitometry software.

Data were analyzed by PROC GLM of SAS (SAS Institute, Inc., Cary, NC) Models included dexamethasone, dietary ergot alkaloids, and the interaction between them. When the F test was significant ($P < 0.10$) the means were separated using the PDIFF option of GLM.

Results and Discussion

Body weight change was affected by presence of ergot alkaloids ($P < 0.05$) and by dexamethasone ($P < 0.01$); however there was no interaction between dietary alkaloids and DXM dosage for body weight change (Table 1; Figure 1). When averaged over the DXM treatments rats on the E- diet lost -0.95 ounces while those on the E+ diet lost significantly more (-1.65 ounces). Means by level of DXM were -0.05, -1.53, and -2.32 ounces for 0, 30, and 60 µg/kg of DXM, respectively. The linear dose response slopes based on DXM treatments were parallel indicating similar responses to the DXM treatment for both dietary treatment groups. Expressed as ADG, means were -0.008, -0.218, and -0.331 ounces for DXM levels of 0, 30, and 60 µg/kg, respectively, and –0.135 and -0.236 ounces for E- and E+ diets.

This change in weight may have been affected by differential feed consumption by experimental animals. Feed consumption was affected by both DXM and ergot alkaloids ($P < 0.01$; Table 1). Illustrated in Figure 2, average daily feed consumption showed a similar decline to that seen with weight gain with additional DXM. This is consistent with symptoms of fescue toxicosis, but not with DXM treatment.

There was an interaction between DXM dose and dietary ergot alkaloids ($P < 0.01$) for liver weight (Figure 3; Table 1); but when expressed as a ratio of body weight there was only a tendency for an interaction ($P = 0.14$). The ability of liver micosomes to modify substrate in vitro as measured by peak area concentrations (Figure 4) was affected by both ergot alkaloid diet and DXM treatment ($P < 0.05$), but there was no interaction. Substrate concentration represented by the mean peak area for ergotamine was 1,290,576 for rats on E- diets and 990,858 for rats on E+ diets. Mean peak areas for DXM levels of 0, 30, and 60 µg/kg were 1,044,422, 984,379, and 1,393,351, respectively, with the 30 DXM level being lower than the 60 DXM level ($P < 0.05$). The greatest decrease in ergotamine peak area is presumed to be in animals that had the most P450 activity. They received infected fescue seed in their diet and dexamethasone at 30 µg/kg. Ergotamine isomer metabolism (data not shown) was affected similarly to ergotamine.

Dot-blotting of microsomal protein measures expression of P450 using cross-reactivity to human P450. Optical analysis of the mean color development of each sample reveals a tendency for an interaction ($P = 0.11$) between dexamethasone and dietary ergot alkaloid resulting in reduction of expression of P450 due to dexamethsone in the E- diet and an increased expression of P450 in the E+ diet (Figure 5).

High doses of corticosteroids have been shown to greatly influence metabolism, as have dietary ergot alkaloids (Oliver et al., 2000). This study was most interested in interactions between the two drug types, especially to determine if dexamethasone could improve some of the deleterious effects of ergot alkaloids.

Dexamethasone is used to relieve stress because it stimulates gluconeogenesis from muscle breakdown and stimulates appetite, which can result in overall weight gain. This study demonstrated that feed consumption and body mass were decreased by dexamethasone treatment. This inconsistency may be due to the low dosages given in this study. One to 6 mg/kg therapeutic dose up to 400 mg/kg to induce P450 in rats have been reported in the literature. Doses given in this study were significantly lower, at total doses of 30 and 60 µg/kg. From a performance standpoint, the healthiest animals were those that received no treatment at all. Both ergot alkaloids and dexamethasone treatment independently reduced performance in a linear, dose dependent manner. This is apparent in weight change, feed consumption, and average daily gain. Liver weight and its relation to body weight would be impacted by both changes in blood volume due to vasoconstrictive effects of ergot and by increased P450 expression due to dexamethasone .

Implications

The presumption of this research was that treatment with dexamethasone would increase the metabolism of alkaloids via the induction of P450 enzymes that increase clearance. The implications of this research for animal health suggest that the increase in metabolism of ergot alkaloids by dosage with dexamethasone may not be the most efficient way of reducing the effects of fescue toxicosis on production and performance.

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Table 1. Treatment means for effects of dexamethasone dosage with and without dietary ergot alkaloids.

Item	No endophyte (E-)			Endophyte present (E+)				
Dexamethasone dose, µg/kg	0	30	60	0	30	60	SE	Significant effects
Weight change, ounce	0.317	-1.238	-1.919	-0.423	-1.819	-2.711	0.324	D e
Total feed consumed, ounce	5.617	3.815	3.727	4.554	3.685	2.752	0.289	D E
Average daily gain, ounce	0.045	-0.177	-0.274	-0.060	-0.260	-0.387	0.046	D e
Liver weight, ounce	0.433	0.374	0.393	0.397	0.392	0.328	0.012	D E D*E
Liver mass:body mass ratio	0.041	0.038	0.041	0.031	0.035	0.032	0.002	E d*e
Total microsomal protein (mg/ml)	14.113	12.212	10.725	14.835	13.168	13.965	0.871	d e

E = endophtye effect ($P < 0.01$).
e = endophyte effect ($P < 0.05$).
D = dexamethasone effect ($P < 0.01$).
d = dexamethasone effect ($P < 0.05$).
D*E = dexamethasone by endophyte interaction ($P < 0.01$).
d*e = dexamethasone by endophyte interaction ($P = 0.14$).

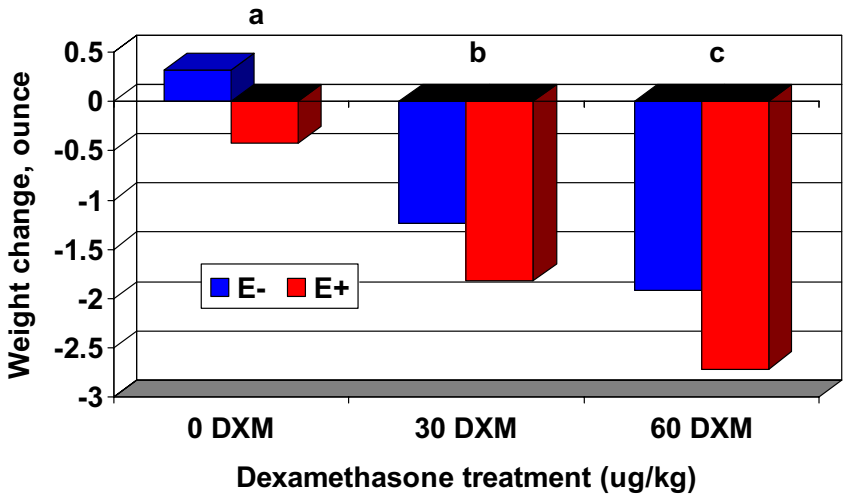

Fig. 1. Body weight gain as affected by dietary ergot alkaloids (E- vs E+) and dexamathasone (DXM) treatments. There was both a DXM effect ($P < 0.01$) and an ergot alkaloid effect ($P < 0.05$) but no interaction. a,b,c DXM treatment means with no letter in common differ ($P < 0.01$).

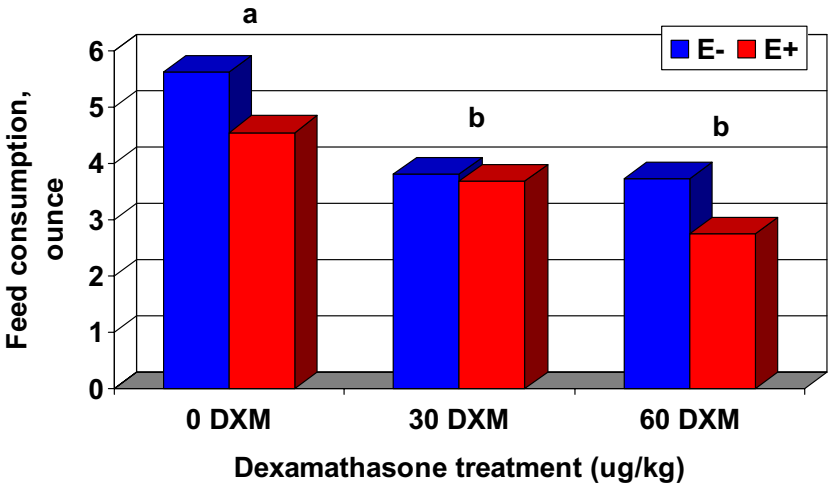

Fig. 2. Average feed consumption as affected by dexamethasone (DXM) dose and dietary ergot alkaloids (E- vs E+). There was both an ergot alkaloid effect ($P < 0.05$) and a DXM effect ($P < 0.01$) but no interaction. a,b DXM treatment means with no letters in common differ ($P < 0.01$).

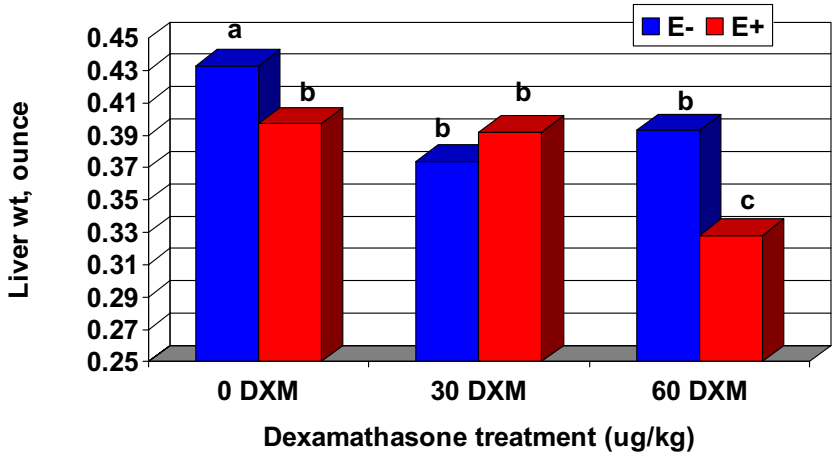

Fig. 3. Liver weights as affected by dietary ergot alkaloids (E- vs E+) and dexamathasone (DXM) treatments. There was an interaction between ergot alkaloid diet and DXM treatment ($P < 0.01$). a,b,c Treatment means with no letter in common differ ($P < 0.01$).

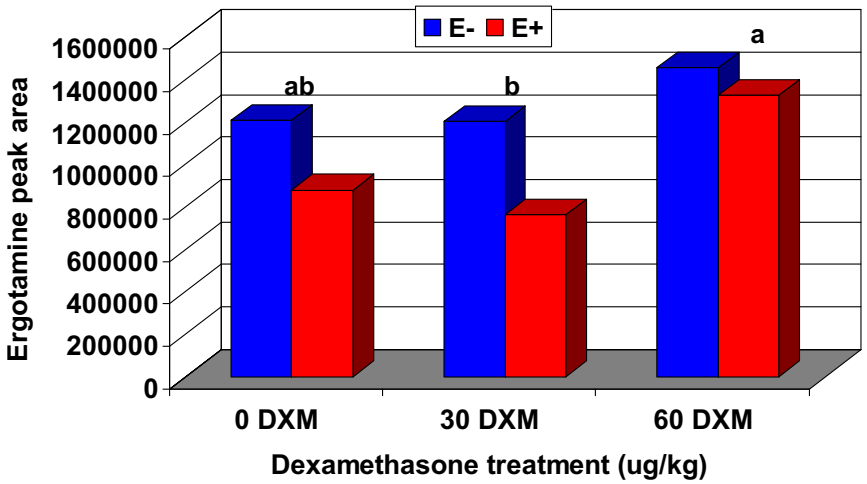

Fig. 4. Ergotamine peak area as affected by dietary ergot alkaloids (E- vs E+) and dexamethasone (DXM) dose. There was both an ergot alkaloid effect and a DXM effect ($P < 0.05$) but no interaction. a,b DXM treatment means with no letter in common differ ($P < 0.05$).

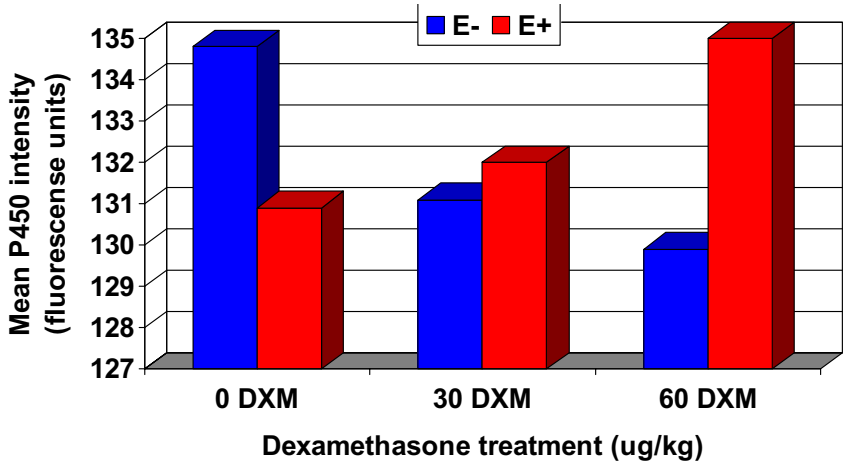

Fig. 5. Mean color development on P450 dot blot for ergot alkaloid (E- vs E+) and dexamethasone (DXM) treatments. There was a tendency ($P = 0.11$) for an interaction, but neither main effect was significant ($P > 0.50$).

Evaluation of Toxic and Non-toxic Novel Endophyte-infected Tall Fescue on Growth Rate and Grazing Behavior of Beef Heifers[1]

C.R. Bailey[3], M.L. Looper[2], K.P. Coffey[3], and C.F. Rosenkrans, Jr.[3]

Story in Brief

Objectives were to examine effects of toxic endophyte and non-toxic novel endophyte-infected tall fescue on performance and grazing behavior of pregnant Brangus and Gelbvieh x Angus heifers. On d 0 (March 28), heifers were weighed, blocked by breed, and assigned to graze non-toxic novel endophyte-infected (HiMag or MaxQ) or toxic endophyte-infected (E+) tall fescue pastures. Heifers were weighed on d 28, 56, and 99. Grazing behavior was monitored for 28 d between 1:00 and 3:00 pm, and heifers were recorded as either grazing or in the shade. At d 28, BW was greater ($P = 0.01$) for Gelbvieh x Angus than Brangus heifers, but was not different ($P > 0.10$) at d 56 or 99. Gelbvieh x Angus heifers exhibited greater ($P = 0.01$) ADG than Brangus heifers from d 0 to 28, but not from d 0 to 56 or 99 ($P \geq 0.12$). On d 28, 56 and 99, HiMag and MaxQ heifers were heavier ($P < 0.01$) than E+ heifers. Heifers grazing HiMag or MaxQ had greater ($P < 0.01$) ADG than E+ heifers. Forage type influenced ($P < 0.01$) grazing behavior. Fewer E+ heifers (17%) were observed grazing than MaxQ (29%) and HiMag (41%) heifers between 1:00 and 3:00 pm. Consequently, 65% of E+ heifers, 51% of MaxQ and 43% of HiMag heifers were observed in the shade ($P < 0.01$). Pregnant heifers grazing HiMag or MaxQ tall fescue performed better than those grazing E+ fescue.

Introduction

Tall fescue occupies nearly 10 million acres in the southeast and east central regions of the United States (Hoveland et al., 1997). Herbivores grazing E+ tall fescue exhibit a number of symptoms including reduced feed intake, ADG, and poor conception rates. These maladies, referred to as fescue toxicosis, are caused by ergot alkaloids synthesized by a fungal endophyte and are estimated to cost the producer $600 million annually in the U.S. (Cheeke, 1995).

Researchers have spent years trying to develop cost effective ways of preventing fescue toxicosis by developing new strains of plants and selecting animals that were more resistant to fescue toxicosis. Recently, cultivars were developed that contain a novel endophyte that does not produce the toxic ergot alkaloids that cause fescue toxicosis (Bouton et al., 2002; Nihsen et al., 2004). In animal research, it was shown that certain animals within a breed, as well as certain breed types are more resistant to fescue toxicosis. Therefore, objectives of this study were to evaluate the effects of toxic and novel endophyte infected tall fescue on growth and grazing behavior of pregnant Brangus and Gelbvieh x Angus heifers.

Experimental Procedures

A 2 x 3 factorial treatment arrangement was used to examine effects of toxic endophyte-infected (E+) and non-toxic endophyte-infected tall fescue on growth rate and grazing behavior of pregnant Brangus and Gelbvieh x Angus heifers (n = 36/breed type; 911 ± 80 lb initial BW). Grazing was initiated on March 28th and terminated July 5th. On d 0, heifers were weighed, blocked by breed, and randomly assigned to graze either E+, Jesup tall fescue with the AR542 endophyte strain (MaxQ™; Bouton et al., 2002), or HiMag tall fescue with strain 4 endophyte (HiMag4; Sleper et al., 2002) pastures (6 pastures/forage type; 4 heifers/2.5 acre pasture). Heifers were weighed on d 28, 56, and 99. Grazing behavior was visually monitored for 28 d (n = 13 observations; June 1st to 29th) between 1:00 and 3:00 pm. Heifers were recorded as either grazing or in the shade.

Data for BW and ADG were analyzed using the PROC MIXED procedures of SAS (SAS Inst. Inc., Cary, N.C.). The model consisted of breed (Brangus or Gelbvieh x Angus), forage (E+, HiMag or MaxQ) and breed x forage interaction. Day 0 BW was used as a covariate due to a breed difference ($P < 0.01$) at the initiation of the study. Grazing behavior was analyzed using the PROC FREQ procedures of SAS for Chi-Square analysis with the response variable being grazing (yes vs no) or standing in the shade (yes vs no).

Results and Discussion

Performance results are listed in Table 1. No breed x forage interactions ($P > 0.05$) were observed for BW or ADG, except d 0 BW ($P = 0.02$), which did not differ between forage treatments, but BW was greater ($P < 0.01$) for Gelbvieh x Angus than Brangus heifers; therefore, BW on d 0 was used as a covariate. At d 28, BW remained greater ($P = 0.01$) for Gelbvieh x Angus than Brangus heifers; BW was similar ($P > 0.10$) between breeds by d 56 and 99 (Table 1). This can be attributed to the fact that Gelbvieh x Angus heifers exhibited greater ($P = 0.01$) ADG than Brangus heifers from

[1] Names are necessary to report factually on available data; however, the USDA does not guarantee or warrant the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that also may be suitable.

[2] USDA-ARS, Booneville

[3] Department of Animal Science, Fayetteville

d 0 to 28, but not from d 0 to 56 or 99 ($P \geq 0.12$). Even so there is no indication from this study that Brangus heifers have a breed advantage compared with Gelbvieh x Angus heifers when grazing E+ tall fescue.

Heifers grazing HiMag or MaxQ tall fescue had greater ($P < 0.01$) ADG than E+ heifers; however, ADG did not differ between heifers grazing HiMag and Max Q tall fescue pastures (Table 1). Heifers grazing HiMag or MaxQ tall fescue were heavier ($P < 0.01$) on d 28, 56 and 99 than heifers grazing E+. Similarly, Nihsen et al. (2004) reported steers grazing novel endophyte-infected fescue did not display the usual symptoms of fescue toxicosis.

Forage type influenced ($P < 0.01$) grazing behavior. Fewer E+ heifers (17%) were observed grazing compared to MaxQ (29%) and HiMag (41%) heifers (Table 1). Consequently, 65% of E+ heifers, but only 51% of MaxQ and 43% of HiMag heifers were observed in the shade ($P < 0.01$). This is not surprising, given the symptoms of fescue toxicosis and the inability of cattle grazing E+ fescue to dissipate heat. Breed did not influence ($P > 0.10$) grazing behavior.

Implications

Incorporation of novel endophyte-infected tall fescue into a grazing program can increase the performance of pregnant beef heifers compared with heifers consuming toxic endophyte-infected tall fescue. Increased performance is partially due to heifers spending more time grazing and less time in the shade than heifers grazing toxic endophyte-infected tall fescue.

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Table 1. Effect of breed and toxic (E+) or non-toxic endophyte-infected (HiMag, MaxQ) tall fescue on performance and grazing behavior of pregnant heifers.

	Pasture type					Breed			
Item	E+	HiMag	MaxQ	SEM[a]	*P*	Brangus	G x A[b]	SEM	*P*
BW, lb									
Initial	917	911	908	13.91	0.91	871	953	11.18	< 0.01
d 28	935[c]	986[d]	997[d]	5.29	< 0.01	966	979	4.01	0.01
d 56	970[c]	1032[d]	1052[d]	8.36	< 0.01	1012	1021	5.58	0.12
d 99	1030[c]	1085[d]	1105[d]	9.79	< 0.01	1072	1074	7.06	0.74
ADG, lb/d									
d 0 to 28	0.82[c]	2.60[d]	2.95[d]	0.20	< 0.01	1.87	2.36	0.13	0.01
d 0 to 56	1.01[c]	2.12[d]	2.49[d]	0.15	< 0.01	1.79	1.94	0.11	0.12
d 0 to 99	1.15[c]	1.72[d]	1.94[d]	0.09	< 0.01	1.59	1.61	0.07	0.74
d 28 to 56	1.21[c]	1.63[d]	2.01[d]	0.20	0.02	1.70	1.52	0.13	0.27
d 28 to 99	1.30	1.37	1.50	0.09	0.30	1.48	1.32	0.07	0.11
d 56 to 99	1.35	1.21	1.17	0.13	0.62	1.32	1.17	0.11	0.28
Behavior[e]									
Shade, %	65	43	51		< 0.01	50	55		0.11
Grazing, %	17	41	29		< 0.01	30	28		0.56

[a]Standard error of the mean.
[b]Gelbvieh x Angus.
[c,d]Means in a row without common superscripts differ ($P < 0.05$).
[e]Chi-square analysis.

Post-Weaning Performance of Fall-Born Beef Steers Weaned from Endophyte-Infected Tall Fescue Pastures on Different Dates in the Spring

J.D. Caldwell[1], K.P. Coffey[1], W.K. Coblentz[2], R.K. Ogden[2], J.A. Jennings[3], D.S. Hubbell, III[4], D.L. Kreider[1], and C.F. Rosenkrans, Jr.[1]

Story in Brief

Weaning fall-born calves grazing tall fescue infected with the toxic wild-type endophyte (E+) prior to early May should reduce exposure of those calves to E+ toxins, resulting in improved long-term animal performance. However, a previous study did not support this hypothesis. Gelbvieh × Angus crossbred steer calves (n = 118) were used in a 3-yr study to determine the optimal time to wean fall-born calves grazing E+ fescue. Fall-calving cow-calf pairs were allocated by weight and age immediately prior to the onset of calving to 1 of 4 weaning dates: 1) March 16 (177 ± 4.7 d of age; **MarW**), 2) April 13 (204 ± 4.7 d of age; **AprW**), 3) May 11 (236 ± 4.7 d of age; **MayW**), and 4) June 8 (264 ± 4.7 d of age; **JuneW**). The MarW and AprW calves were moved to wheat pasture whereas MayW and JuneW were moved to bermudagrass pastures following a 14-d fence-line weaning program. Steer BW at weaning increased ($P < 0.05$), and BW at feedlot shipment tended to increase ($P = 0.06$) linearly across weaning dates, but steer BW at the end of the feedlot period and ADG during the feedlot period did not differ ($P \geq 0.19$) across weaning dates. Hot carcass weight and backfat tended to increase ($P \leq 0.10$) linearly across weaning dates. Therefore, weaning fall-born steer calves from E+ pastures later had short-term benefits, but these BW benefits did not persist during the feedlot period.

Introduction

Early weaning is a management practice that has shown promise as a means of increasing calf growth and carcass quality (Myers et al., 1999). Weaning fall-born steer calves grazing endophyte-infected (E+) pastures before early May may benefit calves by potentially lowering the amount of tall fescue toxins consumed since concentrations of these toxins increase substantially between April and mid-June (Rottinghaus et al., 1991) and performance by steers was impacted more negatively by E+ from mid-May to mid-June than from mid-April to mid-May (Coffey et al., 2001). However, fall-born calves weaned in early April from E+ gained slower between April and June than calves not weaned until early June (Coffey et al., 2005). This supports that other factors, not only fescue toxins, are impacting calf performance as spring progresses. Therefore, the objective in this study was to determine the optimal weaning date for fall-born steer calves grazing tall fescue pastures with emphasis on post-weaning performance.

Experimental Procedures

This 3-yr study was conducted at the University of Arkansas Livestock and Forestry Branch Experimental Station near Batesville, Ark. Pregnant crossbred (Gelbvieh × Angus; n = 238) cows, resulting in 118 steer calves, were stratified by age and BW and allocated randomly in late August to 1 of 8, 24-acre pastures of E+, immediately prior to the initiation of the fall-calving season. Two groups of calves were weaned at 28-d intervals beginning March 16 each year. All calves were born (mean calving date = September 19) and nursed their dams while grazing infected-tall fescue. The groups of cow-calf pairs were allocated randomly to 1 of 4 weaning dates: 1) March 16 (177 ± 4.7 d of age; MarW), 2) April 13 (204 ± 4.7 d of age; AprW), May 11 (236 ± 4.7 d of age; MayW), or June 8 (264 ± 4.7 d of age; JuneW). Both cows and pastures were reallocated to treatments each year.

On their designated weaning date, calves were gathered beginning at approximately 0800, separated from their dams, weighed, and vaccinated against 7 clostridial strains (Alpha 7; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Mo.), infectious bovine rhinotraceitis (IBR), bovine viral diarrhea virus (BVDV), parainfluenza, bovine respiratory syncytial virus (BRSV), *Haemophilus somnus*, and 5 strains of *Leptospira* (Elite 9-HS; Boehringer Ingelheim Vetmedica, Inc.). Calves were then placed in a 4-acre paddock adjacent to their dams for 14 d and offered 2 lb of corn gluten feed daily. After the 14-d weaning period, calves were gathered, weighed, revaccinated (Elite 9-HS; Boehringer Ingelheim Vetmedica, Inc.), and treated for internal parasites (Cydectin, Fort Dodge Animal Health, Overland Park, Kan.). The MarW and AprW calves were placed on wheat until available forage was limiting (< 1000 lb/acre), then placed on bermudagrass, and the MayW and JuneW calves were placed on bermudagrass pastures after their 14-d weaning periods. Starting June 22 of each year all calves were commingled on bermudagrass pastures and grazed those pastures until mid-November, when they were shipped to a feedlot and fed a high-concentrate diet. A commercial trace mineral salt was offered ad libitum to the calves during all grazing phases. At the end of the feedlot period steers were harvested at a commercial slaughter facility and carcass data were collected following a 24-hr chill. Carcass measurements for ribeye area, marbling score, and backfat thickness are only reported for the first 2 yr of the study. The third year's data for these measurements was lost at the slaughter facility.

Statistical analyses were performed by using PROC MIXED of SAS (SAS Inst., Inc., Cary, NC) with each group of animals in a spe-

[1] Department of Animal Science, Fayetteville
[2] USDA-ARS, Marshfield, Wis.
[3] Department of Animal Science, Little Rock
[4] Department of Animal Science, Batesville

cific pasture considered the experimental unit. Linear, quadratic, and cubic contrast statements were used to compare weaning dates. The Chi-square procedure of SAS was used to analyze percent age of each quality grade (choice, select, and standard). Treatment means are reported as least squares means.

Results and Discussion

Average calf birth date did not differ ($P = 0.21$) across weaning dates (Table 1). Calf BW at weaning and 14 d after the last weaning date (June 22) increased ($P < 0.05$) and calf BW at shipping tended to increase ($P = 0.06$) linearly with advancing weaning dates. These results are different from those reported by Lusby et al. (1981) who reported no differences in calf weights between normally weaned (7 mo of age) and early weaned (6 to 8 wk of age) calves raised in a drylot until the normal weaning date. Gains during the bermudagrass grazing period were low for all treatments. This is likely because of insufficient ruminal development in these calves to utilize the high fiber content of bermudagrass.

Final BW at the end of the feedlot phase and ADG during the feedlot phase did not differ ($P \geq 0.19$) as weaning dates progressed. Likewise, days on feed did not differ ($P \geq 0.28$) across treatments.

Hot carcass weight tended to increase ($P = 0.10$) linearly as weaning dates progressed. Dressing percent, ribeye area, yield grade, and marbling score did not differ ($P \geq 0.12$) as weaning dates progressed, but backfat thickness tended to increase ($P = 0.09$) linearly as weaning dates progressed. Quality grade did not differ ($P = 0.84$) as weaning dates progressed, with 47% of the steers grading choice and 53% grading select (Table 2). Therefore, weaning of fall-born steer calves from E+ pastures later had short-term benefits on BW, but those benefits did not persist throughout the feedlot period.

Implications

Based on these results, weaning fall-born calves later in the spring should lead to heavier animals at weaning, which would benefit producers selling to a cash market. Consequently, weaning late may not be beneficial for producers with retained ownership through the feedlot phase.

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Table 1. Post-weaning performance and carcass measurements of fall-born steer calves weaned March 16 (MarW), April 13 (AprW), May 11 (MayW), or June 8 (JuneW) from endophyte-infected tall fescue pastures (3-yr avg).

	Treatments					
Item	MarW	AprW	MayW	JuneW	SEM[a]	Contrasts[b]
Avg birth date	9/20	9/22	9/17	9/18	5.0	ns
Calf BW, lb						
At birth	77	79	79	77	2.4	ns
At weaning	440	485	569	621	23.2	L
June 22[c]	583	569	627	648	19.4	L
At shipping[d]	624	613	650	661	38.9	I
Final weight[e]	1304	1269	1312	1341	34.4	ns
Feedlot ADG	4.1	4.0	4.0	4.2	0.52	ns
Days on feed	163	174	174	163	12.8	ns
Carcass measurements						
HCW, lb[f]	801	781	809	830	28.6	I
Dressing %	61.5	61.5	61.6	61.9	0.79	ns
Ribeye area, in^2[g]	14.6	14.5	14.3	15.2	0.58	ns
Backfat, in[g]	0.46	0.48	0.54	0.57	0.046	I
Yield grade	2.4	2.4	2.5	2.6	0.18	ns
Marbling score[gh]	413	413	400	451	24.9	ns

[a]SEM = Pooled standard error of the mean.
[b]L = a significant linear contrast ($P < 0.05$); I = a linear tendency contrast ($P \leq 0.10$); ns = no significant difference.
[c]June 22 weight was the weight measured 14 d after the June 8 weaning date.
[d]Shipping weight was the weight measured prior to calves being shipped to a feedlot (mid-November).
[e]Final weight was the weight measured prior to harvest.
[f]HCW = Hot carcass weight.
[g]Only first 2 yr of data used, because of lost data from the slaughter facility.
[h]300 = Slight^0, 400 = Small^0.

Table 2. USDA quality grade of fall-born steer calves weaned on March 16 (MarW), April 13 (AprW), May 11 (MayW), or June 8 (JuneW) from endophyte-infected tall fescue (3-yr avg).

	Treatments					
Item	MarW	AprW	MayW	JuneW	Avg[a]	*P* - values[b]
Quality grade distribution, %						
Choice	46.7	46.9	46.7	46.2	46.61	ns
Select	53.3	50.0	53.3	53.8	52.54	ns
Standard	0.0	3.1	0.0	0.0	0.85	ns

[a] Avg = Average of quality grade across weaning dates within quality grade.
[b]ns = no significant difference.

Post-Weaning Performance of Spring-Born Calves Weaned from Tall Fescue Pastures with a Wild-Type Toxic Endophyte or a Non-Toxic Novel Endophyte

K.P. Coffey[1], J.D. Caldwell[1], W.K. Coblentz[2], T.W. Hess[3], D.S. Hubbell, III[3], R.K. Ogden[2], M.S. Akins[1], M.L. Looper[4], and C.F. Rosenkrans, Jr.[1]

Story in Brief

Numerous studies have reported compensatory gain by yearling cattle that grazed toxic endophyte-infected 'KY-31' tall fescue (E+), but few studies have reported post-weaning performance by calves weaned from E+. Our objective was to compare post-weaning performance by spring-born calves grazing E+ with that of calves grazing a non-toxic endophyte-tall fescue association developed at the University of Arkansas (NE+). Gelbvieh × Angus crossbred cows (n = 146; 1,078 lb initial BW) were allocated to 1 of 4, 25-acre pastures in 2005 and to 1 of 8, 25-acre pastures in 2006. Cows began grazing during the fall of each year. Calves were born and remained on their assigned pastures until weaning in 2006, but were removed from NE+ in the summer of 2005 because of low forage availability. After weaning, calves grazed bermudagrass pastures followed by winter annuals. Steers weaned from NE+ were heavier ($P < 0.01$) at weaning and throughout the post-weaning period, and produced heavier hot carcass weights ($P < 0.05$) than steers weaned from E+. Heifers weaned from NE+ tended ($P = 0.07$) to be heavier at weaning than heifers weaned from E+. Calving rates by heifers weaned from NE+ were greater ($P < 0.01$) than those by heifers weaned from E+. Daily gains during post-weaning did not differ ($P \geq 0.33$) between NE+ and E+ for steers or heifers. Therefore, grazing spring-born nursing calves on E+ prior to weaning has negative impacts that were not compensated for during later production stages on non-toxic feedstuffs.

Introduction

Tall fescue pastures are common in northern Arkansas, as well as much of the southeastern US because they are persistent and need little maintenance. This persistency is attributed to an indwelling fungus (*Neotyphodium coenophialum*) that also produces toxins that cause fescue toxicity. In recent years, tall fescue plants were infected artificially with non-toxic endophytes. These plants maintained their vigor, but did not have detrimental effects on cattle (Bouton et al., 2003; Parish et al., 2003; Nihsen et al., 2004). The primary objective of this study was to observe animal production from a tall fescue, "friendly" or non-toxic endophyte association (NE+) compared with tall fescue with the toxic wild-type endophyte (E+). A secondary objective of this study was to observe the impacts of grazing these forages prior to weaning on post-weaning calf performance.

Experimental Procedures

This study was conducted at the Livestock and Forestry Branch Station located near Batesville, Ark. Gelbvieh × Angus crossbred cows (n = 146; 1,078 ± 13.6 lb initial BW) were stratified by weight and age and allocated randomly to 1 of 4, 25-acre pastures in 2005 and 1 of 8, 25-acre pastures in 2006. Pastures were allocated randomly to provide 2 pastures each of E+ and NE+ in 2005 and 4 pastures each of E+ and NE+ in 2006. Cows confirmed as pregnant via rectal palpation began grazing the experimental pastures on October 15, 2004, and November 30, 2005 at a stocking rate of 2.4 acres/cow.

During the summer of 2005, extremely dry summer conditions forced feeding of the winter hay supply. Once the hay from a particular NE+ pasture was depleted, cows were moved to a bermudagrass pasture and fed bermudagrass hay. Cows grazing E+ pastures were fed E+ hay from another location on the research farm and were not removed from their experimental pastures. Early fall rains allowed forage growth to resume and all cows were returned to their respective pastures 7 d prior to weaning. During 2006, forage supply was adequate and cows remained on their assigned pastures until their calves were weaned.

Calves were weaned using a low-stress, fence-line weaning program where they were gathered and vaccinated against 7 clostridial strains (Alpha 7™; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Mo.), infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza, bovine respiratory syncytial virus, *Haemophilus somnus*, and 5 strains of *Leptospira* (Elite 9-HS™; Boehringer Ingelheim Vetmedica, Inc.), and then placed in a pasture adjacent to their dams for 14 d. After this time, calves were gathered, re-vaccinated, dewormed, then moved to a new location and placed on bermudagrass pastures.

Calves were moved to winter annual pastures during the late fall and grazed those through the winter, and early spring. Heifers continued to graze winter annual forages until breeding in early May. Steers grazed winter annual forages until they were transported to the Oklahoma State University feedlot facility near Stillwater, Okla., on March 8, 2006 or until transported to a commercial feedlot near Scott City, Kan., on March 18, 2007.

Calf data were analyzed within gender of calf using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). The original pasture group was used as the experimental unit for all analyses. Heifer pregnancy rates and the percentage of steers grading USDA Choice were analyzed by Chi-square using PROC FREQ of SAS.

[1] Department of Animal Science, Fayetteville
[2] USDA-ARS, Marshfield, Wis.
[3] University of Arkansas Livestock and Forestry Branch Experiment Station, Batesville
[4] USDA-ARS, Booneville, Ark.

Results and Discussion

Steers weaned from NE+ were heavier ($P < 0.05$) at weaning and at all subsequent periods including the final feedlot weight (Table 1). However, daily gains differed ($P < 0.01$) between NE+ and E+ steers only during a grazing period on bermudagrass pasture between the time fence-line weaning was completed and when the steers were placed on winter annual forages. This indicates that steers weaned from E+ pastures were not compensating for reduced gains that occurred during the time they were grazing E+ pastures. Hot carcass weights were heavier ($P < 0.05$) from calves weaned from NE+ than from those from E+ pastures, but no other carcass measurements differed ($P \geq 0.36$) between NE+ and E+ steers.

Heifer weights at weaning tended ($P = 0.07$) to be heavier from NE+ compared with E+ (Table 2). This tendency was maintained ($P \leq 0.09$) through the time heifers were placed on winter annual forages. However, heifer weight at breeding, and daily gains during various periods post-weaning did not differ ($P \geq 0.33$) between heifers weaned from NE+ compared with those weaned from E+ pastures. Calving rates were greater ($P < 0.01$) from heifers weaned from NE+ compared with heifers weaned from E+ pastures, but calving dates did not differ ($P = 0.88$) between treatments. These results are difficult to explain. Although the BW differential between heifers grazing NE+ and those grazing E+ were not as great as observed with steers, exposure to E+ during the preweaning period may have negative impacts on future reproduction by heifers independent of BW.

Implications

Buyers purchasing steer calves weaned from E+ pastures should expect those calves to grow at a similar rate as those weaned from non-toxic pastures and, therefore, should not discriminate against those calves by reducing the price per pound paid. However, producers retaining ownership of calves weaned from E+ pastures should not expect those calves to compensate for the preweaning reduced performance during later production stages. This would likely result in lighter weight steer calves at later production stages, and reduced conception rates by retained heifers.

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Table 1. Postweaning performance and carcass measurements from steers weaned from tall fescue pastures containing either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (NE+)[a].

	E+	NE+	SE	P-value[b]
Steer BW, lb				
No. of steers	34	40		
At weaning	459	549	46.1	<0.01
At wean +14 days	483	578	41.9	<0.01
On winter annuals	503	582	39.0	<0.01
At shipping (shrunk 4%)	690	770	62.0	0.01
At feedlot	710	774	57.3	<0.01
At end of feedlot (shrunk 4%)	1237	1319	51.4	0.02
Gain, lb				
Weaning to shipping	260	238	115.1	0.13
Daily gain, lb				
During 14-d weaning	1.54	2.09	0.384	0.16
Weaning to winter annuals	0.68	0.20	0.240	<0.01
On winter annuals	2.05	2.03	0.880	0.67
Weaning to shipping	1.74	1.68	0.774	0.33
Feedlot (shrunk)	3.95	4.06	0.117	0.46
Days on feed	137	136	27	0.76
Carcass				
Hot carcass wt., lb	783	840	33.3	0.01
Dressing %	63.3	63.7	0.4	0.36
Rib fat, in	0.43	0.63	0.173	0.40
Longissimus area, in^2	13.5	13.8	0.61	0.59
USDA Yield Grade	2.6	2.6	0.29	0.89
Marbling score[c]	37	37	2.3	0.97
% USDA Choice	57	46		0.90

[a] NE+ is a novel endophyte – tall fescue association developed at the University of Arkansas.
[b] P-value for the difference between E+ and NE+.
[c] 30 = $Slight^0$; 40 = $Small^0$.

Table 2. Post-weaning performance by heifers weaned from tall fescue pastures containing either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (NE+)[a].

	E+	NE+	SE	Effect[b]
Heifer BW, lb				
No, heifers	39	32		
At weaning	459	498	38.8	0.07
At weaning +14 d	478	520	37.3	0.07
On winter annual	564	598	13.2	0.09
At breeding	798	820	16.5	0.33
Daily gain, lb				
During 14-d weaning	1.39	1.37	0.368	0.99
Weaning to winter annuals	1.04	0.97	0.287	0.62
On winter annuals	1.98	1.98	0.088	0.9
Weaning to breeding	1.61	1.54	0.157	0.53
Heifer calving rate, %	64.1	90.6		< 0.01
Heifer calving date	1-March	2-March	4	0.88

[a] NE+ is a novel endophyte – tall fescue association developed at the University of Arkansas.
[b] P-value for the difference between E+ and NE+.

Effects of a Lactic Acid/*Lactobacillus* Product and Bale Moisture on the Voluntary Intake and Digestibility of Bermudagrass Hay by Lambs and on In Situ Digestibility by Cannulated Heifers

A.E. Killion, D. Philipp, K.P Coffey, L.A. Hardin, and J.D. Caldwell[1]

Story in Brief

Bermudagrass (*Cynodon dactylon* L.) is commonly used for grazing and haying in Northwest Arkansas. However, the production of high-quality bermudagrass can be challenging due to adverse weather conditions during spring and summer. A field of common bermudagrass was divided into 12 plots using a randomized complete block design with a 2 x 2 factorial treatment arrangement. Half of the plots were sprayed with a lactic acid/*lactobacillus* fermentation product (L) at the time of mowing, and half were not treated (U). Within L and U treatments, half of the plots were baled at either 18% moisture (LM) or 25% moisture (HM). The first objective of this study was to determine the influence of bale moisture and use of a *lactobacillus* fermentation spray product on bermudagrass hay quality and subsequent effects on intake and digestibility by lambs. Sixteen wether lambs were allocated randomly to treatment combinations and fed hay ad libitum. Daily dry matter (DM) intake was not different across spray or moisture treatments at baling; however, DM digestibility and digestible DM intake (lb/d) were greater ($P < 0.05$) from U vs L. Baling bermudagrass hay at 25% moisture did not appear to negatively affect intake and digestibility by lambs, but treating bermudagrass with the lactic acid/*lactobacillus* preservative at the time of mowing may reduce digestibility. The second objective of this study was to evaluate the use of a lactic acid/*lactobacillus* fermentation spray product applied at the time of mowing on in situ ruminal digestibility measurements of bermudagrass hay baled at either 18% or 25% moisture. Samples of the resulting hay were ground, placed in dacron bags, and placed in the rumen of 6 ruminally cannulated heifers. Bags were removed at varied times over a 5-d period to determine ruminal digestion kinetics. The water soluble fraction was greater ($P < 0.05$) and the potentially digestible fraction was lower ($P < 0.05$) from LM compared with HM. Digestion lag time tended ($P < 0.10$) to be greater from HM compared with LM. The digestion rate, undegradable fraction, and effective ruminal digestion did not differ ($P > 0.10$) between moisture concentrations at baling. None of the ruminal digestion measurements differed between L and U. Therefore, baling bermudagrass hay at 25% moisture rather than at 18% moisture resulted in losses of water-soluble components, but did not impact overall effective ruminal digestion. Treating bermudagrass with the lactic acid/*lactobacillus* preservative at the time of mowing had minimal impacts on ruminal DM digestibility.

Introduction

Production of high-quality bermudagrass hay (*Cynodon dactylon* L.) in Northwest Arkansas is challenging due to frequent precipitation events during spring and summer. High moisture levels in hay as a result of insufficient drying periods may result in heat damaged bales and reduced nutritive value. It has been suggested that the application of a *lactobacillus* fermentation spray product at time of cutting will allow producers to bale hay at a higher moisture concentration than recommended while retaining a high nutritive value and palatability for livestock. The first objective of this study was to determine intake and digestibility of bermudagrass hay by lambs either treated or untreated with a *lactobacillus* spray product and baled at either 18 or 25% moisture. Our second objective was to assess the effects of a *lactobacillus*/lactic acid product and baling at differing moisture levels on hay quality and in situ dry matter (DM) disappearance by heifers.

Experimental Procedures

The study was conducted at the University of Arkansas Agricultural Research and Extension Center in Fayetteville. In July of 2008, a field of common bermudagrass was divided into 12 plots in a randomized complete block experiment with a 2 x 2 factorial arrangement of treatments. Half the plots within each block were sprayed with a lactic acid/*lactobacillus* fermentation product (L) at the time of cutting on July 4, 2007, and half were not treated (U). The hay preservative used was Pro-Serve® II (Conklin Company Inc., Shakopee, Minn.). Within L and U plots, half were baled at 25% moisture (HM) and half at 18% moisture (LM). The bermudagrass was at the stem-elongation maturity stage.

To ensure baling at the desired moisture concentration, plots were monitored regularly following the cutting of the bermudagrass. Samples were gathered at random from various plots and dried using microwave oven drying techniques. After baling, 6 bales were selected at random from each plot and stacked in individual 6-bale stacks surrounded with either dry, insulating bales or with Styrofoam insulation. After a 120-day storage, hay bales from each stack were chopped with a chipper shredder. For Objective 1 of our study, bales from all treatment combinations from block 1 were shredded and stored in over-sized plastic bags. For Objective 2, bales from all blocks were sampled, ground, and placed in Dacron forage bags (Ankom Technology Corp., Fairport, N.Y.) for in situ ruminal DM disappearance determination.

Objective 1. Sixteen black-faced wether lambs (95 ± 8.1 lb initial BW) underwent a 28-d adjustment period during which they were offered untreated bermudagrass hay ad libitum. Water was provided in a 15-gallon rubber feeder pan and filled as needed. A small amount of mineral was offered to lambs on arrival and slowly increased to ad libitum access. Any health issues that occurred

[1] Department of Animal Science, Fayetteville

with the lambs were treated with either Excenel® or Nuflor®.

The 16 wether lambs were weighed and placed randomly in individual pens with metal grated floors and nipple waterers. Lambs were assigned randomly to one of the 4 treatment combinations consisting of HM-L, HM-U, LM-L, or LM-U. Each lamb was offered its respective hay throughout a 14-d dietary adaptation period. The assigned hay treatment was offered daily beginning at 8 a.m., and fresh hay was offered throughout the day to ensure ad libitum access to forage while minimizing hay wastage. Water and mineral granules were also provided ad libitum.

Following the 14-d dietary adaptation period, lambs were fitted with fecal collection bags, and total feces were collected twice daily for 7 d. At each collection, total feces were removed from the bag, weighed, and dried at 122°F for later chemical analyses. Unconsumed hay was collected each morning before the 8 a.m. feeding and dried at 122°F for further analysis as well. Lambs were allowed to socialize and exercise for 2 h every 3 d in an enclosed area in the barn. Pen floors were cleaned daily. The lambs were reweighed after the trial.

Objective 2. Six ruminally-cannulated heifers were placed in individual pens with concrete flooring. Heifers were offered a basal diet of a grain mix at 0.3% BW and bermudagrass hay ad libitum for a 10-day adaptation period. Both hay and supplement were offered in equal portions at 8 a.m. and 4:30 p.m. Water was provided ad libitum. Pen floors were cleaned twice daily. Forage samples were grouped by block and each block assigned to 2 heifers. Those 2 heifers received each forage treatment based on the experimental design in the field. Samples were inserted into the ventral rumen of each heifer and incubated for 6, 12, 18, 24, 36, 48, 72, 96, or 120 h. Immediately after removal from the rumen, mesh bags were immersed in cold water to prevent any further microbial degradation. Dacron bags containing in situ residues were rinsed in a top-loading washing machine for 2 minutes and were spun for 1 minute. This process was repeated 10 times for each incubation period. A separate set of bags was pre-incubated and rinsed without ruminal incubation (0 h).

To quantify the residual DM in each bag, after the rinsing process, all of the Dacron bags were dried in a forced-air oven at 122°F. Dacron bags were allowed to equilibrate with atmospheric moisture before weight was recorded. Residual DM remaining in each bag at each sampling time was fit to a non-linear statistical model (Mertens and Loften, 1980) using PROC NLIN of SAS (SAS Inst., Inc., Cary, N.C.) to determine DM degradation kinetic parameter estimates.

Neutral detergent fiber (NDF) of hay samples was determined by using the ANKOM 200 Fiber Analyzer (Ankom Tech. Corp., Fairport, N.Y.). Crude protein (CP) in hay samples was calculated by measuring the percentage of nitrogen in the forage sample and multiplying by 6.25.

Forage quality and digestion kinetic parameter estimates were analyzed using SAS procedures for a randomized complete block design.

Results and Discussion

Objective 1. Dry matter intake was not affected ($P > 0.10$) by either spray treatment or moisture at baling (Table 1). Dry matter digestibility of U was greater ($P < 0.05$) than that of L, and HM tended ($P = 0.07$) to be more digestible than LM. Digestible DM intake (lb/d) did not differ ($P > 0.10$) between HM and LM, but was greater ($P < 0.05$) from U than from L.

Objective 2. The water-soluble fraction was greater ($P < 0.05$) from LM compared with HM but did not differ ($P > 0.10$) between L and U (Table 2). This difference in the water-soluble fraction is likely because of oxidation of soluble carbohydrates during the storage period. The slowly degradable fraction was greater ($P < 0.05$) from HM compared with LM but was not impacted ($P < 0.10$) by L. This increase in the slowly degradable fraction is likely an artifact of the greater loss of soluble carbohydrates from HM leading to greater concentrations of the remaining components. Digestion lag tended ($P < 0.10$) to be greater from HM compared with LM, indicating that HM hay would require a longer period before the ruminal bacteria are able to attach and begin to degrade the forage. The undegradable fraction of the bermudagrass hay DM did not differ ($P > 0.10$) between HM and LM or between L and U. Likewise, effective DM digestion did not differ ($P > 0.10$) between HM and LM or between L and U.

Numerous studies have evaluated the impacts of heat damage on forage quality and nutrient utilization of various forages. However, these evaluations using bermudagrass are somewhat limited, particularly as they pertain to artificial methods of reducing spontaneous heating, such as with hay preservatives. In our previous work, increasing levels of heat damage had little impact on DM intake by lambs, but DM digestibility by lambs (McBeth et al., 2001), and ruminal effective DM disappearance by cattle (McBeth et al., 2003) decreased with increasing heat damage to bermudagrass. However, in vitro digestibility of bermudagrass hay baled at 18% moisture was only 1.7 percentage units greater than bermudagrass hay baled at 25% moisture (Coblentz et al., 2000). Therefore, it is possible that 25% moisture at baling will have some impacts on quality of bermudagrass hay, but will likely not be high enough to result in reduced utilization by lambs. In our study, treatment types had no effect ($P > 0.10$) on forage CP concentrations, but concentrations of NDF were greater ($P < 0.05$) from HM compared with LM (Table 3). The spray treatment had no effect ($P > 0.05$) on concentrations of CP or NDF in bermudagrass.

Implications

Based on these results, the use of a *lactobacillus* spray product on bermudagrass harvested for hay may not be beneficial for improving its digestibility. The use of a *lactobacillus* spray product at time of mowing appeared to have no effect on the ruminal degradation of bermudagrass hay by heifers. Although hay moisture levels at time of baling affected some of the ruminal degradation measurements for bermudagrass hay, effective ruminal digestion was not affected. Therefore, it is unlikely that the treatments evaluated in this study would have a substantial impact on ruminal forage utilization. Further studies should be conducted with animals on other forage types to determine the effect of the utilized spray product on hay quality.

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Table 1. Intake and digestibility by wether lambs offered bermudagrass hay treated with a lactic acid-lactobacillus preservative at the time of mowing and baled at either 18 or 25% moisture.

	Treatments					
Item	High moisture spray	High moisture non-spray	Low moisture spray	Low moisture non-spray	SE	Effects[a]
Lamb wt, lb	95	95	94	95	8.1	ns
DM intake, lb/d	1.5	1.7	1.4	1.6	0.13	ns
DM intake, % BW	1.6	1.8	1.5	1.7	0.20	ns
DM digestibility, %	51.3	54.4	48.7	54.1	0.70	T, m
Digestible DMI, lb/d	0.7	0.9	0.7	0.9	0.07	T
Digestible DMI, % BW	0.8	1.0	0.7	0.9	0.10	t

[a] ns = not statistically different; T, t = spray treatment effect ($P < 0.05$ and 0.10, respectively); m = moisture effects ($P < 0.10$).

Table 2. Ruminal in situ digestion kinetics of untreated bermudagrass hay or bermudagrass hay treated with a lactic acid-lactobacillus preservative at the time of mowing and baled at either 18 or 25% moisture.

	Treatments					
In situ study DM fractions	High moisture treated	High moisture untreated	Low moisture treated	Low moisture untreated	SE	Effect[a]
Water-soluble fraction, %	14.3	14.8	16.9	17.7	1.0	M
Slowly degradable fraction, %	57.1	57.3	54.6	52.9	1.6	M
Digestion rate, /h	0.040	0.037	0.040	0.039	0.005	ns
Digestion lag, h	2.3	2.1	1.4	1.0	0.6	M
Undegradable fraction, %	28.5	28.0	28.5	29.4	2.4	ns
Effective degradability, %	44.4	43.8	45.7	45.0	1.3	ns

[a] ns = not statistically different; M = moisture effects ($P < 0.05$).

Table 3. Post-storage crude protein and neutral detergent fiber of untreated bermudagrass hay or bermudagrass hay treated with a lactic acid-lactobacillus preservative and baled at either 18 or 25% moisture.

	Treatments					
Items	High moisture treated	High moisture untreated	Low moisture treated	Low moisture untreated	SE	Effect[a]
CP, %	14.1	15.1	15.0	15.3	0.5	ns
NDF, %	74.7	74.3	71.2	71.8	0.6	M

[a] ns = not statistically different; M = moisture effects ($P < 0.05$).

Effect of a Lactic Acid-*lactobacillus* Preservative and Moisture Concentration at Baling on Intake and Digestibility of Crabgrass Hay by Lambs and In-situ Digestibility by Heifers

L.A. Hardin[1], K.P. Coffey[1], A.E. Killion[1], J.D. Caldwell[1], D. Philipp[1], W. Coblentz[2]

Story in Brief

Crabgrass is a warm-season annual forage that has greater nutritive value than most other warm-season grasses and is highly palatable, but curing time for crabgrass hay is typically longer than for bermudagrass. Crabgrass hay was either not treated or treated with a lactic acid-*lactobacillus* preservative (LAL) and baled at 2 different moisture levels to determine effects on forage intake and digestion by lambs and in-situ digestibility by heifers. Twelve field plots of crabgrass were assigned randomly to 1 of 4 treatment combinations in a 2 × 2 factorial arrangement. Half of the plots were sprayed with LAL at mowing and half were not sprayed (U). Within LAL and U, half of the plots were baled at 28% (M28) moisture and half at 18% moisture (M18). In Exp. 1, 16 wether lambs were offered 1 of the 4 treatment combinations ad libitum and total feces were collected for 5-d following a 7-d dietary adaptation period. Digestibility of DM was greater ($P < 0.01$) for M28 vs M18 and from LAL vs U. Digestible DM intake (% of BW) was greater ($P < 0.05$) from LAL vs. U. In Exp. 2, in situ ruminal degradation kinetics were determined using 6 ruminally-cannulated heifers. The water-soluble fraction was greater ($P < 0.05$) from M28-LAL and M18-U vs M28-U, and effective degradability was greater ($P < 0.05$) from M28-LAL than the other treatment combinations. The slowly degraded fraction was greater ($P < 0.05$) for M28 vs M18. Therefore, treating crabgrass with LAL improved DM digestion and digestible DM intake by lambs and increased ruminal DM digestibility of hay baled at greater moisture.

Introduction

Crabgrass has an advantage in quality and palatability over many other perennial warm-season grasses, but it also dries slower than bermudagrass, possibly resulting in greater moisture in the hay at baling. Previous studies have reported that improperly preserved forages, or forages baled above 20% moisture, often undergo spontaneous heating that may lead to a reduction in nutritional value in hay (Collins et al., 1987, Turner et al., 2002). Few studies have evaluated how the application of an organic drying agent might affect moisture concentration and nutritive value of crabgrass at baling and after storage, or how it would affect intake, digestion and ruminal in situ disappearance kinetics. The objective of this study was to determine the effects of treatment with a lactic acid-*lactobacillus* preservative at the time of mowing and baling at 2 different moisture levels on voluntary intake and digestion kinetics by lambs fed crabgrass hay and ruminal DM disappearance kinetics of crabgrass hay by heifers.

Experimental Procedures

Forage harvesting and storage. A 4-acre field of common crabgrass was divided into 12 plots that were used in a randomized complete block design with a 2 × 2 factorial treatment arrangement to determine the impact of a lactic acid-*lactobacillus* hay preservative and moisture concentration at baling on DM intake and digestibility by lambs and in-situ digestibility by heifers. The 12 plots were grouped into 3 blocks of 4 plots, such that one plot within each block was assigned randomly to 1 of 4 treatment combinations. Half of the plots within each block were treated at the time of mowing with 2.5 oz/ton DM of a solution containing 11% lactic acid and non-viable *lactobacillus acidophilus* (LAL; Pro-Serve® II, Conklin Company Inc. AgroVantage® Division, Shakopee, Minn.) and half of the plots were not treated (U). Within LAL and U plots, half were baled at 18% (M18) and half at 28% moisture (M28). Six bales per plot were selected at random, weighed, and stored in insulated 6-bale stacks for a minimum of 45 d. Three bales from each block were randomly sampled using a standard hay core sampler prior to storage. The holes created by the core sampler were filled with expanding spray foam immediately prior to storage.

Intake and digestibility by lambs. Sixteen crossbred wether lambs (82 ± 1.6 lb) were offered 1 of 4 different crabgrass hay treatment combinations for free-choice consumption. Hay diets were a combination of bales from each of the 3 bales not sampled and the 3 bales sampled, prior to storage. Hay was chopped using a conventional brush shredder (Briggs & Stratton, 1450 Serious Clipper/Shredder; Cleveland, Ohio) prior to feeding to reduce waste. Lambs were housed in individual pens (3.6 × 5 ft) with expanded metal floors. Diets were offered throughout the day beginning at 0900, and lambs had free-choice access to trace mineralized salt and water. Following a 7-d dietary adaptation period, lambs were fitted with fecal collection bags and total feces were collected for 5 d. Hay samples were collected at each feeding, weighed, and dried at 122°F for DM determination. Unconsumed hay was removed daily at 0800, weighed, and dried at 122°F for DM determination. Feces were removed twice daily, weighed, then dried at 122°F. Data were analyzed statistically using the GLM procedures of SAS (SAS Inst. Inc., Cary, N.C.) with the individual animal as the experimental unit.

In-situ digestibility by heifers. The 6 bales from each plot were chopped through a conventional brush shredder and samples were taken and composited to represent each plot. After grinding

[1] Department of Animal Science, Fayetteville
[2] USDA/ARS, Marshfield, Wis.

through a 2-mm screen, the forage from each plot was placed into nylon bags. Bags were grouped within each original block and 9 bags from each plot within each block were suspended in the rumen of 2 different cannulated crossbred heifers (average weight = 1,321 lb). This resulted in 2 animal observations for each plot and a total of 6 animal observations per treatment combination.

The 6 ruminally cannulated crossbred heifers were housed in individual 9 ft × 14 ft pens with concrete floors in a closed barn. Pens were cleaned daily, and heifers had ad libitum access to water and bermudagrass hay along with a supplemental concentrate offered at 0.3% of body weight (BW). The nylon bags were submerged simultaneously into the ventral rumen following a 10-d dietary adaptation period, and incubated for 6, 12, 18, 24, 36, 48, 72, 96, or 120 h. After removal from the rumen, bags were submerged immediately in cold water to suppress microbial activity, then rinsed 10 times in a top-loading washing machine to remove any contamination from ruminal contents or microorganisms. Zero-h bags were not inserted in the rumen, but were washed as described above to determine the water-soluble fraction. Residual DM from each bag was used to estimate the percentage of the original DM that remained in the bags at each time period. These data were fit to a non-linear statistical model using PROC NLIN of SAS (SAS Inst. Inc., Cary, N.C.) to determine DM degradation kinetic parameter estimates. Forage quality and kinetic parameter estimates were analyzed with the MIXED procedures of SAS.

Results and Discussion

Intake and digestibility by lambs. Total DM intake (lb/d and % of BW) did not differ ($P > 0.16$) among treatments (Table 1). Dry matter digestibility was greater ($P < 0.01$) from M28 vs M18 (55.5 vs 50.1%) and from LAL vs U (56.0 vs 49.7%). Digestible DM intake (% of BW) was greater ($P < 0.05$) from LAL vs U (1.3 vs 1.0). Digestible DM intake (lb/d and % of BW) tended ($P < 0.10$) to be greater from M28 vs M18. In a previous study, digestibility of both DM and CP were inversely related to increasing levels of spontaneous heating (McBeth et al., 2001).

In-situ digestibility by heifers. Concentrations of N (Table 2) were greater ($P < 0.05$) from M28 than from M18. This is consistent with other data evaluating heat damage for forages. When spontaneous heating occurs, soluble carbohydrates are oxidized to heat and carbon dioxide. This generally reduces the concentration of combustible nutrients, but concentrates the non-combustible components such as N and minerals. Concentrations of NDF tended ($P < 0.10$) to be greater from M28 compared with M18, but concentrations of ADF, hemicellulose, and lignin did not differ ($P > 0.10$) among treatment combinations.

The concentration of N bound in the ADF fraction (ADIN) is used routinely to estimate heat damage to the protein fraction of hay. Concentrations of ADIN were greater ($P < 0.05$) from the M28 hay compared with the M18 hay. Spraying the forage with LAL at the time of mowing had no impact ($P > 0.10$) on any of the forage quality measurements.

A moisture level × treatment interaction was detected ($P < 0.05$) for the water-soluble fraction of the crabgrass hay (Table 3); M28-LAL and M18-U had a greater water-soluble fraction than that of M28-U. The water-soluble fraction of M18-LAL was not different ($P > 0.10$) from any of the other treatment combinations. The water-soluble fraction is composed generally of plant sugars and water-soluble protein. When hay is baled at excessive moisture, these fractions may be oxidized or modified chemically, forming insoluble compounds that are analyzed as ADIN. The differential in the water-soluble fraction between LAL and U within M28 but not within M18 indicates that LAL was effective in controlling oxidation of soluble sugars when the hay was baled at excessive moisture.

The slowly-degradable fraction of M28 was greater ($P < 0.05$) than that of M18 (Table 3), but the digestion lag time and the rate of DM degradation did not differ ($P > 0.10$) among treatment combinations. A moisture level × treatment interaction was detected ($P < 0.05$) for the undegradable fraction of the crabgrass hay; M28-LAL had the lowest ($P < 0.05$) undegradable fraction compared with the other treatment combinations. Effective ruminal DM degradation was greatest ($P < 0.05$) from M28-LAL, followed by M18-U. Effective ruminal DM degradation was lowest ($P < 0.05$) from M28-U and M18-LAL, but that of M18-LAL did not differ from that of M18-U.

Implications

Based on these results, treating crabgrass hay with a lactic acid-*lactobacillus* product and baling at 28% moisture may improve both DM digestion and digestible DM intake by lambs and enhance digestibility by cattle. This potentially allows producers to bale crabgrass at greater moisture content without adversely affecting forage quality, but further work should be conducted to insure other negative issues will not occur from feeding heat-damaged crabgrass to lambs or cattle.

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Table 1. Intake and digestibility of crabgrass hay treated or untreated with a lactic acid-lactobacillus preservative and baled at 18 or 28% moisture.

	28% moisture		18% moisture			
Item	LAL[a]	U	LAL	U	SEM	effect[b]
Initial Lamb wt, lb	85	86	88	85	6.5	ns
DM intake, lb/d	1.85	1.92	2.01	1.50	0.145	ns
DM intake, % of BW	2.2	2.3	2.3	1.8	0.23	ns
DM digestion, %	58.9	52.1	53.0	47.2	1.37	M,T
Digestible DM intake, lb/d	1.08	1.00	1.07	0.71	0.080	m,T
Digestible DM intake, % of BW	1.3	1.2	1.2	0.8	0.11	m,T

[a] LAL = treated at mowing with 2.5 oz/ton DM of a solution containing 11% lactic acid and non-viable lactobacillus acidophilus; U = not treated.
[b] ns = not different statistically; M and m = moisture effects ($P < 0.05$ and 0.10, respectively); T = spray treatment effect ($P < 0.05$).

Table 2. Forage quality measurements of untreated crabgrass hay or hay treated with a lactic acid-lactobacillus preservative at the time of mowing and baled at either 18 or 28% moisture that was used in the in-situ degradation experiment.

	Treatments					
	28% moisture		18% moisture			
Item	LAL	U	LAL	U	SEM	Effect[b]
N, %	2.86	2.72	2.65	2.66	0.064	M
NDF, %	68.6	72.2	68.2	68	1.37	m
ADF, %	36.8	38.5	37.9	37.5	0.98	ns
Hemicellulose, %	31.8	33.7	30.3	30.4	1.38	ns
ADL[c], %	5.3	5.8	4.7	4.8	0.72	ns
ADIN[d], % of DM	0.96	1.08	0.71	0.71	0.098	M
ADIN, % of N	33.9	39.8	27.1	26.9	4	M

[a] LAL = treated at mowing with 2.5 oz/ton DM of a solution containing 11% lactic acid and non-viable lactobacillus acidophilus; U = not treated.
[b] ns = not different statistically; M and m = moisture effects ($P < 0.05$ and 0.10, respectively).
[c] Acid-detergent lignin.
[d] Acid-detergent insoluble nitrogen

Table 3. Ruminal DM degradation parameters of untreated crabgrass hay or crabgrass hay treated with a lactic acid-lactobacillus preservative at the time of mowing and baled at either 18 or 28% moisture.

	Treatments[a]					
	28% moisture		18% moisture			
Item	LAL	U	LAL	U	SEM	Effect[b]
Water soluble fraction, %	18.49^{x}	13.66^{y}	16.03^{xy}	17.98^{x}	1.145	M×T
Slowly-degradable Fraction, %	63.32	65.32	61.24	60.04	1.36	M
Degradation rate constant, /h	0.048	0.044	0.047	0.047	0.0089	ns
Degradation lag time, h	1.87	2.1	1.76	1.81	0.981	ns
Undegraded fraction, %	18.2^{y}	21.02^{x}	22.73^{x}	21.98^{x}	1.012	M,t, M×T
Effective ruminal degradation, %	54.09^{x}	49.22^{z}	50.45^{yz}	51.62^{y}	2.556	T,M×T

[a] LAL = treated at mowing with 2.5 oz/ton DM of a solution containing 11% lactic acid and non-viable lactobacillus acidophilus; U = not treated.
[b] ns = not different statistically; M = moisture effects ($P < 0.05$); T and t = spray treatment effect ($P < 0.05$ and $P < 0.10$, respectively), M×T = moisture by spray treatment interaction.
[xyz] Means within a row without a common superscript letter differ ($P < 0.05$).

Effect of Supplemental Cottonseed Cake and Stocking Rate on Performance of Growing Calves Grazing Bermudagrass Pasture

M.S. Gadberry[1], P. Beck[2], T. Hess[3], D. Hubbell, III[3], J. Butterbaugh[4], B. Rudolph[4], and M. Smith[4]

Story in Brief

Seventy-two calves grazing bermudagrass pasture were used to determine the effects of stocking rate (SR) and cottonseed cake (CC) supplementation on calf performance. Calves were stocked to 2-acre paddocks at rates of 1.5, 2, or 2.5 head/acre. In addition, paddocks were further allotted to 1 of 3 CC supplementation rates, 0, 0.3, or 0.6% BW. Overall, no interaction was detected between SR and CC for initial BW (P = 0.90), ADG (P = 0.58), or BW gain per acre (P = 0.68). Average daily gain increased linearly with increased level of CC (P = 0.001). Calves supplemented at 0.3% BW tended (P = 0.06) to be more efficient at converting supplement into additional BW gain/acre compared to calves supplemented at 0.6% BW. Overall, supplementation enhanced performance of summer stockers grazing bermudagrass, and cottonseed cake appears to be a viable supplemental feed option.

Introduction

The Energy Independence and Security Act of 2007 has set a goal of 36 billion gallons of renewable fuels being produced by 2022 with an emphasis for advanced biofuels (fuels from biomass) securing production beyond 2016. Until cost effective technologies are available for converting biomass to fuel, fuels derived from starchy grains or oilseeds will be the leading alternatives to fossil fuel. In response to the increased demand for plant derived oils, Hollybrook Cottonseed Processing erected a cotton extruding facility near Lake Providence, La.

The residual byproduct from extracting oil from delinted cottonseed is a cottonseed cake that contains 31% CP, 38% ADF, and 46% NDF. Because of the high protein and low starch content, this byproduct may be suitable as a good supplemental protein and complimentary energy source for cattle fed a high forage diet.

Cattle grazing bermudagrass pasture have been shown to exhibit greater performance when supplemented with protein (Woods et al., 2004) or energy (Aiken, 2002). As a result, the objective of this project was to evaluate cottonseed cake as a supplement for growing calves grazing bermudagrass pasture at varying stocking rates.

Experimental Procedures

Seventy-two beef calves (638 ± 8 lb) were randomly assigned to 1 of 18, 2-acre bermudagrass pastures at the Livestock and Forestry Branch Station near Batesville, Ark. Pastures were stocked (SR) at 1.5, 2, or 2.5 head/acre. In addition, within each stocking rate, calves were offered cottonseed cake (CC) at 0, 0.3 or 0.6% BW, daily. Calves completely consumed the supplement; therefore, weigh-back of unconsumed feed was not necessary. Body weights were collected at the beginning of the study, conclusion of grazing, and monthly throughout the grazing period. Forage mass was measured on d 0, 28, 56, and 84 using a calibrated rising disk meter. Forage allowance was expressed as lb DM / lb BW to account for differences associated with stocking rates. Calves had free choice access to a complete mineral that contained 14.2% Ca, 6% P, 18% NaCl, 2.5% Mg, 0.3% S, 0.3% K, 9,000 ppm Zn, 6,500 ppm Mn, 3,000 ppm Cu, 184 ppm I, 39 ppm Se and 25 ppm Co (Furst-McNess, Freeport, Ill.). Mineral consumption was monitored weekly by weighing back unconsumed portions prior to replenishing consumed portions.

Supplement intake, initial BW, ADG, and BW gain per acre were analyzed as a 3 by 3 factorial design using pasture as the experimental unit. Sample date was added to the model as an independent variable when evaluating treatment effects on measures of forage mass. Analysis of variance was performed using JMP statistical package (SAS Inst., Inc., Cary, N.C.). Linear and quadratic orthogonal contrasts were used to determine the effect of CC and SR on response variables with the exception of gain:feed ratio where only 2 response levels were comparable.

Results and Discussion

Dry weather condition resulted in early grazing termination of 2 paddocks by d 49 and 7 additional paddocks by d 56. Although 9 of the original 18 paddocks were grazed throughout a 77-d duration, the number of grazing days (66 ± 12.7 d) was not affected by SR (P = 0.33), CC (P = 0.47), or the interaction of SR and CC (P = 0.81).

Forage allowance was affected by the main effects of day (P = 0.001), SR (P = 0.001), but not CC (P = 0.22). Forage mass declined over time in a cubic manner (P = 0.03). On d 28, there was 451 lb/acre less DM compared to d 0; on d 56, there was 271 lb/acre less DM compared to d 28; and by d 84, there was 722 lb/acre less DM compared to d 56.

As stocking rate increased, forage allowance declined linearly (P = 0.001; Table 1), which was to be expected. By design, supplemental feed consumption was similar among SR (Table 1) and

1 Department of Animal Science, Little Rock
2 Department of Animal Science, Hope
3 Department of Animal Science, Batesville
4 Furst-McNess, Freeport, Ill.

increased with increased level of CC (Table 2). Mineral consumption was monitored during the study and responded quadratically among SR ($P = 0.04$, Table 1) and was not explainable. Mineral consumption also responded quadratically ($P = 0.004$) to CC with the 0.3% CC having the lowest mineral intake.

There were no significant interactions between SR and CC for initial BW ($P = 0.90$), ADG ($P = 0.58$), or BW gain per acre ($P = 0.68$). As a result, only performance responses associated with the main effect of SR and CC are reported.

Despite the linear reduction in forage allowance as SR increased, ADG was not affected by SR (Table 1). Gain per acre increased linearly with increased stocking rate ($P = 0.007$).

Independent of SR, CC supplementation increased ADG and BW gain/acre (Table 2). Supplemented calves had an ADG nearly 1 lb/d above controls. All calves gained well for summer stockers during a summer that produced suboptimal forage growing conditions. There was a tendency for a reduction ($P = 0.06$) in feed conversion determined by the ratio of additional BW gain/acre above non-supplemented cattle to the amount of supplemental feed provided.

Implications

Cottonseed cake appears to be a viable supplement for summer stockers grazing bermudagrass. No observed interaction between supplementation rate and stocking rate suggests supplementing at a rate up to 0.6% BW may not result in substitution. However, gain efficiency was not improved by supplementing beyond 0.3% BW.

Acknowledgments

The authors express appreciation to Furst-McNess (Freeport, Ill.) for supporting this project through donation of cottonseed cake and mineral.

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Table 1. Effect of stocking rate on summer stocker performance.

	Stocking rate (head/acre)				
	1.5	2.0	2.5	S.E.	(P-value)[a]
Forage Allowance, lb DM/lb BW[b]	2.5	1.7	1.4	0.14	0.001L
Suppl. Intake, as-fed, lb/head/d	2.2	2.2	2.2	0.03	0.96
Mineral Intake, as-fed, lb/head/d	0.39	0.49	0.41	0.036	0.04Q
Initial BW, lb	631	647	640	7.3	0.51
ADG, lb/d	2.4	2.1	2.3	0.15	0.44
BW gain, lb/acre	259	262	362	22.5	0.007L

[a]Linear and quadratic contrasts were fit. L indicates a significant linear effect, Q indicates a significant quadratic effect. Other P-values are from F-test of the effect in the Analysis of Variance.
[b]Mean forage allowance over entire grazing period.

Table 2. Effect of cottonseed cake supplementation rate (CC) on summer stocker performance.

	Supplementation rate (% BW, as-fed basis)				
	0	0.3	0.6	SE	(P-value)[a]
Forage Allowance, lb DM/lb BW[b]	2.0	1.9	1.6	0.14	0.22
Suppl. Intake, as-fed, lb/head/d	0	2.2	4.4	0.03	0.001L
Mineral Intake, as-fed, lb/head/d	0.55	0.36	0.45	0.036	0.004Q
Initial BW, lb	643	639	636	6.3	0.84
ADG, lb/d	1.6	2.4	2.7	0.18	0.001L
BW gain, lb/acre	199	334	350	22.5	0.05Q
G:F, lb gain/acre:lb CC	--	0.59[a]	0.35[b]	0.08	0.06

[a]Linear and quadratic contrasts were fit. L indicates a significant linear effect, Q indicates a significant quadratic effect. Other P-values are from F-test of the effect in the Analysis of Variance.
[b]Mean forage allowance over entire grazing period.

Glycerol as a Supplement for Weaned Calves Grazing Wheat Pasture

Ken Coffey[1], Greg Montgomery[2], Jim Greenburg[3], Don Hubbell[3], James Caldwell[1], Dirk Philipp[1], and Lorri Hardin[1]

Story in Brief

Glycerol is a liquid co-product of the biodiesel industry and has potential as an energy supplement for livestock. In previous research, glycerol was fermented very rapidly in the rumen, but sometimes caused a reduction in overall dry matter intake by cattle. Thirty crossbred steer and 40 crossbred heifer calves were used at 2 sites to evaluate the impact of low level glycerol supplementation for weaned calves grazing wheat pasture. Steers grazed wheat pastures at the Livestock and Forestry Branch Experiment Station near Batesville for 62 d beginning February 2, and heifers grazed wheat pastures at the Southeast Research and Extension Center near Monticello for 46 d beginning March 11. Calves were allocated randomly into 6 groups of steers and 8 groups of heifers. Animals were either not offered supplemental concentrate or were offered either cracked corn (CORN) or glycerol (GLY) at a level of 0.33% of BW Monday through Friday. Site by treatment interactions did not occur so data were pooled across locations. Calf weights did not differ among the 3 treatments, but gain during the second period tended ($P = 0.11$) to be lower from calves offered GLY. Numerically, response to supplemental CORN was low and that to supplemental GLY was negative, but gains were high for all treatments. Therefore, this level of supplement, especially of glycerol, may not be needed for calves grazing winter annuals.

Introduction

Crude glycerin is a co-product in the production of bio-diesel that contains mainly glycerol and small portions of water, methanol, and other impurities. Limited research reported that glycerol was fermented rapidly in the rumen (Rémond et al., 1993) and increased proportions of propionate (DeFrain et al., 2004) but decreased DM intake (DeFrain et al., 2004). However, glycerol was substituted for grain in high concentrate diets in much of the previous research. Wheat forage protein is degraded very rapidly in the rumen and is absorbed as ammonia. The ammonia is converted to urea and can raise blood urea nitrogen concentrations above acceptable levels causing subclinical toxicity in calves. Availability of a rapidly-fermented energy source can benefit the ruminant animal by providing substrates for the rumen microbes to use along with the ammonia from the winter annuals to make microbial protein. This should benefit the calf by allowing more efficient protein utilization. Our objective was to determine the impact of supplementation with glycerol or corn on growth performance by calves grazing wheat pastures.

Experimental Procedures

Thirty crossbred steer and 40 crossbred heifer calves, all of Gelbvieh × Angus breeding, grazed wheat pastures at 2 sites. All calves originated at the Livestock and Forestry Branch Experiment Station (LFBES) near Batesville and were weaned in October prior to starting the study. Steers remained and grazed wheat pastures at the LFBES near Batesville for 62 d beginning February 2, and heifers grazed wheat pastures at the Southeast Research and Extension Center near Monticello for 46 d beginning March 11. All wheat was sod-seeded into existing bermudagrass pastures using no-till (Batesville) or light-disking (Monticello) seeding techniques.

Calves were allocated randomly by BW into 6 groups of steers and 8 groups of heifers. Groups of calves were allocated randomly to either no supplemental concentrate (CONT; 2 groups of steers and 3 groups of heifers), cracked corn (CORN; 2 groups of steers and heifers), or glycerol (GLY; 2 groups of steers and 3 groups of heifers) at a level of 0.33% of BW Monday through Friday. Groups were then assigned randomly to 1 of 6 (steers) or 1 of 8 (heifers) pastures at the respective locations. All pastures were stocked initially at 1 head/acre. The groups were moved to a different pasture every 14 d to minimize the impact of pasture variation. Calves were weighed without removal from pasture or water at the beginning and end of the study and after approximately 28 d on the study. Supplements were offered at 9:30 am each day to avoid disturbing the normal grazing patterns of the calves.

Results and Discussion

Calves were somewhat reluctant to consume the glycerol initially at both locations. Initially, each group was offered half of the allotted glycerol level top-dressed with cracked corn. Once calves consumed the mixture, glycerol portions were increased and corn portions decreased until only glycerol was offered. This process required approximately 1 wk.

1 Department of Animal Science, Fayetteville
2 University of Arkansas Southeast Research and Extension Center, Monticello
3 Department of Animal Science, Batesville

No treatment × site interactions were detected ($P > 0.10$) for calf weights or gains. Therefore, data were pooled across study sites (Table 1). Calf gains did not differ ($P > 0.10$) among treatments during the study. However, calf gains during Period 2 were lower numerically ($P = 0.11$) from GLY compared with CONT and CORN. The reason for the reduction in gain during Period 2 is unclear, but was consistent at both locations.

Feed-grade glycerol still contains minimal concentrations of methanol, which is a concern in feeding livestock. Other studies have reported reductions in feed intake when glycerol was offered at 10% of the diet. In the present study, glycerol was offered at 0.33% of BW Monday through Friday, which is the equivalent to offering 0.25% of BW over a 7-day period. At this level of intake, glycerol would comprise 10% of the diet if the calves consumed forage dry matter at 2.5% of their BW daily. Therefore, our findings appear to be consistent with those from others who fed glycerol as part of a high-concentrate diet.

Implications

Glycerol is a liquid feedstuff that has potential for use as an animal feedstuff. However, caution should be used in feeding it since the upper limit of glycerol inclusion in the diet appears to be below 10% of total dry matter intake.

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Table 1. Daily gain by weaned calves grazing wheat pasture and offered supplements of corn or glycerol at 0.33% of body weight on Monday through Friday.

	Control	Corn	Glycerol	SEM
Calf weights, lb				
Initial	588	590	588	4.6
Intermediate[a]	675	680	681	7.4
Final	766	773	755	9.7
Gain, lb				
Period 1	86	89	92	6.2
Period 2	91[b]	94[b]	75[c]	6.0
Cumulative	178	183	167	9.1
Daily gain, lb/d				
Period 1	3.14	3.25	3.35	0.230
Period 2	3.4	3.49	2.76	0.270
Cumulative	3.27	3.39	3.09	0.191

[a] Intermediate weights were measured after approximately 28 d of grazing.
[b,c] Means within a row without a common superscript letter differ ($P = 0.11$).

Body Condition and Forage Type Influence Intramuscular and Rump Fat, and Reproductive Performance of Postpartum Brahman-influenced Cows[1]

M.L. Looper[2], S.T. Reiter[3], S. Nabhan[3], R. Flores[4], C.R. Bailey[3], A.H. Brown, Jr.[3], and C.F. Rosenkrans, Jr.[3]

Story in Brief

Multiparous Brahman-influenced cows were managed to achieve marginal (BCS = 4.9 ± 0.1; n = 55) or moderate (BCS = 6.5 ± 0.1; n = 55) body condition (BC) to determine the influence of forage type on estrous characteristics, intramuscular fat percentage (IMF), rump fat (RF), and reproductive performance. Cows within each BC were randomly assigned to graze either common bermudagrass (CB; n = 3 pastures) or endophyte-infected tall fescue (EI; n = 3 pastures) during a 60-d breeding season. Body weight and BC were recorded during the breeding season (d 0, 30 and 60). Cow IMF and RF were measured via ultrasonography at initiation and termination (d 60) of the breeding season. Cows grazing CB tended ($P = 0.07$) to have an increase in BC during the breeding season over cows grazing EI. At d 60, IMF and RF were less ($P < 0.01$) in marginal BC cows compared with cows in moderate BC. Cows grazing CB had increased RF during the breeding season, while cows grazing EI lost RF ($P < 0.05$). Number of mounts, duration of estrus, and quiescence between mounts did not differ ($P > 0.10$) between forage type, BC, or both. Pregnancy rates were similar ($P > 0.10$) among moderate (90%) and marginal (87%) BC cows grazing CB and moderate BC cows grazing EI (88%); however, marginal BC cows grazing EI tended ($P = 0.09$) to have decreased pregnancy rates (68%). Cows grazing EI during the breeding season lost adipose stores, and pregnancy rates tended to be lower in marginal BC cows grazing EI.

Introduction

Reproduction of cows is influenced by nutrient intake and subsequent changes in body energy reserves. Cows in thin body condition at calving have an extended postpartum anestrous period and may not become pregnant during the breeding season (Selk et al., 1988).

Cattle grazing toxic tall fescue are exposed to numerous ergot alkaloids causing several stressful disorders, collectively characterized as fescue toxicosis. Decreased progesterone in heifers fed toxic fescue was prevented by high energy supplemental diets (Estienne et al., 1990). Brahman-influenced cows tend to be more tolerant of the negative effects of toxic fescue (Brown et al., 1997). This may be a function of the heat tolerance of Brahman-influenced cattle. The direct effect of toxic fescue on reproductive performance of cows is not fully understood; therefore, objectives of this experiment were to determine the influence of body condition and forage type on estrous characteristics, intramuscular fat percentage, rump fat, and reproductive performance of Brahman-influenced cows.

Experimental Procedures

The committee for animal welfare at the USDA-ARS, Dale Bumpers Small Farms Research Center, Booneville, Ark., approved animal procedures used in this study. Spring-calving, multiparous Brahman-influenced (1/4 to 3/8 Brahman) cows were managed to achieve marginal (BCS = 4.9 ± 0.1; 1 = emaciated to 9 = obese; Wagner et al., 1988; n = 55) or moderate (BCS = 6.5 ± 0.1; n = 55) body condition (BC). Cows grazed stockpiled and spring-growth, endophyte-infected tall fescue pastures at a stocking rate of either 1 cow/0.9 acres (marginal BC) or 1 cow/2 acres (moderate BC) for 153 d before initiation of the breeding season. Calves were allowed to suckle their dams throughout the experiment. Cows within each BC were randomly assigned to graze either common bermudagrass (CB; n = 3 pastures) or endophyte-infected tall fescue (EI; n = 3 pastures) during a 60-d breeding season. Body weight and BC were recorded during the breeding season (d 0, 30 and 60). Intramuscular fat percentage (IMF) and rump fat (RF) were measured via ultrasonography (Aloka SSD-500V with a 3.5-MHz linear array transducer) at d 0 and 60 of breeding season.

On d 0, all cows were fitted with a radiotelemetry (Heatwatch, HW; DDx Inc., Denver, Colo.) transmitter and exposed to bulls (1 bull/20 cows). Estrous activity was recorded during the first 30 d of the 60-d breeding season (initiation date = May 14). Activities associated with estrus were recorded for each cow and included date and time of onset of estrus, number of mounts received, duration (h) of estrus, and quiescent period. Mean quiescence was defined as the interval between each successive mount and was calculated as: mean quiescence period = duration of estrus (h)/number of mounts received – 1. Mounts were standing events lasting 2 sec or more between the beginning and end of estrus as detected by HW. The first of 2 mounts within 4 h determined onset of estrus. Termination of estrus was the final mount, with a single mount 4 h prior, and no activity the next 12 h. Cows that lost their HW transmitter following initiation of estrus were removed from the statistical analyses for estrous characteristics. Cows were palpated for pregnancy at weaning; 96 d after the end of the breeding season.

Data were analyzed as a 2 x 2 factorial arrangement of treatments (marginal or moderate BC and CB or EI forage type) within a completely randomized design; pasture was used as a random

[1] Names are necessary to report factually on available data; however, the USDA does not guarantee or warrant the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that also may be suitable.

[2] USDA-ARS, Dale Bumpers Small Farms Research Center, Booneville

[3] Department of Animal Science, Fayetteville

[4] University of Arkansas for Medical Sciences, Little Rock

effect. The effect of forage type, BC, and the interaction on BW, BCS, changes in BW and BCS, IMF, RF, changes in IMF and RF, mean duration of estrus, number of mounts received, and quiescence between mounts were analyzed by ANOVA using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Pregnancy rate was analyzed by Chi-square analysis of SAS.

Results and Discussion

Cow BW was influenced ($P < 0.01$) by BC (Table 1); BW and BW change were not affected ($P \geq 0.27$) by a forage x BC interaction. Cows in moderate BC were heavier at d 0, 30 and 60 than cows in marginal BC. Cows grazing CB had greater BW at d 30 and 60 of the breeding season. Cows grazing EI gained less (58 lb; $P < 0.01$) than cows grazing CB (124 lb) during the 60-d breeding season regardless of initial BC (Table 1).

Initial (d 0) average BCS was 4.9 ± 0.1 for marginal BC cows and 6.5 ± 0.1 for cows in moderate BC (Table 2). Body condition score and BCS change were not affected ($P \geq 0.61$) by a forage x BC interaction. Cows in marginal BC had lower ($P < 0.01$) BCS at d 30 and 60 of the breeding season than moderate BC cows. Change in BCS during the breeding season was affected ($P < 0.01$) by BC and tended ($P = 0.07$) to be influenced by forage type (Table 2). Cows in moderate BC (-0.4 ± 0.1 BCS units) lost body condition during the breeding season while cows in marginal BC gained (0.2 ± 0.1 BCS units). We (Flores et al., 2007) recently reported that cows in moderate BC lost more body condition during the postpartum period than thin BC cows. This may be attributed to lower nutrient maintenance requirements for marginal BC cows compared with moderate-BC cows (Hess et al., 2005).

Intramuscular fat percentage was similar ($P = 0.32$) between BC groups at d 0; however, moderate BC cows had greater ($P < 0.01$) IMF at d 60 of the breeding season than marginal BC cows (Table 3). Rump fat was less ($P < 0.01$) in marginal BC cows than cows in moderate BC at d 0. This difference in RF between BC groups remained at d 60 (Table 3). Wagner et al. (1988) reported total carcass fat was correlated (r = 0.91) with visual BCS in cattle. Cows grazing EI lost ($P = 0.03$) RF during the breeding season compared with cows grazing CB (Table 3). It is well established that DMI is reduced in ruminants consuming toxic fescue diets, and decreased DMI results in loss of body condition of cattle.

Number of mounts, duration of estrus, and quiescence between mounts did not differ ($P > 0.10$) between forage type, BC, or both (Table 4). Percentage of cows (overall mean = 73%) exhibiting estrus during the first 30 d of the breeding season was not influenced by forage type, BC, or both. Pregnancy rates were similar ($P > 0.10$) among moderate (90%) and marginal (87%) BC cows grazing CB and moderate BC cows grazing EI (88%); however, marginal BC cows grazing EI tended ($P = 0.09$) to have decreased pregnancy rates (68%).

Implications

Cows grazing endophyte-infected tall fescue during the breeding season may lose adipose stores resulting in decreased pregnancy rates. However, cows in adequate body condition may be more tolerant of the negative effects of consuming endophyte-infected tall fescue.

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Table 1. Body weight and body weight change of cows grazing either common bermudagrass or endophyte-infected tall fescue during the breeding season.

	Forage						
	Bermudagrass		Fescue		*P* value		
Item	Marginal BC[1]	Moderate BC	Marginal BC	Moderate BC	F[2]	BC	F x BC
No. of cows	30	30	25	25	-	-	-
BW, lb							
d 0	1129 ± 29	1338 ± 29	1098 ± 33	1287 ± 31	0.26	0.01	0.76
d 30	1236 ± 29	1443 ± 29	1159 ± 31	1373 ± 31	0.01	0.01	0.92
d 60	1258 ± 26	1448 ± 29	1151 ± 31	1351 ± 31	0.01	0.01	0.85
BW change, lb	130 ± 9	119 ± 11	53 ± 11	62 ± 11	0.01	0.86	0.27

[1]Body condition, [2]Forage.

Table 2. Body condition (BC) score and BC change of cows grazing either common bermudagrass or endophyte-infected tall fescue during the breeding season.

	Forage						
	Bermudagrass		Fescue		*P* value		
Item	Marginal BC	Moderate BC	Marginal BC	Moderate BC	F[1]	BC	F x BC
No. of cows	30	30	25	25	-	-	-
BCS							
d 0	4.9 ± 0.1	6.5 ± 0.1	4.9 ± 0.1	6.6 ± 0.1	0.83	0.01	0.98
d 30	5.3 ± 0.2	6.4 ± 0.2	5.2 ± 0.2	6.2 ± 0.2	0.68	0.01	0.99
d 60	5.4 ± 0.2	6.3 ± 0.2	4.9 ± 0.2	5.9 ± 0.2	0.14	0.01	0.63
BCS change	0.5 ± 0.2	-0.2 ± 0.2	-0.1 ± 0.2	-0.6 ± 0.2	0.07	0.01	0.61

[1]Forage.

Table 3. Intramuscular fat percentage (IMF) and rump fat (RF) of cows in either moderate or marginal body condition (BC) grazing either common bermudagrass or endophyte-infected tall fescue during the breeding season.

	Forage						
	Bermudagrass		Fescue		*P* value		
Item	Marginal BC	Moderate BC	Marginal BC	Moderate BC	F[1]	BC	F x BC
No. of cows	30	30	25	25	-	-	-
IMF, %							
d 0	3.9 ± 0.2	4.2 ± 0.2	3.9 ± 0.2	4.0 ± 0.2	0.61	0.32	0.68
d 60	3.7 ± 0.1	4.3 ± 0.1	3.6 ± 0.2	4.1 ± 0.2	0.42	0.01	0.85
IMF change	-0.2 ± 0.2	0.2 ± 0.2	-0.3 ± 0.2	0.1 ± 0.2	0.78	0.02	0.87
RF, inches							
d 0	0.39 ± 0.08	0.79 ± 0.08	0.39 ± 0.08	0.87 ± 0.08	0.52	0.01	0.58
d 60	0.43 ± 0.08	0.83 ± 0.08	0.35 ± 0.08	0.79 ± 0.08	0.40	0.01	0.76
RF change	0.04 ± 0.04	0.04 ± 0.04	-0.04 ± 0.04	-0.08 ± 0.04	0.03	0.62	0.68

[1]Forage.

Table 4. Influence of body condition (BC) and forage type (F) on estrous characteristics of cows.

	Forage						
	Bermudagrass		Fescue		*P* value		
Item	Marginal BC	Moderate BC	Marginal BC	Moderate BC	F	BC	F x BC
No. of cows	26	20	14	15	-	-	-
Estrus, %	73	80	64	73	0.50	0.49	0.60
Dur. of estrus, h	5.0 ± 1.1	6.4 ± 1.3	6.2 ± 1.6	5.7 ± 1.5	0.88	0.72	0.42
# of mounts	12.2 ± 2.7	13.8 ± 2.9	8.8 ± 3.7	11.6 ± 3.4	0.49	0.43	0.81
Quiescence[1]	0.7 ± 0.1	0.6 ± 0.2	0.8 ± 0.2	0.7 ± 0.2	0.64	0.54	0.93

[1]Quiescence between mounts, h.

Effects of Bovine Somatotropin and Suckling on Reproductive Performance, Ovarian Follicles, and Concentrations of Ghrelin, GH, and IGF-I in Postpartum Brahman-influenced Cows[1]

R. Flores[2], M.L. Looper[3], R.W. Rorie[2], C.R. Bailey[2], D.M. Hallford[4], S.T. Reiter[2], and C.F. Rosenkrans, Jr.[2]

Story in Brief

Effects of bovine somatotropin (bST) and calf suckling on reproductive performance, number of follicles, and serum concentrations of ghrelin, growth hormone (GH), and insulin-like growth factor-I (IGF-I) were examined in postpartum Brahman-influenced beef cows. Cows (n = 100; mean BCS = 5.7 ± 0.1; mean BW = 1,261 ± 19 lb) were blocked by suckling status (n = 71 suckled; n = 29 not suckled) and treated twice with bST or no bST (control) every 2 wk for 4 wk (d -28 and -14) beginning at 28 d prior to breeding. Blood was collected at each bST treatment and initiation (d 0) of a 70-d breeding season. Ultrasound was performed on d 0 to determine number of follicles ≥ 8 mm. Concentrations of ghrelin were greater ($P < 0.05$) on d -14 and 0 than d -28. Cows treated with bST had greater ($P < 0.05$) concentrations of GH on d -14 and 0 than control cows. On d -14 and 0, bST-non-suckled cows had greater ($P < 0.05$) concentrations of IGF-I than bST-suckled cows. Pregnancy rates tended ($P = 0.08$) to be greater for control-suckled (100%) and bST-suckled (92%) cows than control-non-suckled (86%) and bST-non-suckled (80%) cows. Treatment with bST increased concentrations of IGF-I in suckled beef cows; however, the influence of GH on reproduction may be mediated differentially depending on suckling status.

Introduction

Calf suckling is a major factor that influences the postpartum anestrous interval in beef cattle (Short et al., 1990). The nutritional status of cattle is communicated within the hypothalamic-pituitary-ovarian axis via metabolic hormones that include growth hormone (GH) and insulin-like growth factor-I (IGF-I; Keisler and Lucy, 1996; Hess et al., 2005). Treatment of Brahman-influenced cows with bovine somatotropin (bST) prior to breeding increased first-service conception and pregnancy rates during the first 3 d of the breeding season (Flores et al., 2007). Further, postpartum bST treatment increased the size of the dominant follicle in anestrous cows and increased the concentrations of IGF-I in thin beef cows (Flores et al., 2008). Ghrelin is a peptide hormone produced by ruminal tissue of cattle whose primary role is to initiate DM intake. Ghrelin stimulates GH release and thus may serve as an endocrine signal that integrates energy balance and reproduction (Garcia et al., 2007). A better understanding of the effects of suckling and bST on ovarian and endocrine responses in Brahman-influenced cattle is warranted; therefore, objectives were to determine the effects of suckling and bST on reproductive performance, number of follicles and serum concentrations of ghrelin, GH, and IGF-I in postpartum Brahman-influenced cows.

Experimental Procedures

Spring-calving crossbred (1/4 to 3/8) multiparous Brahman-influenced cows (n = 100; mean BCS = 5.7 ± 0.1; mean BW = 1,261 ± 19 lb) were blocked by suckling status (n = 71 suckled; n = 29 not suckled). Management of suckled cows was such that calves were allowed to suckle their dams throughout the experiment. Cows grazed endophyte infected tall fescue pastures during the cooler months and bermudagrass pastures during the warmer months.

Beginning 36 ± 2 d postpartum, cows were randomly assigned to treatment with or without bST. Control cows received no bST treatment, and treated cows were administered bST (500 mg, s.c.; Posilac, St. Louis, Mo.) on d -28 and -14 before the breeding season. Ultrasonography (Aloka SSD 500 V ultrasound scanner equipped with a 7.5 MHz linear array transrectal transducer; Aloka Co. Ltd., Wallingford, Conn.) was performed at the initiation (d 0) of a 70-d breeding season to determine the number of follicles ≥ 8 mm. Blood samples were obtained from cows at bST treatment (d -28 and -14) and d 0. Serum concentrations of hormones were determined in duplicate aliquots using radioimmunoassay procedures.

The effect of bST treatment and calf suckling on the number of follicles ≥ 8 mm was analyzed by ANOVA using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). Comparisons of concentrations of GH, IGF-I, and ghrelin on d -28, -14, and 0 were analyzed using the MIXED procedure of SAS for repeated measures. If

[1] Names are necessary to report factually on available data; however, the USDA does not guarantee or warrant the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may be suitable. This work was supported in part by USDA, Agricultural Research Service cooperative agreement #58-6227-8-040.

[2] Department of Animal Science, Fayetteville

[3] USDA-ARS, Dale Bumpers Small Farms Research Center, Booneville

[4] Department of Animal and Range Sciences, New Mexico State University, Las Cruces, N.M.

the interaction of bST treatment x day, suckling x day, or bST treatment x suckling x day interaction was significant ($P < 0.05$), then mean separations were evaluated on each day using the PDIFF function of SAS. Chi-square analysis using the FREQ procedure of SAS was utilized to evaluate categorical data.

Results and Discussion

Treatment with bST, suckling status, or the interaction did not influence ($P > 0.71$) the number of follicles ≥ 8 mm at the initiation of the breeding season. The mean number of follicles ≥ 8 mm was 2.6 ± 0.3. Our observations are in agreement with a recent report whereby treatment of Brahman-influenced cows with bST prior to breeding did not influence the number of follicles ≥ 10 mm (Flores et al., 2008).

Serum concentrations of ghrelin were influenced by sampling day ($P = 0.001$). Concentrations of ghrelin were greater on d -14 (639.0 ± 17.7 ng/mL) and 0 (621.6 ± 19.2 ng/mL) than on d -28 (562.8 ± 18.2 ng/mL). Although bST treatment did not influence the concentrations of ghrelin, greater serum concentrations of ghrelin on d -14 and 0 may be of physiological significance. Ghrelin stimulates GH release and ghrelin has been implicated as an endocrine signal that integrates energy balance and reproduction (Garcia et al., 2007).

Serum concentrations of GH were influenced by a bST treatment x day interaction ($P = 0.001$; Figure 1). Cows treated with bST had greater concentrations of GH on d -14 and 0 compared with control cows. Similarly, serum concentrations of GH were increased in beef cows treated with bST (Flores et al., 2007).

Serum concentrations of IGF-I were influenced ($P = 0.016$) by a bST treatment x suckling x day interaction (Figure 2). On d -14 and 0, bST-non-suckled cows had greater concentrations of IGF-I compared with bST-suckled cows. However, bST-suckled cows had greater concentrations of IGF-I than control-non-suckled and control-suckled cows on d -14 and 0.

The nutritional status of cattle is communicated between the brain and ovaries by circulating metabolic hormones (Keisler and Lucy, 1996). Cows nursing calves may become thin and lack reproductive cycles; thin beef cows generally have decreased concentrations of IGF-I. A positive relationship has been reported between concentrations of IGF-I and the size of the dominant follicle; treatment of thin beef cows with bST increased serum concentrations of IGF-I (Flores et al., 2008). The diameter of the largest follicle has been reported to be greater for anestrous cows treated with bST compared with anestrous cows receiving no bST (Flores et al., 2008) and this may be attributed to greater concentrations of GH and (or) IGF-I.

Pregnancy rates tended ($P = 0.08$) to be greater for control-suckled (100%; 35/35) and bST-suckled (92%; 33/36) cows than control-non-suckled (86%; 12/14) and bST-non-suckled (80%; 12/15) cows. Recently, we reported that cumulative 70-d breeding season pregnancy rates were not influenced by bST treatment; however, first-service conception and pregnancy rates were greater for cows treated with bST compared with cows receiving no bST during the first 3 d of the breeding season (Flores et al., 2007).

Implications

Influence of GH and other metabolic hormones on cow reproduction may be mediated differentially depending on suckling status. Additional research is needed to determine how serum concentrations of ghrelin and IGF-I may be used to enhance reproductive efficiency in postpartum beef cows.

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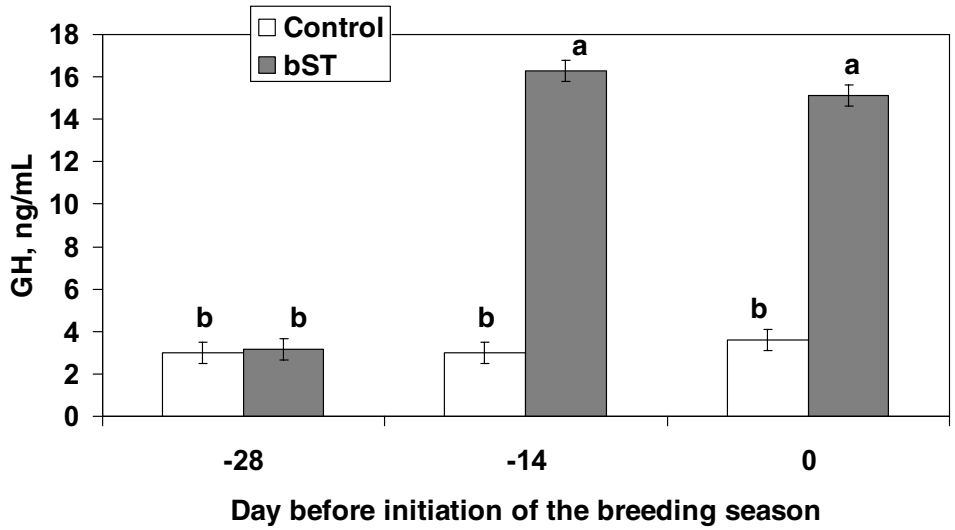

Fig. 1. Serum concentrations of growth hormone (GH) of Brahman-influenced cows treated with bovine somatotropin (bST) or without (control). Cows were treated with bST every 2 wk for 4 wk (d -28 and -14) before initiation of the breeding season (d 0). Growth hormone was influenced ($P = 0.001$) by a bST treatment x day interaction. [a-b]Within a day, means without common superscripts differ ($P < 0.05$).

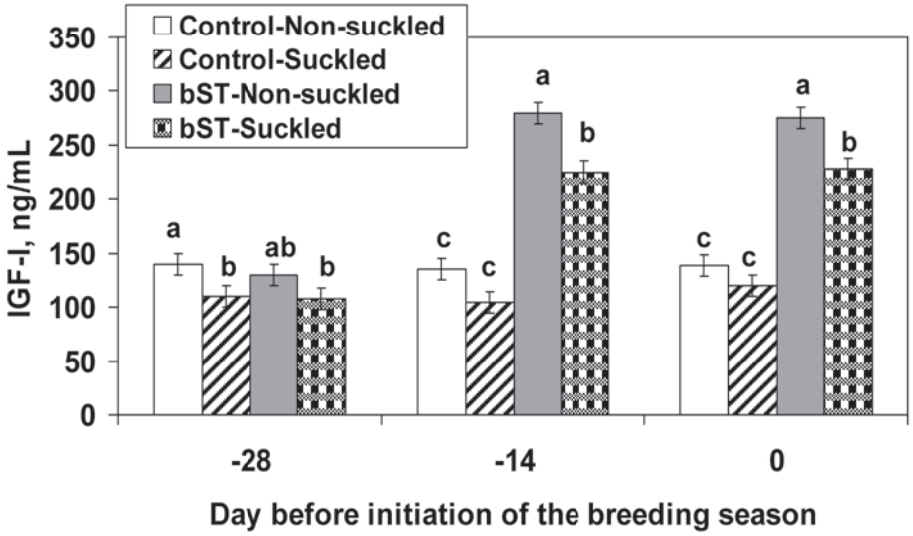

Fig. 2. Serum concentrations of insulin-like growth factor-I (IGF-I) of Brahman-influenced cows treated with bovine somatotropin (bST) or without (control). Cows were treated with bST every 2 wk (d -28 and -14) for 4 wk before initiation of the breeding season (d 0). Insulin-like growth factor-I was influenced ($P = 0.016$) by a bST treatment x suckling x day interaction. [a-c]Within a day, means without common superscripts differ ($P < 0.05$).

Comparison of Use of Two Modified Select Synch Protocols with Timed Artificial Insemination in *Bos indicus*-influenced Females

W.A. Whitworth[1,2], T.G. Montgomery[2], and S.A. Gunter[3]

Story in Brief

In each of 2 years (year 1: n = 60; year 2: n = 82), multiparous *Bos indicus*-influenced (at least 3/8 Brahman, predominantly Beefmaster breeding) females were synchronized using either 1) a 100 μg injection of gonadotropin releasing hormone (GnRH; G) or 2) a 1 mg injection of estradiol 17β (E) at insertion of a controlled internal drug release device (CIDR). In both treatment groups, CIDRs were removed after 7 d and a 25 mg injection of prostaglandin (PGF2α; PGF) was administered. All females were observed for estrus and artificially inseminated (AI) following the AM/PM rule. Any female who had not exhibited estrus was given a 100 μg injection of GnRH and inseminated approximately 84 h after PGF administration. Overall AI pregnancy rates in year 1 were 40%, with the E group having 46% pregnancy rates and the G group having 30%. In year 2, overall AI pregnancy rate was 42% with the E group having 50% AI pregnancy rates and the G group having 34.88%. The second injection of GnRH in either treatment group resulted in 7 additional AI calves in year 1 and 12 additional calves in year 2. These results imply that additional GnRH injection to facilitate follicular wave turnover has use in increasing AI conception rates.

Introduction

Widespread use of estrous synchronization and artificial insemination (AI) is not common in the beef cattle industry; however, progressive producers may employ these tools to maximize production of genetically superior calves. The use of timed artificial insemination programs has become more desirable, both from a cattle handling perspective and a labor cost standpoint. Producers want to produce as many superior calves as possible, but most of them do not have the time or resources to perform adequate estrous detection. In the southern United States, *Bos indicus*-type females are extremely common due to their adaptability to hot, humid environments; however, these females often do not exhibit favorable responses to timed artificial insemination programs. The objective of this study was to determine if acceptable pregnancy rates could be attained using a combination of heat detection and insemination with a timed insemination protocol in *Bos indicus* females.

Experimental Procedures

In mid-December in each of 2 years, fall-calving, multiparous lactating (at least 45 d postpartum) females at the Southeast Research and Extension Center in Monticello were randomly allocated to 1 of 2 treatment groups: 1) 100 μg injection of gonadotropin releasing hormone (GnRH) (Cystorelin7, Meriel Limited, Duluth, Ga.) at insertion of a controlled internal drug release device (CIDR) followed by a prostaglandin F2α (PGF; ProstaMate, Agri-Laboratories Ltd, St. Joseph, Mo.; G) injection 7 d later at CIDR removal or 2) a 1 mg injection of estradiol 17β (MedShop Pharmacy, Longview, Texas; E) at CIDR insertion followed by a PGF injection 7 d later at CIDR removal. Estrous detection was performed for 90 min each morning and evening (0630 to 0800 and 1530 to 1700) by observation. Females who exhibited estrus were inseminated following the AM/PM rule by a single insemination technician. Insemination took place between 9 and 14 h after observation of standing estrus. All females who had not exhibited standing estrus were subjected to timed AI (TAI) and a second 100 μg GnRH injection approximately 84 h after PGF administration (Figure 1). High quality Beefmaster semen was used for all cows. After being inseminated, females were placed with Angus bulls that had passed a standard breeding soundness exam for a 60 d breeding season. Females were palpated per rectum for pregnancy approximately 100 d after bulls were removed. At birth, paternity of each calf was determined using visual appraisal (presence of horns, head shape, presentation of *Bos indicus* characteristics) to distinguish between Beefmaster and Angus sired calves.

Number of calves resulting from treatment groups was expressed as percentage of calf crop, then converted using an arcsine transformation so that data could be adjusted to a normal distribution, and analyzed using PROC GLM of SAS (SAS Inst., Inc., Cary, N.C.). Length of gestation for AI calves was analyzed for comparison among treatment groups using the PROC GLM.

Results and Discussion

Overall responses to each treatment for entire experiment are presented in Table 1. No treatment differences were seen in either year of this trial ($P > 0.10$). It was interesting to note that females who received E17β at CIDR insertion showed numerically higher conception rates to artificial insemination in both years. Overall pregnancy rates to artificial insemination were low compared to previous studies on *Bos taurus* females (Lamb et al., 2001), but were similar to studies using females of similar genotype (Saldarriaga et al., 2007). Researchers have demonstrated acceptable TAI concep-

[1] University of Arkansas, Monticello
[2] Southeast Research and Extension Center, Monticello
[3] Department of Animal Science, Hope

tion rates using several protocols and length of time following PGF administration to insemination (Patterson et al., 2003). Again, most research of this type has been performed on *Bos taurus* cattle that often exhibit markedly different responses to exogenous hormone treatments when compared to *Bos indicus* females. While it has been argued that *Bos indicus* females have an inherent disadvantage in fertility compared to *Bos taurus* females, many authors have refuted this argument (Saldarriaga et al., 2007). This trial also demonstrated favorable overall conception rates (86.67% in year 1 and 85.54% in year 2) even though the cattle were bred in the winter months, which do not typically show optimal conception rates for *Bos indicus* cattle. Figure 2 shows number of calves produced through AI and natural service by females synchronized in year 1 and 2.

Although no treatment differences were observed in length of gestation for females conceiving to artificial insemination in either year of the experiment ($P > 0.10$), females in the G treatment group exhibited numerically shorter length of gestation. In year 1, the E treatment group averaged 285.6 days of gestation and the G treatment group averaged 282.1 days of gestation. The same pattern was observed in year 2, with the E treatment group averaging 283.8 days of gestation and the G treatment group averaging 280.5 days of gestation.

To maximize the number of AI calves realized, this trial incorporated both estrous detection and a timed insemination program. Use of these programs may also be desirable to producers who only have a finite amount of time to dedicate to estrous detection. Figure 3 illustrates additional calves realized by incorporating an additional GnRH injection at the time of insemination. Larson et al. (2006) found that this type of strategy demonstrated increased AI pregnancy rates from 9 to 11% in suckled *Bos taurus* females, maximizing the producers' benefit from this synchronization and AI program. Ultimately, it is up to the individual producer to determine if the additional cost of a second GnRH administration to a large group of females will yield enough benefits to be economically feasible.

Implications

While *Bos indicus*-influenced females do not seem to respond favorably to timed artificial insemination protocols, a need exists to devise synchronization strategies maximizing producer benefits. Using a combination of estrous detection and AI with a timed insemination program numberically increased AI conception rates, allowing realization of profits from superior calves.

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Table 1: Summary of treatment responses[a].

	Year 1		Year 2	
Item	E17β	GnRH	E17β	GnRH
Females in treatment group	30	30	40	42
Females observed in estrus	19	14	18	22
Females receiving 2nd GnRH injection	11	16	22	21
Calves conceived from AI on observed estrus	10	7	13	10
Calves conceived from TAI and GnRH injection	4	3	7	5

[a] GnRH = 100 μg injection of gonadotropin releasing hormone; E17 β = 1 mg injection of E17β; AI = artificial insemination; TAI = timed artificial insemination. No differences were observed between treatments in either year ($P > 0.10$).

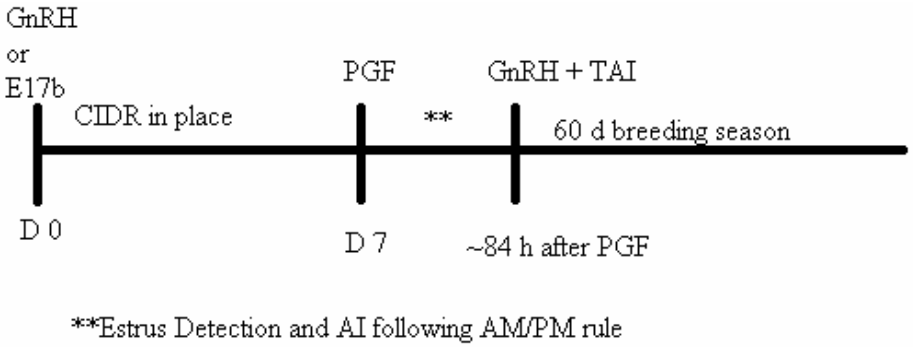

Fig. 1. Experimental Design B 1 mg injection of estradiol 17β (E) or 100 μg injection of gonadotropin releasing hormone (GnRH) at insertion of a controlled internal drug release device (CIDR). PGF = prostaglandin F2 α; AI = artificial insemination; TAI = timed artificial insemination.

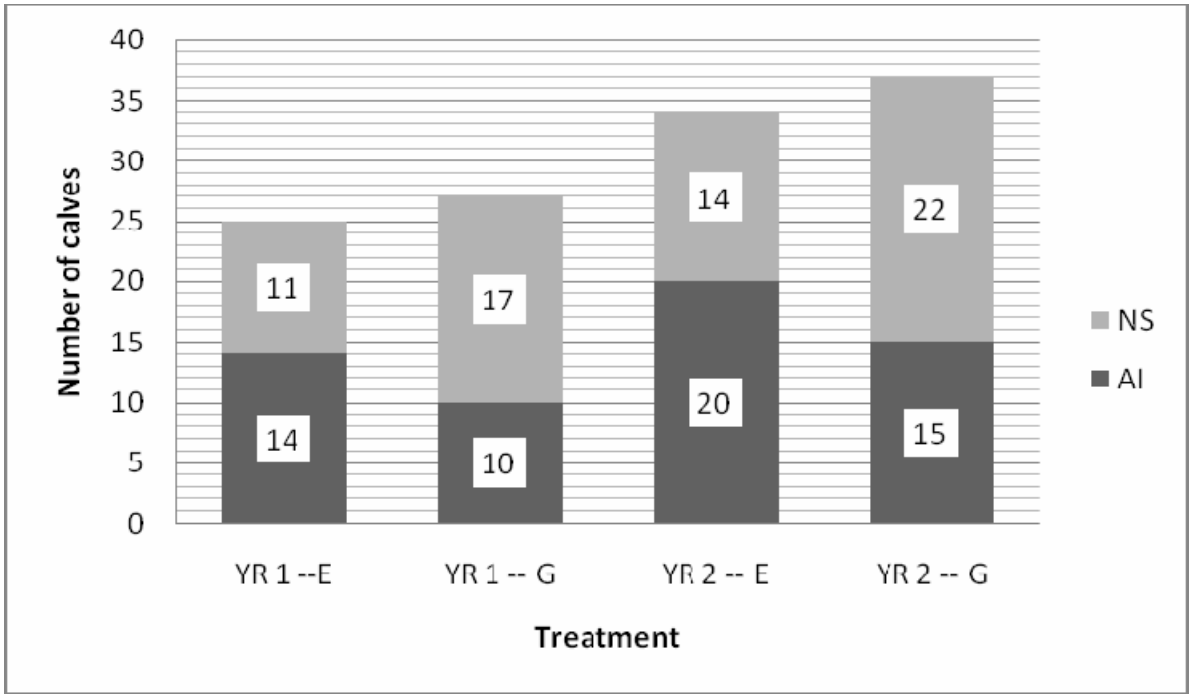

Fig. 2. Number of calves produced via artificial insemination (AI) and natural service (After being inseminated, females were placed with Angus bulls who had passed a standard breeding soundness exam for a 60 d breeding season; NS) by treatment for year 1 and year 2 (E and G). E = 1 mg injection of estradiol17β and G = 100 μg injection of gonadotropin releasing hormone (GnRH).

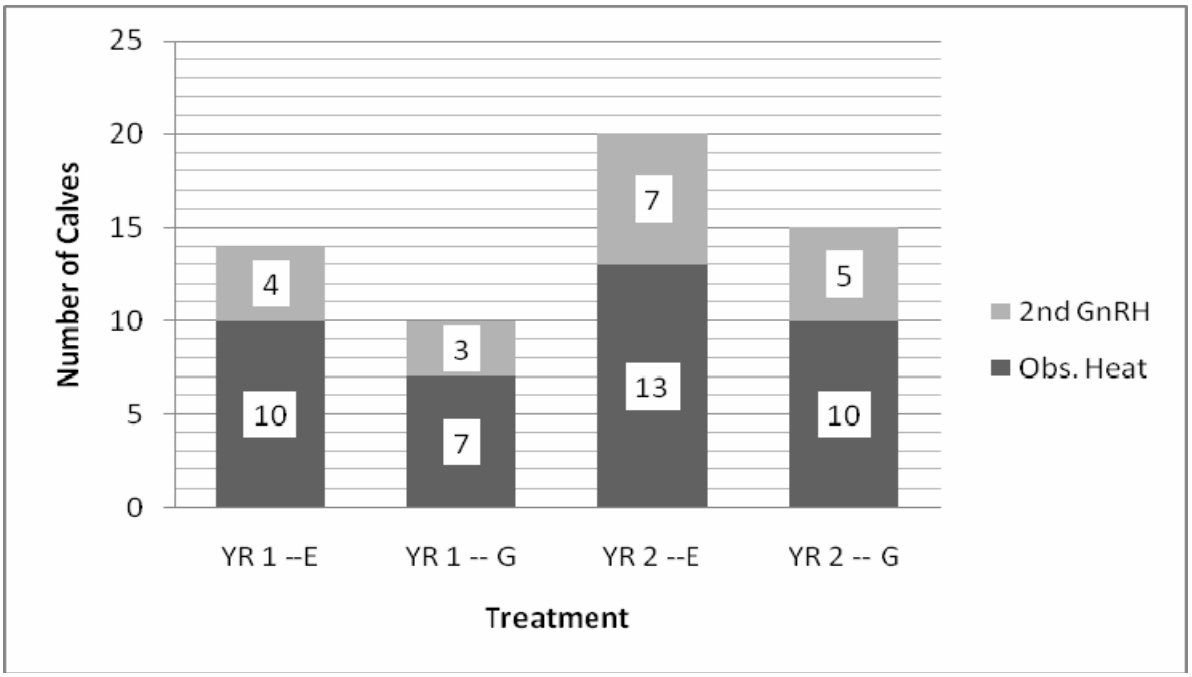

Fig. 3: Comparison of calves conceived via artificial insemination (AI) by females bred on observed heat or timed AI (2nd injection of gonadotropin releasing hormone; 2nd GnRH) for year 1 and year 2 (E and G). E = 1 mg injection of estradiol17β and G = 100 μg injection of GnRH.

Effects of On-Arrival Versus Delayed Clostridial or Modified-Live Respiratory Vaccinations on Health, Performance, Bovine Viral Diarrhea Type I Titers, and Physiological and Immunological Measures in Newly Received Beef Calves

J.T. Richeson[1], E.B. Kegley[1], M.S. Gadberry[2], P.A. Beck[3], J.G. Powell[1], and C. Jones[4]

Story in Brief

Four treatments were compared in a 2 × 2 factorial arrangement to evaluate the effect of on-arrival (d 0) vs delayed (d 14) administration of Alpha® 7 (CLOS) and/or Express® 5 (RESP) vaccine on health, performance, bovine viral diarrhea (BVDV) antibody titers, and physiological immune measurements of newly received calves. Crossbred calves (n = 263) were weighed (524.6 ± 2.7 lb) and randomly assigned to vaccination treatment: 1) arrival CLOS, arrival RESP; 2) arrival CLOS, delayed RESP (ACDR); 3) delayed CLOS, arrival RESP; and 4) delayed CLOS, delayed RESP (DCDR). Gain performance did not differ during the entire 56-d trial. Vaccination timing did not affect morbidity; however, there tended to be a CLOS timing effect ($P = 0.07$) and RESP timing effect ($P = 0.09$) on days to initial bovine respiratory disease treatment episode. Calves on the DCDR treatment had greater ($P = 0.01$) white blood cell counts than calves on the ACDR treatment. Serum cortisol concentrations were greater on d 0 than d 14 ($P < 0.01$) or d 28 ($P = 0.01$) but no treatment × day interaction was observed. RESP timing affected ($P = 0.001$) serum BVDV type I titer levels, with greater ($P < 0.01$) levels in calves administered RESP vaccine on arrival. Delaying CLOS or RESP vaccination did not affect gain or morbidity in newly received stocker calves. Calves administered RESP vaccine on d 0 developed antibody titers to BVDV type I at greater levels than delayed RESP treatments. Total leukocyte count was greatest when RESP and CLOS vaccination was delayed (DCDR).

Introduction

Bovine respiratory disease (BRD) is the leading cause of morbidity and mortality according to a recent survey of US feedlots (Woolums et al., 2005). Calves purchased at local auction outlets throughout the southeastern US are typically classified as high-risk for developing symptoms of BRD because these cattle are of unknown origin and recently weaned from small, cow-calf operations that seldom utilize vaccination or other BRD prevention strategies. These high-risk cattle may experience a combination of commingling, transport, nutritional, weaning, and environmental stressors that can compromise the immune system, and the transportation stress period can endure for several days post-receiving. Vaccine efficacy may be reduced if administered during immunosuppression, and a review of field vaccine efficacy by Perino and Hunsaker (1997) referred to published data supporting BRD vaccination at arrival in North American feedlots as equivocal. Other complications with on-arrival vaccination may include reduced gain performance (Richeson et al., 2008), perhaps due to immunological challenge from vaccine antigens during immunosuppression. Thus, the objective of this study was to evaluate the effect of delaying (14 d) respiratory and/or clostridial vaccination on health, performance, serum bovine viral diarrhea (BVDV) type I titers, and physiological stress and immune measures in high-risk, newly received calves.

Experimental Procedures

Two hundred and sixty-four crossbred bull and steer calves (BW = 524.6 ± 2.7 lb) were procured from auction barns located in western Arkansas and eastern Oklahoma and shipped to the University of Arkansas Agricultural Experiment Station located near Savoy. Three separate shipment dates representing each block in the experimental model were received on February 12 (Block 1, n = 90), March 1 (Block 2, n = 91), and April 17, 2007 (Block 3, n = 83). Calves in each block were divided into 8 pens (10 to 12 calves/pen); thus, each of the 4 treatments was replicated 6 times.

Upon arrival, cattle were weighed, assigned a unique ear identification tag and gender was determined. Within gender (bull or steer), calves were randomly distributed to 1 of 8 pens. The 8 pens had been randomly assigned to 1 of 4 vaccination-timing treatments. Treatments were arranged as a 2 × 2 factorial with 7-way clostridial (Alpha® 7, Boehringer Ingelheim Vetmedica [BIVI], St. Joseph, Mo.; CLOS) or 5-way modified-live respiratory vaccines (Express® 5, BIVI; RESP) administered either on arrival (d 0) or delayed (d 14), resulting in the 4 treatments: 1) arrival CLOS and RESP (ACAR), 2) arrival CLOS and delayed RESP (ACDR), 3) delayed CLOS, and arrival RESP (DCAR), and 4) delayed CLOS and RESP (DCDR).

In addition to receiving their assigned vaccination treatment on d 0, calves were treated for internal and external parasites (Cydectin, Fort Dodge Animal Health, Fort Dodge, Iowa), branded,

[1] Department of Animal Science, Fayetteville
[2] Department of Animal Science, Little Rock
[3] Department of Animal Science, Hope
[4] Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Mo.

administered metaphylactic antibiotic treatment with tilmicosin (Micotil, Elanco Animal Health, Indianapolis, IN) according to BW, and bull calves were surgically castrated. An ear notch sample was collected from each animal to test for persistently infected BVDV (Cattle Stats, LLC, Oklahoma City, Okla.). One animal in Block 1 tested positive for persistently infected BVDV and was removed from the study pen and quarantined on d 3. Furthermore on d 0, 2 blood samples from 5 randomly selected animals in each pen were drawn intravenously into Vacutainer® (BD Inc., Franklin Lakes, N.J.) tubes for subsequent analysis of serum cortisol concentrations and BVDV type I titer levels (plain tube), and white blood cell (WBC) total and differential counts (tube containing ethylenediaminetetraacetic acid (EDTA)). Cattle were then moved to their assigned 1.1-acre pens and provided 2 lb/hd (as-fed basis) of a receiving supplement (20.6% CP, DM basis) and free-choice access to bermudagrass hay (14.5% CP, 33.6% ADF, 68.3% NDF, and 7.9% ash, DM basis). Supplement offered increased to a maximum of 4 lb/hd/d as calves began consuming the supplement.

A booster vaccination of RESP was administered 14 d following initial RESP vaccination according to treatment protocol. Cattle were re-weighed at 14-d intervals during the trial (d 14, 28, 42, and 56) to determine interim and overall differences in gain performance. The same 5 animals per pen selected for blood collection upon arrival were similarly sampled on d 14, 28, 42, and 56. Serum cortisol concentrations were used as an indication of overall physiological stress, and were determined using commercially available radioimmunoassay (RIA) kits (DPC, Los Angeles, Calif.), with an intra- and inter-assay CV of 1.04 and 23.0%, respectively. Frozen serum samples were shipped on ice via overnight parcel service to the Oklahoma Animal Disease Diagnostic Laboratory (Stillwater, Okla.) for determination of serum neutralizing antibodies for BVDV type I. Whole blood collected in tubes containing EDTA was kept refrigerated and used within 24 h to determine concentrations (n cells/μL) of total WBC, and differential WBC (lymphocytes, neutrophils, monocytes, eosinophils, and basophils) with an automated hematology analyzer (Cell-Dyn 3500 system, Abbott Laboratories, Abbot Park, Ill.) standardized for analysis of bovine blood.

Calves were observed each morning for symptoms of respiratory illness. Cattle with 2 or more visual symptoms of BRD were pulled and considered morbid if rectal temperature was ≥ 104°F. Morbid animals were given antibiotic therapy following a predetermined antibiotic treatment protocol and returned to the home pen. A re-check temperature was taken 48 h following initial treatment. If the re-check temperature was ≥ 104°F, a second antibiotic treatment was administered. If the re-check temperature was < 104°F, the animal was left untreated until further symptoms developed. This procedure was repeated until a third and final antibiotic treatment was administered. Cattle that continued to display BRD symptoms after the third treatment were considered chronically ill and no further treatment was administered. Treatment data were recorded for individual animal including treatment date, rectal temperature, and amount and type of antibiotic administered.

Titers were evaluated to determine differences in the concentration of BVDV type I antibodies and the percentage of animals in each treatment with positive seroconversion to BVDV type I using the serum neutralization (SN) method. Serum that did not provide protection at the 1:4 level were reported as <4, and were considered negative for seroconversion to BVDV. Samples with a reported SN value of ≥4 were considered positive for seroconversion to BVDV. For the titer level analysis, the reported values were $\log_2$ transformed and evaluated. Receiving-day BVDV titer comparisons were made from samples collected on d 0, 14, 28, and 42. Vaccination timing-equivalent comparisons were made for BVDV titers based on the number of d post-initial RESP vaccination (d 0 ACAR, DCAR vs. d 14 ACDR, DCDR) and post-booster vaccination (d 14 ACAR, DCAR vs. d 28 ACDR, DCDR).

Statistical analysis. Performance and morbidity data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Pen was considered the experimental unit. Block and block × replicate × treatment were treated as random effects in the model. Orthogonal contrasts evaluating effects of CLOS timing, RESP timing, and the interaction were used. If the interaction was significant ($P \leq 0.10$), treatment means were separated with a t-test using the PDIFF option in SAS. Cortisol, total and differential WBC, and BVDV type I titer data were analyzed using the MIXED procedure with repeated measures. Pen was considered as the experimental unit for these data. Contrasts for the repeated measures data included CLOS timing; RESP timing; interaction; and linear, quadratic, cubic, and for some variables, quartic effects of day.

Results and Discussion

Performance. No differences ($P \geq 0.34$) in ADG were observed during the 56-d receiving period. Although non-significant ($P = 0.87$), calves receiving both vaccine injections on d 0 (ACAR) had a numerical advantage in ADG. The numerical advantage was particularly evident during the early part of the receiving period (d 0 to 14; $P = 0.65$) with ACAR gaining 2.43 lb/d compared to 2.07, 2.11 and 2.06 lb/d for ACDR, DCAR and DCDR, respectively. In a recent trial (Richeson et al., 2008), calves that received delayed (14 d) vaccination of a modified live (MLV) respiratory vaccine (Express® 5) had greater ADG than those vaccinated on arrival. Reasons for conflicting results of vaccination on receiving cattle performance may be due to vitamin/mineral status, vaccination history, nutritional status and the stress level of a particular group.

Health. Morbidity rate was high, but not different ($P \geq 0.23$) with 71.4, 60.7, 75.3 and 69.5% of ACAR, ACDR, DCAR and DCDR calves being treated at least one time for BRD (Table 1). Likewise, no differences were observed in the number of 2nd ($P \geq 0.18$) or 3rd ($P \geq 0.37$) BRD treatment episodes. Combined death loss was 1.9% for all treatments, but not different ($P \geq 0.64$) among treatments. There was a vaccine type × timing interaction ($P = 0.05$) for the percentage of chronic animals. The ACDR treatment group had a greater percentage of chronic animals (11.4%) than ACAR (1.5%), but not DCAR (6.3%) or DCDR (3.2%).

There was a CLOS timing effect ($P = 0.07$) and RESP timing effect ($P = 0.09$) on d to initial BRD treatment episode. Days to initial BRD treatment episode were fewer ($P = 0.01$) for ACAR (6 ± 0.8 d) than DCDR (8 ± 0.8 d). This difference may be due to additive effects of on-arrival vaccination on the visual symptoms of BRD in cattle receiving both CLOS and RESP on d 0 (ACAR) vs. cattle receiving no vaccine until d 14 (DCDR). Furthermore, CLOS ($P = 0.01$) and RESP ($P = 0.05$) timing affected rectal temperature at the time of initial antibiotic treatment. Days to second treatment was greater for DCDR than ACAR ($P = 0.002$). Because DCDR calves were pulled later than calves on the other treatments, discrepancy in disease stage may explain the greater rectal temperature at the time of initial BRD treatment. There was also an impact (vaccine type × timing interaction, $P = 0.05$) on the days to treatment with the second antibiotic, in that DCDR calves were treated later (d 13 ± 1.3) than calves on the other treatments (d 9 ± 1.3).

BVDV type I antibody titers. Two separate comparison methods were used to evaluate differences in BVDV type I titers: 1) trial-day basis and 2) equivalent-day post-RESP vaccination basis. Furthermore, results were analyzed and reported as either antibody concentration or percent positive seroconversion as described previously in the experimental procedures section.

Trial-day basis comparison. There was a treatment × day interaction ($P \leq 0.04$) for BVDV type I titers for both analysis methods. On d 14, BVDV type I titer level for ACAR was greater than ACDR ($P = 0.001$) or DCDR ($P = 0.01$). On d 28, both treatments administered RESP on-arrival (ACAR and DCAR) had greater ($P \leq 0.005$) BVDV type I titers than treatments administered delayed RESP vaccination (ACDR and DCDR). Results were similar when trial-day basis titer data were analyzed as percent seroconversion to BVDV type I (Fig. 1). Positive seroconversion to BVDV type I was faster ($P = 0.01$) when RESP was administered on d 0. On d 14 and 28, ACAR and DCAR had greater percentage seroconversion than ACDR or DCDR; however, by d 42 of the trial essentially all animals had positive seroconversion to BVDV type I.

Equivalent-day post-RESP comparison. There was no treatment × day interaction ($P \geq 0.82$) for the equivalent-day post-RESP comparison method. The overall $\log_2$ concentration of BVDV type I antibody was 5.2, 4.9, 5.0, and 4.7 for ACAR, ACDR, DCAR, and DCDR treatments, respectively, but not different ($P = 0.68$). Likewise, no differences ($P = 0.56$) were detected when analyzed as percent seroconversion by the equivalent-day post-RESP comparison.

The BVDV titer results in this study suggest that high-risk, newly received calves administered RESP vaccination on-arrival are able to respond adequately to RESP vaccination despite the typical stress and immune challenges present during the initial 14 d of receiving.

Differential white blood cell count. There was no treatment × day interaction for total WBC count ($P = 0.97$). There was a main effect of CLOS timing ($P = 0.08$) on total WBC count (Table 2). Overall, delaying CLOS resulted in greater WBC counts. There was also a vaccine type × timing interaction ($P = 0.06$); DCDR had greater WBC counts than ACDR ($P = 0.01$), with ACAR and DCAR being intermediate. The greater WBC levels recorded for DCDR may indicate that these cattle had greater occurrence of pathogenic infection. However, greater total WBC count may also indicate that an animal has increased ability to mount an innate or adaptive immune response to a foreign antigen, which is a key goal of vaccination. There were effects of day of sampling on differential percentages (Fig. 2) and total WBC count, the percentage of lymphocytes (quartic, $P < 0.001$), monocytes (quartic, $P = 0.02$), eosinophils (linear, $P < 0.001$), and the WBC count increased ($P < 0.001$) as the study progressed; while the percentage of neutrophils decreased (quartic, $P < 0.01$).

There were no treatment × day interactions ($P \geq 0.18$) for differential percentages of WBC (Table 2). Overall, CLOS timing affected differential percentages. Delaying CLOS increased ($P = 0.03$) the percentage of lymphocytes and decreased ($P \leq 0.05$) the percentage of monocytes and eosinophils. The neutrophil:lymphocyte ratio tended to be affected by a vaccine type × timing ($P = 0.10$) interaction with DCDR having the lowest neutrophil:lymphocyte ratio; therefore, stress may have been the least for calves that received delayed administration of both vaccines.

Serum cortisol. There was no treatment × day interaction ($P = 0.21$) for serum cortisol concentrations (Fig. 3), nor were there any treatment differences ($P \geq 0.53$); however, there was a significant day effect ($P = 0.002$) on cortisol level. Cortisol concentrations averaged 3.04 μg/dL on d 0 and declined on d 14 (2.43 μg/dL, $P < 0.001$) and d 28 (2.57 μg/dL, $P = 0.01$), suggesting that physiological stress was greatest during the first 14 d from arrival.

Implications

Vaccination timing did not affect gain or morbidity in newly received calves. Antibody titers to bovine virus diarrhea type I developed earlier when cattle were administered a respiratory vaccine on day 0. Several differential white blood cell measures were greater when both vaccines were delayed. Serum cortisol levels were greatest during the first 14 days of receiving.

Acknowledgments

Appreciation is expressed to Boehringer Ingelheim Vetmedica Inc., St. Joseph, Mo., for financial support and product donation, Elanco Animal Health, Indianapolis, Ind., for product donation, P. Hornsby and S. Behrends for their expertise in animal care, and D. Galloway and S. Tsai for assistance with analyses.

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Table 1. Effect of clostridial and bovine respiratory disease vaccination timing on health of newly received cattle.

	Treatment					Contrasts[1], *P* =		
Item	ACAR[2]	ACDR[3]	DCAR[4]	DCDR[5]	SEM	CLOS	RESP	Interaction
Morbidity, %	71.4	60.7	75.3	69.5	9.6	0.36	0.23	0.72
Day 1st treated	6.0	7.3	7.3	8.0	0.76	0.07	0.09	0.56
Rectal temperature at treatment, ºF	104.5	104.6	104.7	105	0.11	0.01	0.05	0.47
Rectal temperature 48 h after treatment, ºF	103.6[a]	103.8[a]	103.6[a]	103.1[b]	0.24	0.05	0.36	0.04
Treated with 2nd antibiotic, %	38.5	39.5	36.1	25.5	8.7	0.18	0.43	0.34
Day 2nd treated	8.8[b]	10.0[b]	8.7[b]	13.1[a]	1.3	0.07	0.002	0.05
Treated with 3rd antibiotic, %	20.5	22.4	19.8	10.8	9.4	0.37	0.61	0.43
Dead, %	1.4	1.6	3.0	1.5	2.4	0.67	0.7	0.64
Chronic, %	1.5[b]	11.4[a]	6.3[ab]	3.2[ab]	4.7	0.59	0.29	0.05

[a,b]Means within a row without a common superscript are different ($P < 0.05$).
[1]CLOS = main effect of timing of clostridial vaccination (d 0 vs. 14), RESP = main effect of timing of respiratory virus vaccination,
Interaction = vaccine type × timing.
[2]ACAR = Arrival (d 0) clostridial and respiratory vaccination.
[3]ACDR = Arrival clostridial and delayed (d 14) respiratory vaccination.
[4]DCAR = Delayed clostridial and arrival respiratory vaccination.
[5]DCDR = Delayed clostridial and respiratory vaccination.

Table 2. Effect of clostridial and bovine respiratory disease vaccination timing on blood components.

	Treatment					Contrasts[1], *P* =		
Item	ACAR[2]	ACDR[3]	DCAR[4]	DCDR[5]	SEM	CLOS	RESP	Interaction
White blood cells, n × 10^3/μL	10.3[ab]	9.9[b]	10.2[ab]	10.9[a]	0.37	0.08	0.62	0.06
Neutrophils, %	25	26	25	22	2.6	0.08	0.51	0.18
Lymphocytes, %	61	61	63	65	2.3	0.02	0.38	0.31
Monocytes, %	10.7	10.4	9.8	9.9	0.61	0.04	0.79	0.58
Eosinophils, %	2.3	1.9	1.7	1.6	0.34	0.05	0.30	0.59
Neutrophil:lymphocyte ratio	0.55[a]	0.58[a]	0.54[ab]	0.45[b]	0.06	0.06	0.39	0.10
Red blood cells, n × 10^6/μL	9.7	10.3	10.0	10.4	0.25	0.34	0.02	0.51
Platelets, K/μL	516	662	589	663	55	0.43	0.02	0.44

[a,b]Means within a row without a common superscript are different ($P \leq 0.05$).
[1]CLOS = main effect of timing of clostridial vaccination (d 0 vs. 14), RESP = main effect of timing of respiratory virus vaccination, Interaction = vaccine type × timing.
[2]ACAR = Arrival (d 0) clostridial and respiratory vaccination.
[3]ACDR = Arrival clostridial and delayed (d 14) respiratory vaccination.
[4]DCAR = Delayed clostridial and arrival respiratory vaccination.
[5]DCDR = Delayed clostridial and respiratory vaccination.

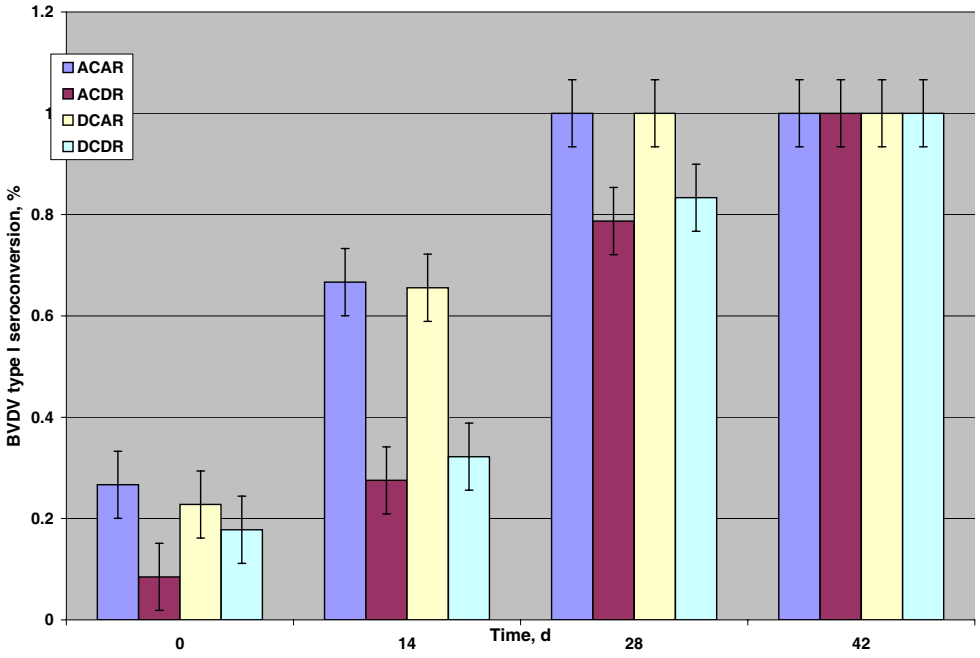

Fig. 1. Effect of clostridial and bovine respiratory disease vaccination timing on proportions of calves with antibody concentrations against bovine viral diarrhea Type I. ACAR = arrival (d 0) clostridial and respiratory vaccination, ACDR = arrival clostridial, and delayed (d 14) respiratory vaccination, DCAR = delayed clostridial, and arrival respiratory vaccination, and DCDR = delayed clostridial and respiratory vaccination.

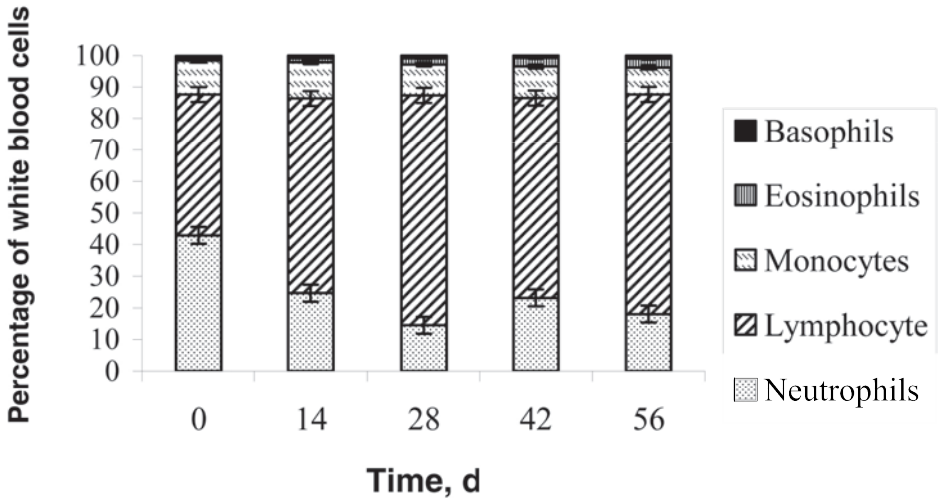

Fig. 2. Effect of day on differential proportions of white blood cells. Basophils – cubic effect of day, $P = 0.04$. Eosinophils – linear effect of day, $P < 0.001$. Monocytes – linear ($P < 0.001$) and quartic ($P = 0.02$) effects of day. Lymphocytes – linear, quadratic, cubic, and quartic effects of day, ($P < 0.001$). Neutrophils – linear, quadratic, cubic, and quartic effects of day, ($P < 0.001$).

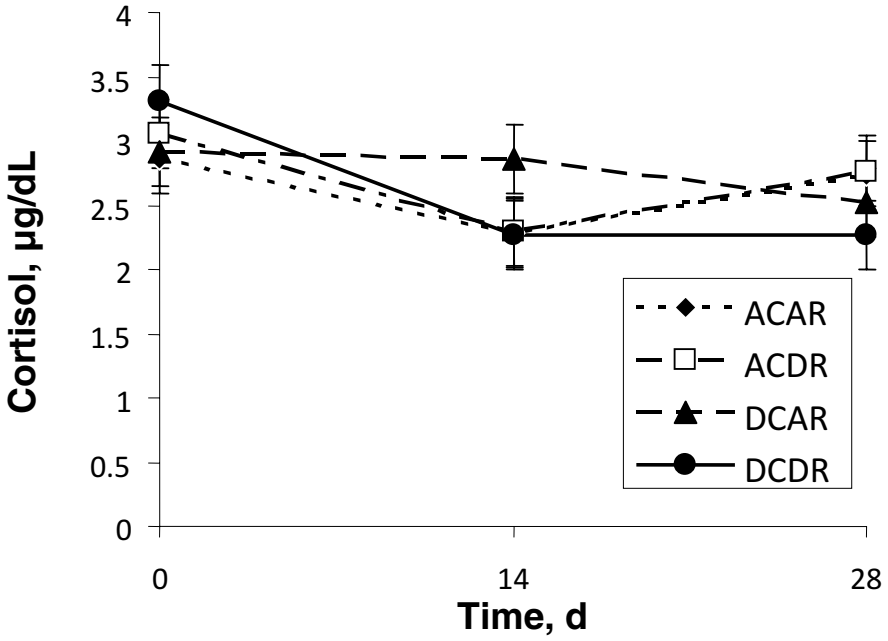

Fig. 3. Effect of clostridial and bovine respiratory disease vaccination timing on serum cortisol concentrations. ACAR = arrival (d 0) clostridial and respiratory vaccination, ACDR = arrival clostridial and delayed (d 14) respiratory vaccination, DCAR = delayed clostridial and arrival respiratory vaccination, and DCDR = delayed clostridial and respiratory vaccination.

Evaluation of Long-acting Moxidectin and Ivermectin in the Development of Replacement Beef Heifers

J.G. Powell[1], T.A. Yazwinski[1], C.A. Tucker[1], Z.B. Johnson[1], J.L. Reynolds[1], A.H. Brown[1], J.A. Hornsby[1], and C. Prewett[2]

Story in Brief

An experiment was conducted to assess the efficacy and benefit of ivermectin and long-acting moxidectin in replacement heifers. Recently weaned replacement heifers carrying naturally acquired parasite infections (n = 105) were evaluated for 149 d. Heifers were weaned on May 15, 2006 and assembled at the University of Arkansas Beef Research Unit near Fayetteville, AR. Heifers were randomly allocated to 1 of 3 treatments: Ivomec® Plus injectable (IVO), Cydectin® Long-Acting injectable (MXD), and a negative control (CON). Treatments were administered on d 0, each animal was weighed, and a fecal sample was taken on d 0, 14, 64, and149. Hip heights and pelvic area measurements were recorded for each heifer on d 29 and d 149, respectively. Statistical analyses were conducted using a general linear mixed model procedure. Average BW was 478 ± 47.6 lb on d 0. Results identified no significant differences for BW or strongyle eggs per gram of feces on d 0. Fecal egg counts (FEC) were lower ($P < 0.01$) for MXD-treated calves on d 14, 64, and 149 compared to the IVO and CON groups. The FEC for the IVO group was lower ($P < 0.01$) compared to the CON on d 14. Mean BW was only greater ($P < 0.05$) for MXD-treated calves compared to CON group on d 149. Average daily gains were greater ($P < 0.01$) for MXD and IVO compared to CON for gains made from d 0 to d 149. No differences were identified for pelvic area or hip height among treatment groups.

Introduction

The development of replacement heifers is a major economic burden to the beef cattle industry and is considered a costly and intensive process. Intestinal parasitism can significantly decrease growth and performance of grazing animals (Perry and Randolph, 1999). Heifers that are selected for replacements can suffer from poor development due to intestinal parasite burdens.

The most widely used class of anthelmintic today is the macrocyclic lactones. This class of drug includes ivermectin, doramectin, eprinomectin, and moxidectin. A prime target of these pharmaceuticals is the glutamate-gated chloride channels of the parasite's nervous system (Wolstenholme and Rogers, 2005).

New formulations of long-acting macrocyclic lactones have been shown to be more effective in controlling parasite burdens and more beneficial to growth performance than conventional formulations (Yazwinski et al., 2006). The objective of this study was to compare long-acting moxidectin treatment to ivermectin plus clorsulon treatment for efficacy of parasite control and benefits to growth performance in beef replacement heifers for a 149-day period.

Experimental Procedures

In total, 131 beef replacement heifers of predominately Angus breeding were delivered on May 15, 2006, to the University of Arkansas Beef Research Unit near Fayetteville, AR. All heifers were born between September 3 and December 27, 2005, and were carrying naturally acquired parasite infections upon entering the study. Following their arrival, study animals were given a 30-day acclimation period during which BW and fecal egg counts (FEC) were measured. Based on the above BW and FEC measurements, 105 heifers were selected to be used during the 149-day study.

Animals were housed and cared for in compliance with the Animal Care Protocol #06052 for cattle experimentation issued by the University of Arkansas Animal Care and Use Committee. All study animals were managed in one group and were given ad libitum access to pasture forage, water and mineral supplementation. A soy-hull ration was fed daily at the rate of 1% animal BW, and animals were observed daily for general health and well-being.

For treatment allocation, heifers were blocked into 5 blocks based on d -2 FEC and ranked within each block by d -1 BW. Blocks contained 21 animals that were bracketed by 3's into replicates. Each of the 3 heifers within each replicate was randomly assigned 1 of 3 treatments: Ivomec® Plus injectable (IVO), Cydectin® Long-Acting injectable (MXD), and a negative control (CON).

Treatments were administered on d 0. Treatment MXD was a 10% solution administered subcutaneously into the left ear with a 1-inch, 18-gauge, B-bevel needle at the rate of 1mL/100kg BW. Treatment IVO was administered subcutaneously into the left side of the neck with a ¾-inch, 16-gauge needle at a rate of 1mL/50kg BW. Control animals received no placebo treatment.

Body weight and FEC were measured on d 0, 14, 64, and 149. Hip heights and pelvic area measurements were recorded for each heifer on d 29 and d 149, respectively. Throughout the 149-day study, the heifers were comingled and managed as one group.

Statistical analyses were determined using general linear model of SAS (SAS Inst., Inc., Cary, N.C.). Traits of BW, FEC, ADG, pelvic area, and hip height were analyzed for significant differences at $P < 0.05$. The FEC were transformed [$Y = \log_{10} (x + 1)$] prior to analysis.

[1] Department of Animal Science, Fayetteville
[2] Department of Animal Science, Little Rock

Results and Discussion

Geometric means of FEC by treatment are shown in Table 1. All treatment groups had similar FEC on d 0. The FEC was lower ($P < 0.01$) for MXD-treated calves on d 14, 64, and 149 compared to the IVO and CON groups. The FEC for the IVO group was lower ($P < 0.01$) compared to the CON on d 14. These data show that MXD treatment provided far greater fecal egg count reductions than did IVO treatment for the entire study.

Mean animal BW was similar among treatments on d 0; however, by study d 149, MXD-treated calves had a higher mean BW ($P < 0.05$) when compared to CON (Table 2). Average daily gains for the study period were greater ($P < 0.01$) for animals on MXD and IVO treatments compared to CON (Figure 1). Pelvic area and hip height were not different ($P > 0.10$) among all treatment groups. These data show that even though average daily gains were statistically similar for the MXD and IVO treatment groups, only the MXD-treatment provided significant improvement for mean body weight when compared to the control group on d 149 of the study.

Implications

Results indicate that Cydectin® LA has superior efficacy and extended activity against intestinal nematodiasis when compared to Ivomec® Plus and a negative control. Replacement heifers treated with Cydectin® LA and Ivomec® Plus had similar average daily gains as measured from d 0 to d 149, but only Cydectin® LA treatment significantly improved gains relative to negative controls.

Acknowledgments

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Table 1. Strongyle fecal egg counts (FEC), geometric means by treatment group and study day.

Treatment	Day 0	Day 14	Day 64	Day 149
Cydectin® LA	31.2[a]	1.4[c]	7.4[b]	16.6[b]
Ivomec® Plus	35.5[a]	8.7[b]	73.9[a]	68.1[a]
Control	35.0[a]	65.7[a]	115.8[a]	56.5[a]

[a,b,c] Means on the same day with no superscript in common differ ($P < 0.01$).

Table 2. Mean animal body weights (lb) by treatment group and study day.

Treatment	Day 0	Day 14	Day 64	Day 149
Cydectin® LA	527.9	578.3	661.3	739.9[a]
Ivomec® Plus	533.5	580.5	668.1	733.5[ab]
Control	533.1	579.6	655.5	707.4[b]

[a,b] Means on the same day with no superscript in common differ ($P < 0.05$).

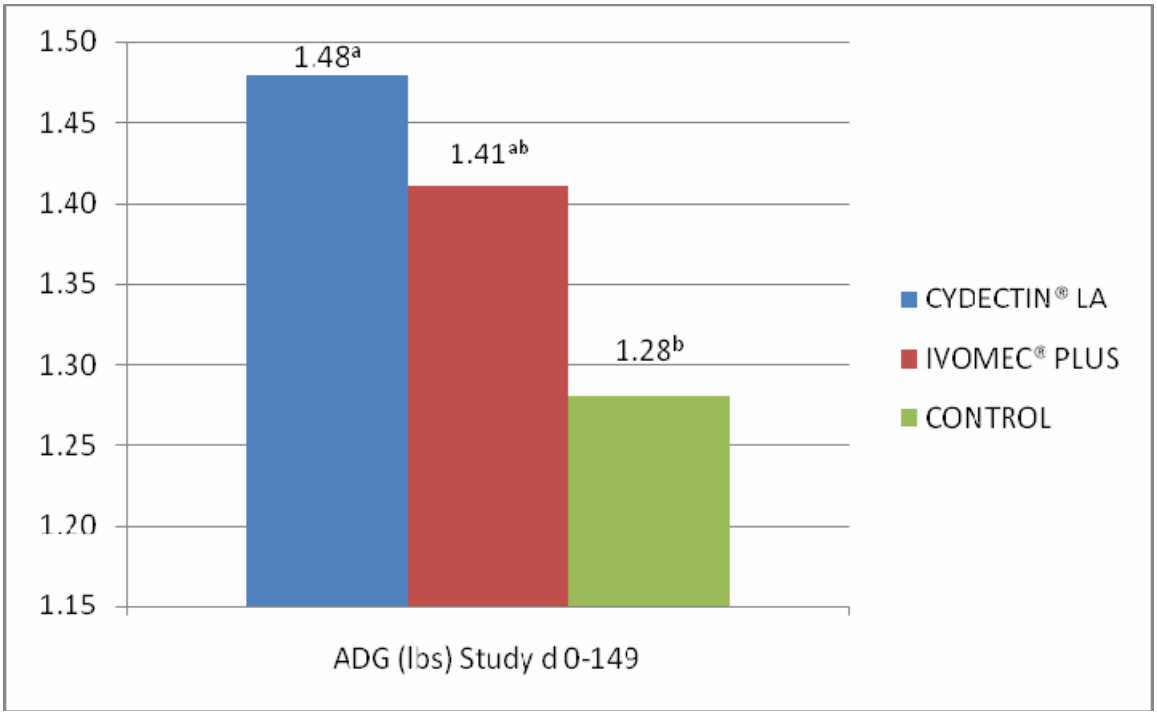

Fig. 1. Mean average daily gain (lbs) by treatment group between d 0-149.
[a,b] Means with no superscript in common differ ($P < 0.01$).

Effects of *Morinda Citrifolia* (Noni) Pulp on Growth Performance and Stress Responses of Growing Cattle

J.W.S. Yancey, J.K. Apple, and E.B. Kegley[1]

Story in Brief

The pulp of *Morinda citrifolia* (Noni), a Tahitian plant known to reduce stress and improve immunity in lab rats, was fed to growing cattle. Thirty crossbred beef calves (578 lb) were limit-fed diets that were top-dressed with 0, 1, or 2% Noni pulp for 28 d. Every 4 d, cattle were weighed, bled, and assessed for subjective and objective excitability scores. Average daily gain increased linearly ($P = 0.03$) as the percentage of Noni in the diet increased from 0 to 2%. Cattle tended to gain more efficiently, as the feed to gain ratio decreased linearly ($P = 0.08$), with increasing Noni addition. Noni-fed cattle also were healthier, as indicated by the decreasing concentration of white blood cells in the blood with increased Noni concentration (linear; $P = 0.01$). Control cattle had similar serum cortisol concentrations to those fed Noni pulp ($P = 0.22$). Exit velocity, as well as subjective pen and chute excitability scores, also was not affected ($P \geq 0.05$) by the addition of Noni to the diet. Therefore, we concluded that Noni has the potential to improve growth in growing cattle.

Introduction

Morinda citrifolia, more commonly known as the Noni plant, is a medicinal evergreen found in tropical areas, specifically the islands of Polynesia. The native peoples of the islands have used the roots, stems, bark, leaves, flowers, and fruit of the Noni plants as medicine as well as a source for food, juices, and dyes. Commercially, Noni juice is marketed as an alternative herbal remedy for several illnesses in humans including cancer, arthritis, diabetes, ulcers, and depression. Furthermore, Noni products are endorsed by several well-known equestrians as supplements for performance horses competing in physically grueling events, and research indicates that Noni extract has an analgesic effect on rats.

Improving the reaction of cattle to stress factors has the potential to decrease the percentage of cattle that develop the dark-cutting condition. Caused by the depletion of glycogen antemortem, this condition costs the beef industry $132 to $170 million/year. In addition to the obvious cost of dark-cutting beef, the expense of excitable cattle also is evident in non-quantifiable measures. In the feeding and processing facility, calm cattle are less likely to cause worker injuries or bruises to their pen-mates. Cattle with calm temperament scores had greater ADG than cattle with more excitable temperaments (Voisinet et al., 1997b), and excitable cattle have been shown to produce steaks with higher Warner-Bratzler shear force values, indicating tougher beef (Voisinet et al., 1997a; King et al., 2005).

The objective of this study was to determine the effects of feeding the pulp from *Morinda citrifolia* on feeder cattle temperament scores, production traits, and stress indicators in the blood.

Experimental Procedures

Thirty crossbred beef calves (6 steers and 24 heifers, Brangus cross dams with Charolais sires) were obtained from a local cattle producer. Cattle were transported to the facility and allowed to adapt to the feeding pens and diet for 2 wk before the start of the study. On d –2, calves were weighed (578 ± 10.6 lb), then blocked by gender and body weight (BW; 5 blocks). Calves within a block were assigned randomly to pens (2 calves/pen, 3 pens/block). Treatments were assigned randomly within blocks to pens. The 3 treatments were no supplemental Noni, or 1 or 2% feed intake (as fed basis) of Noni. Noni was analyzed to contain 8.3% DM, and 8.5% CP, 0.63% fat, 21% NDF, 18% ADF, and 15.4% ash (DM basis). Cattle were fed 2.75% of their initial BW (Table 1). Therefore, the doses of Noni were 0, 0.0275, and 0.055% of initial BW. Calves were fed a grain mix (75% of intake) at approximately 0900, and the appropriate amount of Noni was top-dressed onto this feed each morning. At approximately 1400, hay was fed (25% of intake). Calves were housed in 12 ft × 98 ft pens with a 10-ft concrete feedbunk in the front of each pen. Calves had ad libitum access to water.

Calves were sampled every 4 d for the 28-d study. At 0800 each sampling day, calves were moved by pen to the working facility. Beginning at the easternmost pen, 2 observers opened the rear gate. Observers did not enter the pen with the calves, but instead walked on the outside of the east side of the pen. Observers walked quietly past the calves, and without consulting one another, each observer recorded a pen score for each calf (Table 2). Observers moved into that pen (behind the calves) and moved calves to the crowding pen and alley system in the working facility barn (approximately 430 ft). After each pen was caught in the crowding pen, observers returned to the barn and consistently repeated the process until all 15 pens had been moved.

Upon arrival at the working facility, calves were moved as quickly and quietly as possible through the alley; excessive noise, etc. was discouraged. When put on the scale before the chute, individual calves were scored (chute score, Table 2) within 1 min; 2 people made these observations without consulting each other. After the chute score was assigned, BW was recorded. Calves were caught in the chute and blood collected via jugular venipuncture. Blood was collected in a plain glass vacuum tube for serum cortisol. On d

[1] Department of Animal Science, Fayetteville

0, 4, 8, 12, 20, and 28 a vacuum tube containing EDTA (ethylenediaminetetraacetic acid) for differential and total blood cell counts also was collected. Before exiting the chute, a bar was placed in close proximity to the rear of the calf so that it could not back up. Exit velocity of the calf was measured electronically (Polaris Wireless Timer; FarmTek, Inc.; Wylie, Texas) over a 6 ft distance beginning 6 ft in front of the head gate.

Blood samples were stored on ice prior to centrifugation at 2,100 × g for 20 min for separation of serum. Serum was stored frozen until used to analyze for cortisol concentrations by radioimmunoassay (DPC, Los Angeles, Calif.), with intra- and interassay CV of 2 and 9.1%, respectively. An automated system (Hemavet 1500, CDC Technologies Inc., Oxford, Conn.) was used for determination of the total and differential cell counts, hematocrit, and hemoglobin. Samples were analyzed within 24 h of collection.

Data were analyzed using the MIXED procedures of SAS (SAS Inst., Inc., Cary, N.C.). Pen means were used for all analyses. The model for the performance data included dietary treatment as a fixed effect and BW block as a random effect. Contrast statements were used to test the linear and quadratic effects of Noni addition. Prior to statistical analyses, observations from both observers were averaged to obtain pen and chute scores. Blood data, exit velocities, and pen and chute scores were analyzed using the repeated statement with a SP (POW) covariance structure and pen as the subject. The model included BW block, treatment, day, and the day by treatment interaction as fixed effects.

Results and Discussion

Noni-supplemented diets increased ADG linearly ($P = 0.03$) as the percentage of Noni-pulp in the diet increased from 0 to 2% (Table 3). The efficiency of gain also improved linearly ($P = 0.08$) with increased Noni levels in the diets (Table 3). Although the effects of Noni pulp on gain in cattle have not been previously researched, cattle with calmer temperaments have been shown to have greater ADG (Voisinet et al., 1997b), and Noni juice has been shown to have calming effects on other mammalian species (Wang et al., 2002). The addition of Noni pulp was applied as a top-dressing, thus the caloric intake of the diets was potentially not balanced between treatments. The digestibility of the Noni pulp is unknown. However, assuming that Noni is completely digestible, the additional calories provided by the Noni pulp would not have been great enough to account for the differences observed in weight gain.

The addition of Noni pulp to the diets did not cause refusal of the diets as evidenced by the similarities in feed intake ($P = 0.54$) among the treatments. Because the cattle were offered a fixed amount of feed (2.75% of BW), it is not known how Noni might affect ad libitum feed intake.

The concentration of white blood cells decreased linearly ($P = 0.01$) with the inclusion of Noni in the diet (Table 4). Furthermore, there was a quadratic relationship between monocytes and Noni dose ($P = 0.0004$) with the cattle fed 1% Noni having the largest percentage of monocytes. The relationship of Noni dose and eosinophils also was quadratic with a similar pattern ($P = 0.01$). No time × treatment interactions existed for total white blood cells or percentage of neutrophils, lymphocytes, monocytes, and eosinophils. There was a time × treatment interaction ($P < 0.01$) only for the percentage of basophils (Figure 1). Cattle supplemented with 2% Noni pulp had a large increase in the percentage of basophils on d 4 and 8 with no differences between the treatments on d 12 or later. The biological significance of this observation is unknown. The addition of Noni pulp did not affect the neutrophil to lymphocyte ratio, red blood cell counts, hemoglobin concentration, or hematocrit. Wang et al. (2002) noted the antibacterial and immunological activities of Noni plant extracts, but specific effects of Noni products on white blood cell counts in cattle have not been previously studied. The neutrophil to lymphocyte ratio has been used as an indicator of stress in cattle, with the ratio increasing in a stressed animal.

Noni pulp treatments did not affect serum cortisol ($P = 0.22$) concentrations at any time during the study (Figure 2). No previous research has been conducted on the effects of Noni products on cortisol concentrations in cattle. King et al. (2005) found numerical, but no statistical differences in cortisol concentrations between calm and excitable yearling-fed and calf-fed steers after the cattle had been on feed. In our study, there was variability between days ($P < 0.0001$) in serum cortisol concentrations, but no consistent trend could be identified.

Exit velocity also is used as a measure of excitability and has been correlated to gain and tenderness when measured in young cattle not exposed to human contact (Falkenberg et al., 2005; King et al., 2005). Nevertheless, adding Noni to the diet did not affect ($P > 0.05$) exit velocity scores (Figure 3), nor did time on feed and exposure to handling, as exit velocity times did not change ($P > 0.05$) with time. Falkenberg et al. (2005) found that exit velocity scores in yearling-fed cattle were not related to gain. This was in contrast to the present study, as the cattle were young and unexposed to human contact and the exit velocity scores did not improve with time.

Objective pen and chute scores were not affected ($P > 0.05$) by the inclusion of Noni pulp in the diet (Figure 4). Although there was no interaction ($P > 0.05$) between day of sampling and Noni pulp treatment, both pen and chute score decreased ($P < 0.0001$) with time, indicating that the cattle became calmer as the study progressed. No previous research has been conducted with Noni products in cattle, but rats have shown much calmer, less stressed demeanors when fed Noni (Wang et al., 2002). When Noni juice was supplemented in the drinking water for rats at 5, 10, and 20% for 10 d, animals were more tolerant than controls of antimony potassium tartrate-induced pain in a dose-dependent manner (Wang et al., 2002). In a separate study, female rats with Noni supplemented at 10 and 20% in their drinking water for 7 d were less reactive to hot-plate induced pain than control rats (Wang et al., 2002). Moreover, Younos et al. (1990) found that, in addition to being more pain tolerant, rats fed aqueous extracts from the roots of Morinda citrifolia showed less locomotor activity than controls in several tests. These researchers linked the sedative effect of Noni to its central analgesic effect.

In conclusion, cattle supplemented with Noni had greater gains and gained more efficiently than controls. The improvement in growth may be attributed to improved immune function. Noni-fed cattle were healthier, indicated by lower white blood cell concentrations. The effects of Noni juice on stress factors were not observed in stress and excitability measures such as neutrophil to lymphocyte ratio, serum cortisol, exit velocity, or subjective pen and chute scores.

Implications

This study should be the first of many investigating the effects of *Morinda citrifolia* (Noni) on large, domestic mammals. Further

studies should examine the effects of Noni on grass-fed cattle in cow-calf and stocker operations, feedlot cattle, as well as various levels of pork production. Noni may have the potential to decrease the incidence of dark cutters in beef and the pale, soft, and exudative condition in pork.

Acknowledgements

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Table 1. Composition of diet (as fed basis).

Ingredient	%
Bermudagrass hay	25
Corn	47.92
Soybean meal	5.6
Wheat midds	15
Molasses	3.75
Fat	1
Salt, white	0.3
Limestone	1.35
Vitamin premix[a]	0.05
Trace mineral premix[b]	0.03
Rumensin[c]	+

[a]Premix contained 1,710,000 IU vitamin A, 343,000 IU vitamin D, and 11,600 IU vitamin E/lb.
[b]Premix contained 12% Zn, 8% Mn, 4% Cu, 500 ppm Co, 2,000 ppm I, and 600 ppm Se.
[c]Provided 11.25 mg of monensin/lb of diet.

Table 2. Description of criteria used to assign behavior scores.

Item	Score	Description
Pen scores	1	Walks slowly, can be approached slowly, not excited by humans
	2	Runs along fences, stands in corner if humans stay away
	3	Runs along fences, head up and will run if humans come closer, stops before hitting gates and fences, avoids humans
	4	Runs, stays in back of group, head high and very aware of humans, may run into fences and gates
	5	Excited, runs into fences, runs over anything in its path
Chute scores	1	Calm – no movement
	2	Restless shifting
	3	Squirming, occasional shaking of weigh box
	4	Continuous vigorous movement and shaking of weigh box
	5	Criteria for a score of 4, plus rearing, twisting, or violently struggling

Table 3. Growth performance, feed intake, and feed to gain ratio of calves supplemented with Noni[a].

	Noni, % of diet (as fed)				*P* value	
Item	0	1	2	SE	Linear	Quadratic
Initial BW, lb	569	563	570	25.6	0.92	0.49
Final BW, lb	609	608	625	29.6	0.18	0.34
ADG, lb	1.42	1.60	1.95	0.194	0.03	0.61
Daily feed intake, lb	15.9	15.9	15.8	0.69	0.54	0.89
F/G	12.0	10.8	8.2	1.38	0.08	0.71

[a]Noni is the pulp of *Morinda citrifolia*, a Tahitian plant.

Table 4. Blood cell counts, hemoglobin, and hematocrit of calves supplemented with Noni[a].

	Noni, % of diet (as fed)				*P* value	
Item	0	1	2	SE	Linear	Quadratic
White blood cells, 1,000/μL	13.2	11.1	10.6	0.53	0.01	0.27
Neutrophils, %	35.4	34.7	36.9	1.8	0.59	0.54
Lymphocytes, %	54.7	52.5	54.2	1.7	0.84	0.37
Monocytes, %	5.6	7.0	5.4	0.21	0.51	0.0004
Eosinophils, %	3.9	5.2	3.2	0.37	0.19	0.01
Neutrophil:lymphocyte ratio	0.68	0.68	0.71	0.053	0.73	0.82
Red blood cells, 1,000,000/μL	10.8	10.7	10.3	0.22	0.14	0.49
Hemoglobin, g/dL	12.1	12.3	11.5	0.33	0.24	0.30
Hematocrit, %	41.2	42.3	39.7	1.05	0.34	0.20

[a]Noni is the pulp of *Morinda citrifolia*, a Tahitian plant.

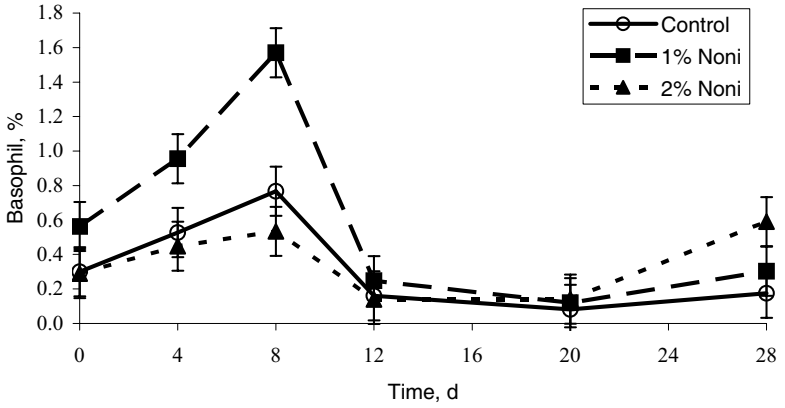

Fig. 1. Effect of supplemental Noni on percentage of basophils in whole blood (treatment, $P = 0.02$; day, $P < 0.001$, treatment × day, $P = 0.01$)

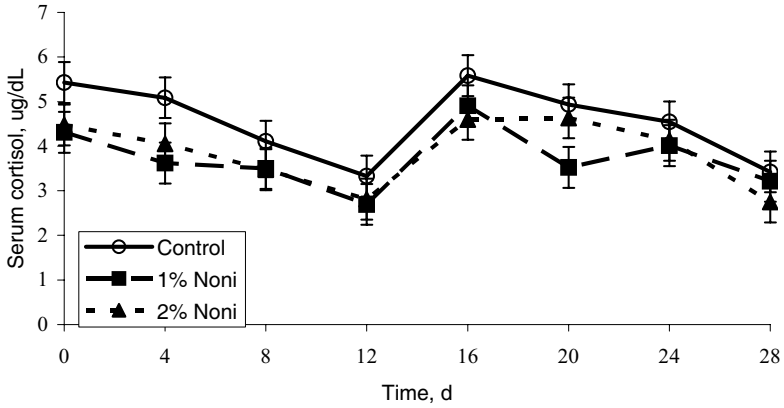

Fig. 2. Effect of supplemental Noni on serum cortisol concentrations (treatment, $P = 0.22$; day, $P < 0.0001$; treatment × day, $P = 0.18$).

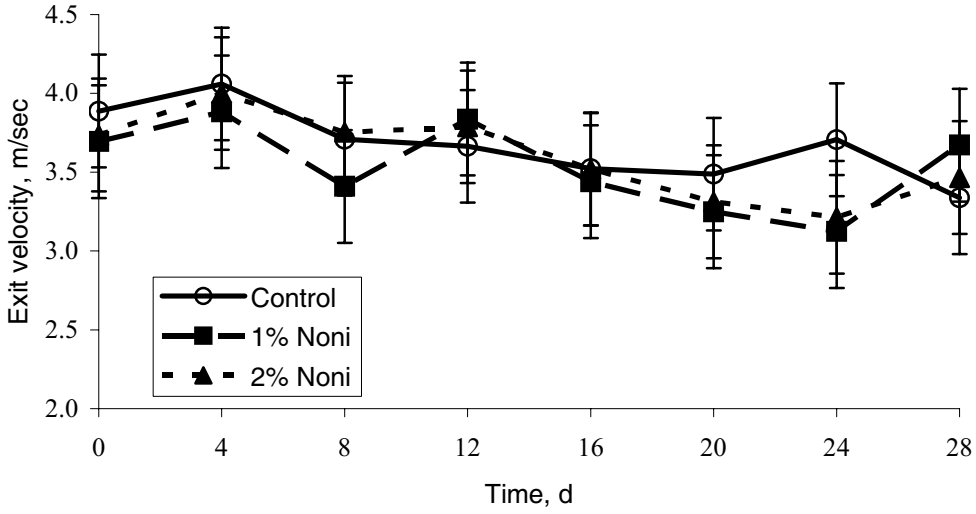

Fig. 3. Effect of supplemental Noni on chute exit velocity (treatment, $P = 0.92$; day, $P = 0.21$; treatment × day, $P = 0.93$).

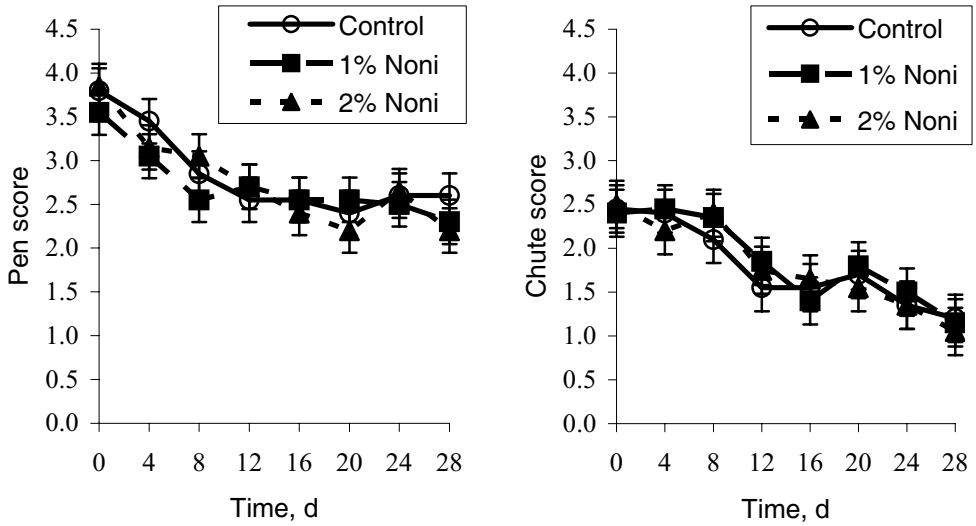

Fig. 4. Effect of supplemental Noni on pen and chute scores (treatment, $P \geq 0.81$; day, $P < 0.0001$; treatment × day, $P \geq 0.80$)

Sire Breed Effects for Cow and Calf Performance to Weaning in a Commercial Cow Herd

A.H. Brown,Jr.,[1], M.L. Looper[2], C.R. Rosenkrans, Jr.[1], C.W. Wall[3], and Z.B. Johnson[1]

Story in Brief

Crossbred calves (n = 384) were studied across 5 years to determine sire breed and dam effects for calf performance to weaning in a commercial cowherd in west central Arkansas. Calf breeds included Angus (AN) x AN (n = 62), Charolais (CH) x CH (n = 3), AN x CH (n = 109), CH x AN (n = 30), CH x Crossbred (CR) (n = 67), AN x CR (n = 89), AN x Hereford (H) (n = 7), and CH x H (n = 17). Dams were weighed at calf weaning. Calf traits of birth BW, ADG, weaning BW, hip height, body condition (weight:height ratio), and muscle thickness scores were determined. Dam efficiency (dam:calf ratio) was determined. Data were analyzed with mixed model procedures. The model included the fixed effects of sex, sire breed of dam (SBD), sire breed of calf (SBC), and the interaction of SBD by SBC and random effects of dam. Year was a repeated measure, and age of dam was a covariate for all traits. Age of calf was a covariate for calf weaning traits. The relationship between dam efficiency (as measured by dam weight/calf weight) and calf condition was determined by regression analysis. The model used for the regression included year, sex, and age of dam. Sire breed of calf affected birth BW ($P < 0.01$), hip height ($P < 0.01$), muscle thickness score ($P < 0.01$), and ADG ($P < 0.05$). Sex of calf was significant for birth BW ($P < 0.01$), ADG ($P < 0.01$), weaning BW ($P < 0.01$), hip height ($P < 0.01$), body condition ($P < 0.01$), and cow efficiency ($P < 0.01$). Age of dam influenced calf body condition ($P < 0.05$), ADG ($P < 0.05$), weaning BW ($P = 0.08$), and dam efficiency ($P < 0.05$). The coefficient of regression of dam efficiency on calf body condition was -0.4095 ($P < 0.01$). These results suggest that more efficient dams produced calves with greater estimated body condition. Charolais-sired calves were heavier at birth and taller at weaning than Angus-sired calves; however, Angus sired calves had greater muscle thickness at weaning.

Introduction

Where there is an adequate supply of nutrients, usually the most limiting factor influencing calf performance is the genetic makeup of the calf. A major genetic influence on nutrition of the calf is the genetic ability of the cows to produce an adequate supply of milk. Growth potential of the calf and maternal ability of the cow are influenced by selection and breeding. Thus, the choice of service sire breed and the choice of cow sire breed are important because they affect cow-calf performance. The objectives of this study are to determine sire breed of calf and sire breed of dam effects for calf performance to weaning in a commercial cowherd and determine the relationship between cow efficiency and calf condition at weaning in a commercial cowherd.

Experimental Procedures

All experimental procedures were reviewed and accepted by the Agricultural Research Service Animal Care and Use Committee and were in accordance with the Federation of Animal Science Society's *Guide to Care and Use of Agricultural Animals in Agricultural Research and Teaching*.

Data were collected on a commercial cow-calf operation in west central Arkansas. Preweaning data were available on 384 cow-calf pairs over 5 production cycles (years 1998-2003). Presented in Table 1 is a distribution of calves by sire breed of calf and sire breed of cow. Cows in the study resulted from top crossing mixed-breed cows to Angus, Hereford, and Charolais sires. There was a group of cows with unknown parentage that were included in the study as crossbred. All calves were born before April 1 of each production cycle. Calves received no creep feed. Bull calves were castrated, using a knife or emasculation methods, and implanted with Ralgro® at 3 mo of age. Cattle were primarily grazed on a mixed grass pasture made up of approximately 90% Bermudagrass and 10% fescue. Cows were rotated among pastures. Cattle were supplemented December 1st through the first 6 weeks of the breeding season. Dams were supplemented with 2 lb/d of ground corn with free choice hay. Annual vaccinations for dams consisted of a Lepto shot, Colstridal shot, deworming, and dehorning if necessary. Each year, cows were mated by natural service to Angus and Charolais bulls. Cows were randomly assigned to single-sire pastures. Bulls were selected on the basis of a balanced approached to EPDs. Sires were turned in with the cows the second week in April and removed from the breeding units the second week of July. All calves were weaned in September of each production cycle. Within 24 h of birth all calves were weighed and ear tagged. At calf weaning, each cow and calf were weighed, measured at the hips, calf condition (weight:height ratio) and muscle thickness determined. Muscle thickness was appraised visually and recorded on the basis of 1 to 3. Number 1 thickness was calves with high beef quality, considerable muscle thickness through the hindquarter, wide topped, and broad based. Number 2 thickness included calves that were narrow through the hindquarters. Number 3 thickness was calves that were narrow made from front to rear. Calf body condition was estimated as weight/height ratio. A dam/calf ratio was determined as dam weight at weaning divided by calf weight at weaning. Calf weaning rate over the 5 years averaged 95%.

[1] Department of Animal Science, Fayetteville
[2] USDA/ARS, Booneville
[3] Former county extension agent for Arkansas Cooperative Extension Service, Van Buren

Data were analyzed by mixed model least squares procedures. The linear model included the fixed effects of sex, sire breed of dam (SBD), sire breed of calf (SBC), and the interaction of SBD and SBC. Cow was considered a random effect and terms for cow within SBD, cow within SBD and SBC, and cow within sex by SBD and SBC were included in the random statement to generate error terms because of repeated (or split-plot) nature of the data. Cows could have been bred to more than one breed of sire and could have had both male and female offspring; however cows could have been bred to the same breed of sire and had the same sex offspring in more than one year; therefore, year was included as a repeated measure with the subject being cow within sex by SBD and SBC. Age of cow in years was a covariate for all traits. Age of calf at weaning was a covariate for calf traits at weaning. A linear regression analysis was conducted to determine the change in calf body condition as dam:calf ratio changed. The mathematical model included terms for year, sex, and age of dam. All analyses were conducted using PROC MIXED of SAS (SAS Institute, Inc., Cary, N.C.). Means were separated with the PDIFF option in SAS.

Results and Discussion

The SBD by SBC interaction was non-significant ($P > 0.05$) for all traits studied. Sex of calf was an important source of variation ($P < 0.01$) in calf birth BW, calf ADG, calf weaning BW, calf hip height, calf body condition, and dam:calf ratio. Year of calf weaning was an important source ($P < 0.01$) of variation in all traits studied, except for weaning weight ($P = 0.07$) and calf body condition score ($P = 0.09$). Age of dam was significant ($P < 0.01$) for calf ADG, calf weaning BW, calf body condition and cow efficiency. Age of dam was non-significant ($P > 0.05$) for calf birth BW, calf hip height, and muscle thickness score. Sire breed of cow was non-significant ($P > 0.05$) for all calf traits. Sire breed of calf was non-significant ($P > 0.05$) for calf weaning weight, calf body condition, dam efficiency ratio and dam's weight at calf weaning.

Sire breed of calf effects were significant ($P < 0.01$) for calf birth BW, ADG from birth to weaning, hip height, and muscle thickness score. Least squares means and standard errors for calf traits by sire breed are presented in Table 2. Charolais calves were heavier at birth ($P < 0.05$) than Angus-sired calves (81 vs 73 lb). These results are supported by the work of Nelson and Beavers (1987) and Peacock et al. (1978) who reported that Charolais-sired crossbred calves were heavier at birth than Angus-sired crossbred calves. Charolais-sired calves were numerically heavier (although not statistically; $P = 0.16$) in mean weaning BW when compared to Angus-sired calves (564 vs 546 lb). Peacock et al. (1978) found that Charolais-sired F_1 crossbred calves were 54 lb heavier at weaning than Angus-sired crossbred calves. Charolais-sired calves had greater ($P < 0.05$) ADG from birth to weaning when compared to Angus-sired calves (2.54 vs 2.42 lb/d). Charolais-sired calves were 1 in taller ($P < 0.05$) than Angus-sired calves. There were no differences in estimated mean body condition of Angus and Charolais bred calves. Angus-sired calves had greater ($P < 0.05$) mean muscle thickness scores when compared to Charolais-sired calves (1.5 vs 1.2).

Sex of calf was an important source of variation in calf birth BW, weaning BW, preweaning ADG, hip height, and estimated body condition score. Least squares mean and standard errors for calf traits by sex of calf are presented on Table 3. Birth BW of steer calves was 8% greater than that of heifer calves (80 vs 74 lb). Steer calves were 18 lb heavier ($P < 0.05$) at weaning than heifer calves (564 vs 546). Mean preweaning ADG was greater for steer calves when compared to heifer calves. Steer calves were 1 in greater in mean hip height than heifer calves. Steer calves had more ($P < 0.01$) mean estimated body condition when compared to heifer calves.

Sex of calf was an important source of variation ($P < 0.01$) for cow efficiency. Least squares means and standard errors for dam:calf ratio by sex of calf are presented in Table 4. Heifer calves had a greater ($P < 0.05$) cow efficiency (2.3 ± 0.04) than steer calves (2.1 ± 0.04).

Cows with smaller values for dam:cow ratio were more efficient. The coefficient of regression of dam efficiency on estimated calf condition was -0.4095 indicating that more efficient dams produced calves with greater body condition.

Implications

Sire breed of calf and sex of calf influenced several calf traits. Charolais-sired calves were heavier at birth and taller at weaning than Angus-sired calves; however, Angus-sired calves had greater muscle thickness at weaning.

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Table 1. Distribution of calves by sire breed of calf and sire breed of cow.

	Breed of sire of cow				
Breed of sire of calf	Angus	Charolais	Hereford	Crossbred	Total
Angus	62	109	7	89	267
Charolais	30	3	17	67	117
Total	92	112	24	156	384

Table 2. Least squares means and standard errors for calf traits by sire breed.

Breed of sire of calf	Trait				
	Birth BW, lb	Weaning BW, lb	ADG, lb	Hip height, in	Muscle thickness score[a]
Angus	73 ± 1.3[b]	546 ± 8.28[c]	2.42 ± 0.03[c]	44.6 ± 0.20[c]	1.5 ± 0.06[b]
Charolais	81 ± 1.9[c]	564 ± 11.0[b]	2.54 ± 0.04[b]	45.5 ± 0.27[b]	1.2 ± 0.09[c]

[a]Muscle thickness score of 1 to 3: 1 = calves with high beef quality, considerable muscle thickness through the hind quarter, wide topped, and broad based; 2 = calves that were narrow through the hind quarters; 3 = calves that were narrow made from front to rear.
[bc]Trait means with different superscripts differ ($P < 0.01$).

Table 3. Least squares means and standard errors for calf traits by sex of calf.

Sex	Trait				
	Birth BW, lb	Weaning BW, lb	ADG, lb/d	Hip Height, in	Estimated body condition[a]
Heifers	74 ± 1.3[c]	530 ± 8.0[b]	2.37 ± 0.03[c]	44.5 ± 0.20[c]	2.1 ± 0.03[c]
Steers	80 ± 1.3[b]	581 ± 8.1[b]	2.58 ± 0.03[b]	45.5 ± 0.20[b]	2.3 ± 0.03[b]

[a]Weight:height ratio.
[bc]Trait means with different superscripts differ ($P < 0.01$).

Table 4. Least squares means and standard errors for dam:calf ratio by sex of calf.

Sex	Dam:calf ratio[a]
Heifers	2.3 ± 0.04[c]
Steers	2.1 ± 0.04[b]

[a]Dam BW at weaning/adjusted 205d BW.
[bc]Trait means with different superscripts differ ($P < 0.01$).

Heterosis, Direct, and Maternal Effects for Preweaning Traits of Angus, Hereford, Red Poll, Santa Gertrudis, and Their Reciprocal Crosses

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

Story in Brief

Production records of cow-calf pairs (n = 1,631) were used to determine heterosis, maternal, and direct effects for calf performance from birth to weaning. Straight-bred Angus (n = 514), Hereford (n = 414), Red Poll (n = 51) and Santa Gertrudis (n = 24) and two-breed-cross calves of Angus x Hereford (n = 239), Hereford x Red Poll (n = 94), Angus x Red Poll (n = 166) and Angus x Santa Gertrudis (n = 129) and their reciprocal crosses were included in the study. Data were birth BW, preweaning ADG, weaning BW, weaning grade and body condition score. Heterosis effects were significant ($P < 0.01$) for birth BW, preweaning ADG, and weaning BW for Angus x Hereford. Heterosis was significant for preweaning ADG, weaning BW and weaning body condition score for Angus x Santa Gertrudis. No significant effects of heterosis were determined for weaning grade. Maternal effects were significant for all traits studied for Angus x Hereford. Maternal effects were significant for birth BW and preweaning ADG for all breed combinations except for preweaning ADG for Hereford x Red Poll. Direct effects for birth BW were significant for Angus x Hereford and Angus x Santa Gertrudis. Angus x Santa Gertrudis had a lower negative direct effect followed by Angus x Hereford. Direct effects for weaning body condition score were significant ($P < 0.05$) only for the Angus x Santa Gertrudis. Direct effects for weaning grade were significant for Angus x Hereford, Angus x Red Poll and Hereford x Red Poll. This study indicated that heterosis, maternal effects and direct effects should be considered in optimizing calf production potential in crossbreeding scenarios.

Introduction

Crossbreeding programs focus on increasing productivity of the cow-calf unit through utilization of information on breeds and breed combinations and their respective heterosis effects to influence traits that are of economic importance. Effective breeding programs utilize maternal contributions to progeny through maternal effects. Heterosis effects through crossbreeding can lead to increased productivity through greater production weight and improved average daily gains. This has been documented by many researchers including Long and Gregory (1974). This paper reports heterosis, maternal effects and direct effects (sire breed effects) for Angus x Hereford, Hereford x Red Poll, Angus x Red Poll and Angus x Santa Gertrudis two-breed-cross calves.

Experimental Procedures

Crossbreeding was utilized as the mating system for feeder calf production over a 10-year period, 1968 to 1977, at the Pine Tree Station in the University of Arkansas Agricultural Experiment Station System. Both straight-bred and two-breed-cross calves and their reciprocal crosses were produced. There were Angus (n = 514), Hereford (n = 414), Red Poll (n = 51) and Santa Gertrudis (n = 24) and Angus x Hereford (n = 239), Hereford x Red Poll (n = 94), Angus x Red Poll (n = 166), and Angus x Santa Gertrudis (n = 129). These data are relevant to today's industry because of the moderation in mature size that has occurred in cowherds in the southern states. The station is located approximately 43 mi due west of Memphis, Tenn., and 3.9 mi west of Colt, Ark., in St. Francis County in the L'Anguille River drainage system. The topography is relatively flat and the soils for pasture production are poorly drained. For the study period, mean annual low and high ambient temperature was 50°F and 73°F, respectively, and mean annual ambient temperature was 62°F. Mean annual rainfall at this location was approximately 55 in (National Climatic Data Center, Asheville, N.C.). Each year, during the spring and early summer ecto – and endo – parasite populations were considerably above the economic threshold. Also, it was common to count 30 to 40 horse flies per cow during the peak of the horse fly season. The incidence of anaplasmosis was high. The Pine Tree Station represents the most environmentally challenging area for feeder calf production in the state.

In each year of the study, pastures consisted of approximately a 60:40 ratio of unimproved pasture to improved pasture. The unimproved pasture consisted of stands of little blue stem grass and other native species. The improved pastures were stands of Kentucky 31 tall fescue that was approximately 80% infected with fungal endophyte, which has a negative impact on cattle performance (Patterson et al., 1995). Cows grazed unimproved pastures in the warm season and the improved pastures in the cool season. Fescue stands were fertilized in the fall according to the soil test recommendations. Broad leaf weeds were controlled by shredding pastures in the late summer and early fall. Stocking rate on the warm season grass was one cow-calf unit per 3.7 acre and stocking rate on the fescue was one cow-calf unit per 1.2 acre. Cows were fed a liquid protein supplement free choice from a tank through the use of a lick wheel in the late fall and during the winter until grass was available the following spring. The liquid protein supplement consisted of approximately 45% wood molasses, 29% molasses/urea mix, 20% condensed corn distillers solubles, and 6% mineral and vitamins (Southern Farmers Association Cooperative, Little Rock, Ark.). Cows received approximately 31 lb (air dry basis) of a medi-

[1] Department of Animal Science, Fayetteville

um quality Bermudagrass hay (45 to 55% TDN and 10 to 12% CP, air dry basis; NRC, 1996) during the late fall, winter and early spring. Calves received no creep feed. Throughout the study, animal management would have been consistent with recommendations by the Consortium (1988).

The initial Angus, Hereford, Red Poll and Santa Gertrudis cows in the study were born and developed in the purebred herds of the Arkansas Agricultural Experiment Station System and transferred to the Pine Tree Station. Four sire breeds were utilized including Angus, Hereford, Santa Gertrudis, and Red Poll. Bulls were selected based on performance in the Agricultural Experiment Station gain test at Fayetteville and tests sponsored for cooperating breeders at other locations throughout the state. All cows in the study were managed similarly and management practices during the study period were consistent with those for commercial beef production in the state. Cows were exposed for natural service mating in single sire pastures in a 120-d breeding period from January 15 though May 15 of each year. Bulls were exposed to breeding soundness evolution approximately 60 days prior to the start of the breeding period and, within sire breed group assignment, bulls were rotated among pastures to improve mating performance. Calving started around November 1 and ended around March 1 of each year. Within 24 hours of birth, calves were ear tagged, tattooed, weighted and male calves were castrated. Calves were weighed and weaned in late August.

Weaning body condition score and weaning grade were independently determined by trained personnel. Data for these observations were the mean of the independently determined scores and grades for each calf. The same personnel scored all calves in the study. Weaning grades were based on the 17-point Arkansas Beef Improvement Program grading chart and weaning body condition scores were based on the 7-point system of the same program and are shown in Table 1. The following equations are examples of the equations that were used to compute the values for heterosis, maternal and direct effects (Sandelin et al. 2002).

Heterosis equation (units)

$$[(\mathbf{AxH} + \mathbf{HxA})/2 - (\mathbf{AxA} + \mathbf{HxH})/2]$$

Direct effects (Sire breed effects): (Angus-Hereford comparison)

$$[(\mathbf{AxA} + \mathbf{AxH}) - (\mathbf{HxH} + \mathbf{HxA})]$$

Maternal effects equation (Difference between reciprocals)

$$[(\mathbf{HxA} - \mathbf{AxH})]$$

Birth weight and weaning weight were adjusted for age of dam and sex of calf based on adjustment factor information from the Beef Improvement Federation (BIF, 1996). Data were analyzed by least squares analysis of variance with unequal subclass numbers. Source of variation in birth weight and weaning traits was separated with a mathematical model that included terms for an overall mean, year, sex of calf, sire breed, dam breed, the two-way interactions of sex of calf x sire breed and sex of calf x dam breed, the three-way interaction of sex of calf x sire breed x dam breed, and residual. In a preliminary analysis the three-way interaction of sex of calf x sire breed x dam breed was non significant and was deleted from the model. Heterosis, maternal effects and direct effects were estimated using the ESTIMATE function, and least squares means were calculated for traits where interaction effects were significant and for main effects where interaction effects were non-significant using the LSMEANS option in GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.).

Results and Discussion

Heterosis, maternal effects and direct effects for birth and preweaning traits by breed combination are in Table 2. Heterosis effects for the Hereford x Red Poll breed comparison were not significant for birth or any preweaning trait. These data are not in agreement with Gregory et al. (1978) who found that heterosis effects for preweaning average daily gain and weaning weight were significant for the Hereford x Red Poll breed comparison. Heterosis values were significant and positive for birth weight of calves between Angus x Hereford and Angus x Red Poll breed comparison (3.26 and 3.2 lb, respectively). Heterosis values for calf birth weight for all breed combinations studied were positive indicating an increase in birth weight of crossbred calves over their purebred contemporaries. Gregory et al. (1978) reported average heterosis effects to be small for birth weight in the Red Poll, Hereford, Angus, and Brown Swiss breeds. Heterosis values of Angus x Hereford and Angus x Santa Gertrudis breed comparisons were significant ($P < 0.01$) for preweaning average daily gain and weaning weight. Crossbred Angus x Santa Gertrudis and Santa Gertrudis x Angus calves had a greater average daily gain and weaning weight (0.163 lb/day and 49.4 lb, respectively) than their purebred contemporaries. In our data, no difference ($P > 0.05$) was observed for heterosis effects on weaning grade. Heterosis effects between Angus x Red Poll and Angus x Santa Gertrudis breed comparisons were significant for weaning body condition score. Angus x Santa Gertrudis and reciprocal cross calves scored over one half of a point higher than did their purebred contemporaries.

Direct effects for the Angus x Santa Gertrudis breed comparison were significant ($P < 0.05$) for birth weight and weaning body condition score and were negative for all birth and preweaning traits except weaning grade and weaning body condition score. Santa Gertrudis bulls sired calves that were heavier ($P < 0.01$) at birth (12.46 lb) and had a lower ($P < 0.05$) weaning body condition score than calves from Angus sires. Calves sired by Continental European breed bulls were heavier than Angus or Hereford sired calves at weaning. Our data are in agreement with Hohenboken and Weber (1989) who stated Simmental, Pinzgauer, and Tarentaise sires produced calves that were 7 to 15 lb heavier at weaning than were calves sired by Hereford x Angus bulls. Direct effects were significant for preweaning average daily gain, weaning weight and weaning grade in the Angus x Red Poll breed combination. Red Poll bulls sired calves which were 59.3 lb heavier ($P < 0.01$) at weaning, gained ($P < 0.01$) 0.29 lb more per day, and graded almost three quarters of a point lower ($P < 0.05$) than calves sired by Angus bulls.

Direct effects for the Angus x Hereford breed comparison were significant and negative for birth weight and weaning grade, indicating that Hereford sires produced calves which were heavier at birth and graded higher at weaning than did calves from Angus sires. All breed comparisons in this study differed ($P < 0.05$) for maternal effects of birth weight. Our data do not agree with Gregory et al. (1978) who found that maternal effects were not significant for birth weight of Angus x Hereford and Hereford x Red Poll breed comparisons. Arthur et al. (1994) found that in breed comparisons involving Hereford and Brahman breeds, maternal effects and direct effects were not significant for birth weight. Maternal effects for birth weight were negative for the Angus x Hereford breed comparison indicating that Hereford x Angus calves were lighter at birth than were Angus x Hereford calves. Maternal effects for all other breed comparisons were negative for birth weight as well. British breed dams gave birth to smaller calves than did the continental European breed dams. Angus x Hereford

and Angus x Santa Gertrudis breed comparisons had significant maternal effects for weaning weight (28.4 and 74.1 lb, respectively). Our data agree with Gregory et al. (1978) that Hereford x Angus cross calves had a 26.0 lb advantage over the Angus x Hereford cross calves at weaning. Santa Gertrudis x Angus cross calves were 74.1 lb heavier at weaning when compared to Angus x Santa Gertrudis cross calves. Hereford x Angus cross calves were 28.4 lb heavier ($P < 0.01$) at weaning than were Angus x Hereford cross calves.

Implications

This research demonstrates that crossbred calves generally have an advantage over their purebred contemporaries under unfavorable environmental conditions. Increasing economically important production traits can be accomplished through heterosis, maternal effects, and direct effects. Sire breeds with genetic potential for growth generally pass this on to their progeny, resulting in increased preweaning average daily gain and weaning weights. The dam can also have a tremendous impact on progeny performance resulting in production increases through maternal ability.

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Table 1. Scoring scenario for weaning grade and weaning body condition.

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

Table taken from Brown et al. (1970)

Table 2. Heterosis, maternal effects and direct effects for birth and preweaning traits of calves by breed combination.

Combination	Birth weight , lb	Preweaning ADG, lb/day	Weaning weight, lb	Weaning grade[a]	Weaning body condition score[b]
Heterosis					
Angus x Hereford	3.26**	0.055**	21.2**	-.08	.03
Hereford x Red Poll	2.20	0.026	6.2	.19	.03
Angus x Red Poll	3.20*	-0.024	-3.3	.08	.26*
Angus x Santa Gertrudis	4.06	0.163**	49.4**	.104	.52**
Maternal					
Angus x Hereford	-5.20**	0.110**	28.4**	.81**	.39**
Hereford x Red Poll	-9.79*	-0.090	-32.4	-1.04*	.06
Angus x Red Poll	-10.10**	0.174**	-26.5	-12.0	-.14
Angus x Santa Gertrudis	7.65*	-0.236**	-74.1**	-33.6**	.40
Direct					
Angus x Hereford	-7.78**	0.037	8.20	-.37*	-.16
Hereford x Red Poll	4.21	-0.15	-37.0	1.39**	-.02
Angus x Red Poll	1.94	-0.29**	-59.3**	.72*	.40
Angus x Santa Gertrudis	-12.46**	-0.07	-16.56	.51	.67*

[a]17 = Fancy +, 16 = Fancy, 15 = Fancy -, 14 = Choice +, 13 = Choice, 12 = Choice -, 11 = Good +, 10 = Good, and 9 = Good -
[b]7 = Very fat, 6 = F, 5 = Average +, 4 = Average, 3 = Average -, 2 = Thin, 1 = Very thin
**$P < 0.01$, *$P < 0.05$

Arkansas Steer Feedout Program 2006-2007

Brett Barham, John Richeson, and Sammy Cline[1]

Story in Brief

The objective of the Arkansas Steer Feedout Program is to provide cow-calf producers information about the post-weaning feedlot performance and carcass characteristics of their calves. For the 2006-2007 feedout, quality grade, initial weight, hot carcass weight, yield grade, and medicine costs were factors that affected ($P < 0.05$) the feedlot return over specified costs. Cow calf producers who participated in the program will be able to use the information to evaluate how their cattle breeding programs fit the needs of the beef cattle industry.

Introduction

The University of Arkansas Cooperative Extension Service Steer Feedout Program provides cow-calf producers the opportunity to acquire information about postweaning performance and carcass characteristics of their calves. It also points out factors that influence value beyond the weaned calf phase of beef production. The program is not a contest to compare breeds or breeders or to promote retained ownership. The Feedout Program creates an opportunity for producers to determine how their calf crop fits the needs of the beef industry. The program also provides the information needed to determine if changes in genetics and/or management factors are warranted for producers to be competitive in beef production.

Experimental Procedures

On November 9, 2006, 117 steer calves from 15 Arkansas producers representing 10 counties were placed on feed at Wheeler Brothers Feedyard in Watonga, Okla. Calves were weighed on November 10, 2006. All calves were processed and placed in one pen. Management factors such as processing, medical treatments, and rations were the same as for the other cattle in the feedyard. Electronic identification (EID) tags were utilized to help the feedyard and Extension personnel manage individual animal medicine costs and weights. The feedyard manager and Extension personnel selected animals for harvest when they reached the weight and condition regarded as acceptable for the industry and market conditions. Cattle were sold on a carcass basis with premiums and discounts for various quality grades, yield grades, and carcass weights. Feed, processing, and medicine costs were financed by the feedyard. All expenses were deducted from the carcass income, and proceeds were sent to the owners.

Of the 117 steers that started on feed in the fall, 2 died (1.7% death loss). Three calves were sold as railers due to lack of performance or being chronically ill. These 5 calves were not included in the statistical analyses. Therefore, 112 steers were used in the analyses.

Results and Discussion

Table 1 is the overall financial summary. Table 2 is a financial summary of the bottom 25%, top 25% and average for steers based on feedlot net return. A farm break-even value was calculated by dividing the feedlot net return by the in weight. If the feeder calf could have been sold in the fall of 2006 for more than the farm break-even value, financially it would have been better to sell the calf in the fall than to feed it. The steers' farm break-even averaged $1.10 per pound (average initial weight was 643 lb) and ranged from $0.76 to $1.63 per pound. For the week ending November 10, 2006, 500 to 600 pound steers were selling for $0.97 to $1.05 per pound.

The sick pull rate averaged 29% with 35 calves treated for sickness. This is very similar to last year's 28% pull rate. The pull rate was high for cattle that were all listed as being preconditioned. The average medicine cost for the entire pen was $7.72 per head, $1 more than last year's average. The health status of cattle in the feedyard usually has a major impact on performance and profit. Healthy steers had higher ($P < 0.05$) feedlot net returns ($713) than steers that became sick ($605). Steers that did not receive treatment had higher average daily gain and hot carcass weights and lower feed cost of gain and total cost of gain ($P < 0.01$). No differences were noted between healthy and sick steers for dressing percentage, yield grade, ribeye area, and ribeye area per cwt of carcass weight ($P > 0.10$).

Given the past health issues that the cattle in the program have faced, producers need to implement a sound health management plan. By implementing a sound vaccination program at the ranch of origin, predictability and consistency of calves increases along with product value, and calves have the opportunity to express their genetic potential.

The average steer initial weight and final weights were 629 pounds (range = 425 to 823 lb) and 1,319 pounds (985 to 1,566 lb), respectively. Average daily gain was 3.69 pounds and ranged from 2.38 to 5.12 pounds. Overall, 44% of the steers graded Choice, compared to the national average of 56.8%. Ten head received a premium for Certified Angus Beef or Angus Pride Choice. Table 2 summarizes the carcass data.

[1] Department of Animal Science, Little Rock

Industry standards. Carcass standards for the beef cattle industry are Choice quality grade, yield grade of less than 4, and hot carcass weight between 550 and 950 pounds. Thirty-five percent of the steers fit these industry standards. Table 3 shows the steers that met the industry standards averaged $35 per head more than those that did not fit the industry standards ($P < 0.05$). They had higher carcass values because they graded Choice, and they were not discounted for yield grades greater than 4.0 or for carcasses outside the weight range. Of the steers that were in the top 25% based on feedlot net return, 92% met the industry standards, and for those in the bottom 25% based on feedlot net return, 100% did not meet the industry standards.

Factors affecting steers' feedlot net return. Listed below are the significant ($P < 0.05$) factors that affected feedlot net return for steers in the 2006-2007 program. Factors are listed in descending order of importance.

1. **Hot Carcass Weight** - The relationship between hot carcass weight and feedlot net return was positive. As hot carcass weight increased, so did feedlot net return (Table 4). The more carcass pounds sold, the greater the gross income and feedlot net return. Table 4 shows the relationship between hot carcass weight, total cost of gain, average daily gain, feedlot net return, and calculated return. Factors that affect hot carcass weight include frame size, muscle thickness and backfat. Muscle thickness is a major factor that relates to carcass weight. Thickness, depth, and fullness of quarter and width (without excessive fat) of back, loin, and rump are indications of muscling. The current USDA Feeder Cattle Grades utilize 4 muscle thickness scores (1 = thick, 2 = slightly thick, 3 = narrow and 4 = very narrow). Thickness is related to muscle-to-bone ratio at a given degree of thickness. Thicker muscled animals will have more lean meat. "Double-muscled" animals are included in the Inferior grade (unthrifty animals). Although such animals have a superior amount of muscle, they are graded U.S. Inferior because of their inability to produce acceptable degrees of meat quality. The ideal calf should be Feeder Cattle Grade U.S. 1. Number 1 is thrifty and moderately thick throughout. They are moderately thick and full in the forearm and gaskin, showing a rounded appearance through the back and loin with moderate width between the legs, both front and rear.
2. **Medicine Cost** - Healthy calves outperformed sick calves. A good preconditioning vaccination program will not guarantee a healthy feedyard calf, but it is the best management tool available. Healthy calves had a higher feedlot net return ($713 vs $605 per head) than calves that were treated for illness.
3. **Initial Weight** - The relationship between initial weight and feedlot net return was negative. As initial weight increased feedlot net return decreased. This relationship is slightly misleading though. The main reason initial weight shows up as a significant factor was due to the market at the time of harvest. The first group of steers harvested received the lowest carcass price of the 3 harvest groups. This first harvest group of steers was largely made up of the calves with heavier initial weight. Generally, the heavier the calf upon entrance to the feedyard the fewer days it took to reach slaughter weight. With the rising cost of feed, steers that are placed into the feedyard at heavier weights should be at an advantage.
4. **Quality Grade** - Cattle that graded Choice, Select, and No Roll had feedlot net returns of $782, $672, and $535 per head, respectively. All feedlot net returns based on quality grades differed ($P < 0.0001$). Marbling is the primary factor that affects a calf's ability to grade Choice. Three main factors that affect marbling are: (1) the genetic ability to marble; (2) the maturity or the physiological age, not the chronological age; and (3) ration. Some cattle breeds report marbling EPD's in their sire summaries. Carcass traits such as marbling are highly heritable; therefore, selecting high marbling EPD bulls can be effective for improving the marbling ability of their calves. Breeds can also influence a calf's ability to grade Choice. Calves with a high percentage of English breeding usually have an increased ability to grade Choice. Physiological age influences frame score. Large-frame cattle must be older (chronologically) to reach the same physiological age to express marbling as compared to smaller-frame cattle. Steers should be medium to large frame, and extremes at both ends of the scale (small and extremely large) should be avoided.
5. **Yield Grade** - As yield grade increased from 1 to 4, feedlot net return changed very little ($685, $709, $747, and $685 per head for yield grades 1, 2, 3, and 4, respectively). A positive note for this year's steers was that no carcasses fell in to the yield grade 5 classification. Yield grade 3 carcasses had higher returns than grades 1, 2 and 4 ($P < 0.05$). There were no differences among grades 1, 2 and 4 for feedlot net return ($P < 0.05$).

Implications

The purpose of the Arkansas Steer Feedout Program is to provide the opportunity for cow-calf producers to determine how their cattle fit the needs of the industry. With the traditionally large price spread between Choice and Select, it was very important to the "bottom line" that calves graded Choice. The program demonstrates that when cattle are sold on a grade and yield formula, it is very important that the cattle grade Choice and yield grade less than 3.5. Whether cattle are sold on a grade and yield formula or not, the industry wants cattle to grade and yield well. Regardless of the selling formula used (included live pricing), quality grade and yield are considered when determining the bidding price.

Table 1. Financial results summary, 2006-2007.[a]

Item	Average per head, $	Range, $
Gross income	1,209.79	871 to 1,562
Expenses		
Feed	396.64	301 to 547
Freight, interest, etc	72.73	78 to 87
Medicine	8.37	0 to 64
Total	**477.74**	**379 to 625**
Feedlot net return	707.66	479 to 940
In value	600.64	359 to 727
Calculated return	110.16	-118 to 366

[a]112 head.

Table 2. Performance summary of the bottom 25%, top 25% and average steers based on feedlot net return.

Item	Bottom 25%	Top 25%	Average
Number of steers	28	28	112
Gross Income per head, $	1,059[a]	1,343[b]	1,209
Carcass value per lb, $	1.46[a]	1.55[b]	1.49
In Value per head, $	550[a]	604[b]	600
Medicine per head, $	8.34[c]	3.30[d]	8.37
Feed cost per head, $	377[a]	434[b]	396
Total expense per head, $	464[a]	513[b]	477
Feedlot net return per head, $	595[a]	829[b]	708
Calculated return per head, $	44[a]	225[b]	107
Days on feed	181	191	192
Feed cost per lb of gain, $	0.62	0.59	0.71
Total cost per lb of gain, $	0.76	0.70	0.89
In weight, lb	604[a]	665[b]	643
Muscle score	1.7	1.6	1.7
Frame score			
Large	73%	79%	78%
Medium	27%	21%	21%
Final weight, lb	1,234[a]	1,411[b]	1,363
Average daily gain, lb	3.47[a]	3.94[b]	3.85
Hot carcass weight, lb	725[a]	863[b]	825
Carcass value, $/lb	1.46[a]	1.55[b]	1.49
Dressing percentage	61.2%[a]	63.7%[b]	62.6%
Ribeye area (REA), sq in	13.0	14.0	13.5
Backfat	0.44	0.48	0.52
REA per 100 lb carcass weight	1.80[a]	1.62[b]	1.69
Quality grade			
Prime	0%	0%	0%
Choice	10%[a]	86%[b]	44%
Select	21%[a]	14%[b]	51%
No roll	68%[a]	0%[b]	5%
Yield grade	1.82	2.44	2.32

[a,b] Values within rows with no superscripts in common differ ($P < 0.0001$).

Table 3. Feedlot net return, average daily gain and carcass value for steers that did or did not meet industry standards.[a]

Item	Met standards	Did not meet standards	Difference
Feedlot return, $	700	665	35[b]
Average daily gain, lb	3.66	3.75	0.09
Carcass value, $	1.45	1.55	0.10[b]

[a]USDA Quality Grade Choice, yield grade < 3.0 and carcass weight of 550 to 950 lb.

[b]$P < 0.05$.

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

Hot carcass weight, lb	Total cost of gain, $	ADG, lb	Feedlot net return per head, $	Calculated return per head, $
600-699	0.86	3.0	539	-34
700-799	0.71	3.6	675	124
800-899	0.68	3.8	738	145
900-999	0.68	4.3	872	243

First-Year Beef IQ Program Participant Survey Results

M.S. Gadberry[1], B. Barham[1], P. Beck[2], R. Hogan[3], J. Powell[4], W. Whitworth[5], and J. Richeson[4]

Story in Brief

The Arkansas Beef IQ program was implemented in 2007 for cattle producers that were interested in in-depth subject matter training in beef cattle production and management. Sixty-six individuals signed up for the 2007 program. Attendees experience in the beef industry ranged from less than 10 years (34%) to more than 20 years (41%). Throughout the 2007 calendar year, 6 different topic areas were repeated on 2 consecutive days, Monday's at Batesville and Tuesday's at Hope. Broad topic areas included Breeding and Genetics (February sessions), Reproduction (March sessions), Health (May sessions), Economics (July sessions), Pastures and Forages (September sessions), and Nutrition (October sessions). The knowledge gained by attending each session was examined in a pre- and post- self-examination of subject matter knowledge level ranking within each topic presented. The overall pre-session knowledge level averaged 2.6 compared to an average knowledge level of 4.0 after completing the sessions ($P < 0.001$). By attending the Beef IQ program, 71% of the session respondents agreed or strongly agreed that the subject matter covered would help them overcome limitations in farm resources. The agreement or disagreement rate did not differ among session topics ($P = 0.46$).

Introduction

Traditional county-level beef production workshops, short-courses and field days provide a foundation of basic knowledge for developing management practices that improve the productivity and efficiency for today's beef cattle producer. Unfortunately, time and travel limitations, along with a diversity of topics, can constrain the depth of training provided by these traditional methods. Often, producers leave with an intent to adopt, but may not have developed a sufficient knowledge basis to proceed with on-farm evaluation, planning, and practice adoption. The Arkansas Beef IQ program was implemented in 2007 for cattle producers that were interested in in-depth, subject matter training in beef cattle production and management. The course was designed to benefit ranch owners and ranch managers, as well as full-time and part-time cattle producers that desire to improve the profitability of the beef cattle enterprise.

The objective of this paper is to illustrate the producer participation background demographics and knowledge gained by first-year program participants.

Experimental Procedures

The 2007 Beef IQ program was offered at 2 locations, the Livestock and Forestry Branch Station in Batesville and the Southwest Research and Extension Center, Hope. Participants pre-registered for the program by December, 2006. Throughout the 2007 calendar year, 6 different topic areas were repeated on 2 consecutive days, Monday's at Batesville and Tuesday's at Hope. Broad topic areas included Breeding and Genetics (February sessions), Reproduction (March sessions), Health (May sessions), Economics (July sessions), Pastures and Forages (September sessions), and Nutrition (October sessions). All sessions began at 10 am and concluded by 4 pm. At the request of participants, activities and presentations continued through the designated lunch break. Some topics included hands-on activities such as cattle processing, castration, weighing and performance based selection exercises.

At the conclusion of each session, participants completed an evaluation that consisted of 4 questions consistent across all sessions. Question 1 asked participants to rank their current intensity level of management (low, moderate, or high) for the session topic presented. Question 2 asked participants to rank (scale of 1 to 5 with 1 = very little knowledge and 5 = very knowledgeable) their knowledge of each subtopic (Table 1) presented before and after attending the session. Question 3 asked participants to rank from 1 to 5 their most-limiting resource to least-limiting resource regarding the session topic. The 5 available resources included animals, land, financial, time, and knowledge. The final question (4) asked participants how strongly they agreed (strongly disagree, disagree, neither agree or disagree, agree, or strongly agree) with the following statement 'After completing the session, I am better prepared to overcome limiting resources.'

Survey data were summarized by combined location results and analyzed using JMP 7 (SAS Inst., Inc., Cary, N.C.). Chi-square analysis was conducted to determine if the 6 broad topic areas differed for current management intensity level (question 1) and whether broad topics addressed were equally likely to help producers overcome limited resources (question 4). Analysis of variance was used to determine if limited resource rank differed among sessions. In addition, analysis of variance of the mean rank for each subtopic question was used to determine if initial knowledge and knowledge gained differed among sessions.

[1] Department of Animal Science, Little Rock
[2] Department of Animal Science, Hope
[3] Texas A&M, Fort Stockton, Texas
[4] Department of Animal Science, Fayetteville
[5] Southeast Research and Extension Center, Monticello

Results and Discussion

Sixty-six individuals signed up for the 2007 program. Eighty-eight percent of attendees were beef cattle operation owners, 3% did not own cattle but were attending to learn prior to starting a herd, 3% managed cattle for someone else, and 6% were professionals including county Extension agents and an FFA instructor. Of the operations owned and managed, 57% were larger than 50 head, 34% were 25 to 50 head, and 9% were less than 25 head. The attendees experience in the beef industry ranged from less than 10 years (34%) to more than 20 years (41%). Eighty-two percent were commercial cow-calf operations, 9% were purebred operations, and the remainder represented a combination. Sixty-seven percent received part of their income off-farm, 23% received all of their income on the farm but had a complimentary livestock or farming enterprise, and 10% relied on the beef cattle enterprise as the sole income source.

The current intensity level of management (question 1: low, moderate, or high) did not differ among topic sessions ($P = 0.21$). Among topics, 51% of attendees ranked their current management intensity level, moderate; 31% ranked their intensity level, high; and 18% ranked their management intensity level, low.

The knowledge gained by attending each session was examined in a pre- and post- self-examination of subject matter knowledge level ranking within each topic presented. The overall pre-session knowledge level averaged 2.6 compared to an average knowledge level of 4.0 after completing the sessions ($P < 0.001$). Paired comparisons indicated all pre-session knowledge levels differed from all post-session knowledge levels (Table 2). Within the pre-session responses, the overall knowledge of the nutrition topics was lower than the knowledge of the health topics. Pre-session knowledge of all other topics was intermediate to health and nutrition. Post-session knowledge of economics remained the lowest and did not differ from the post-session knowledge of breeding and genetics or health. Post-session knowledge levels did not differ among nutrition, pasture management, reproduction, and health. Although some differences occurred statistically, average pre- and post-session knowledge levels ranged from 2.4 to 2.7 and 3.7 to 4.1, respectively.

The most-limiting factor affecting ranch productivity and profitability did not differ among session topics (session x resource interaction, $P = 0.44$). Overall, resource limitations differed ($P < 0.001$) with farm finances (2.6), land (2.9), and time (2.5) not differing but ranking as more significant limiting resources compared to knowledge (3.3) or animals (3.7).

By attending the Beef IQ program, 71% of the session responses agreed or strongly agreed that the subject matter covered would help them overcome limitations in farm resources. The agreement or disagreement rate did not differ among session topics ($P = 0.46$)

Implications

The Beef IQ program offered cattle producers an opportunity to expand their knowledge of beef production through six in-depth, subject matter based sessions. Participants of the Beef IQ program indicated they gained knowledge in all areas of beef production, which increased their chances of overcoming factors that were currently identified as limited resources.

Acknowledgments

The Beef IQ program planning committee expresses appreciation to Farm Credit Services of Western Arkansas, Arkansas Beef Council, Arkansas Farm Bureau, Boehringer Ingelheim, and AgHeritage, Farm Credit Services for sponsoring the 2007 program. The program planning committee also expresses appreciation to all instructor volunteers.

Table 1. Outline of subtopics covered during Beef IQ sessions.

Session	Subtopic	Speaker
Breeding and genetics	Carcass quality and tenderness	Dr. Brett Barham
	Crossbreeding systems	Dr. Brett Barham
	EPD's	Dr. Brett Barham
	Bull selection and management	Dr. Brett Barham
	Beef checkoff program	Mr. Travis Justice
Reproduction	Reproductive tract anatomy	Dr. Whitney Whitworth
	Estrous synchronization	Dr. Whitney Whitworth
	Heifer development	Dr. Tom Troxel
	Culling practices	Dr. Tom Troxel
	Breeding soundness examination	Dr. Whitney Whitworth
Herd health	Internal parasitism	Dr. Tom Yazwinski
	External parasitism	Dr. Kelly Loftin
	Immunology and vaccination	Dr. Jeremy Powell
	Electronic ID	Dr. Brett Barham
	Chute-side procedures	Dr. Jeremy Powell
	Toxic plant and plant ID	Dr. John Boyd
	Visual selection of replacements	Mr. Brian Kutz
	Disease Risk Management (poster)	
Economics	Being prepared to borrow	Mr. Junior Beshears, Mr. Tom Cox
	Essential tools for running a business	Mr. Scott Stiles
	What does it cost to produce it?	Dr. Rob Hogan
	Retained vs. purchased replacement heifers	Dr. Rob Hogan
	Managing production costs	Dr. Rob Hogan
	The cattle cycle	Dr. Rob Hogan
	Basis in beef cattle marketing	Dr. Rob Hogan
	Price slides in marketing	Dr. Rob Hogan
	Factors affecting beef business (COOL, NAIS, PETA, etc)	Mr. Travis Justice
Pasture and forages	Forage inventory for decision making	Dr. John Jennings
	Complimentary forages	Dr. Paul Beck
	Stockpiling forages	Dr. John Jennings
	Hay quality	Dr. Shane Gadberry
	Weed control	Mr. Blair Griffin, Mr. Mike McCarter
Nutrition	Rumen ecology (video)	
	Choosing the right supplement	Dr. Paul Beck
	Nutritional disorders	Dr. Shane Gadberry, Mr. Joe Paul Stuart
	Mineral and vitamin supplementation	Dr. Shane Gadberry
	Time management	Mrs. Allisen Penn

Table 2. Beef IQ participant pre- and post-session knowledge levels of session topics.

	Knowledge rank[a]	
Session	Pre-session	Post-session
Breeding and Genetics	2.6[e,f]	3.8[c,d]
Reproduction	2.5[e,f]	4.0[b,c]
Health	2.7[e]	4.0[b,c,d]
Economics	2.6[e,f]	3.7[d]
Pasture and Forages	2.6[e,f]	4.1[b]
Nutrition	2.4[f]	4.1[b]

[a]Knowledge rank on 1 to 5 scale (1 = very little knowledge and 5 = great deal of knowledge).
[b,c,d,e,f]Means with no superscript in common differ ($P < 0.05$; SEM = 0.1).

Effects of Ca Salts of Conjugated Linoleic Acid and Previous Rate of Weight Gain on Fatty Acid Composition of Adipose and Muscle of Beef Cattle

H. Flórez-Díaz[1], E.B. Kegley[2], J.W.S. Yancey[2], D.L. Galloway[2], and J.K. Apple[2]

Story in Brief

Crossbred beef steers (n = 35) were used to determine the effects of previous rate of gain and rumen-protected Ca salts of conjugated linoleic acid (CLA) on fatty acid composition of subcutaneous fat and *longissimus* muscle (LM). Growing diets were formulated for a low (LRG, 1.50 lb/d) or a high rate of gain (HRG, 3.0 lb/d) and contained either 4% Ca salts of palm oil or 4% Ca salts of CLA. After 56 d, cattle were transferred to finishing diets with a consistent goal for rate of gain, but remained on their treatment fat sources throughout an additional 56 to 113 d finishing period, and were slaughtered at approximately 1,250 lb. Subcutaneous fat and LM samples were removed 9 d postmortem. Feeding rumen protected CLA increased ($P < 0.001$) concentrations of CLA in both tissues, lowered ($P = 0.01$) percentages of total monounsaturated fatty acids in the subcutaneous fat, and decreased ($P < 0.01$) the LM omega-6:omega-3 ratio. The HRG diet increased ($P \leq 0.03$) CLA*cis9trans*11 in both tissues, and decreased ($P < 0.01$) concentrations of total polyunsaturated fatty acids in the LM. In conclusion, previous rate of gain did not have a large effect on the subcutaneous fat, but cattle fed to achieve a higher rate of gain had lower concentrations of polyunsaturated fatty acids in the LM. Feeding CLA salts was effective at increasing CLA in tissues, but decreased monounsaturated fatty acids in the subcutaneous fat and increased trans fatty acid concentrations.

Introduction

Conjugated linoleic acid (CLA) is a mixture of positional and geometric isomers of the omega-6 essential fatty acid, linoleic acid that is produced by ruminal biohydrogenation. Increasing dietary CLA has resulted in increased feed efficiency of rats, and decreased subcutaneous fat thickness, and increased lean tissue in finishing steers (Gassman et al., 2000).

The CLA content of beef may be increased by feeding Ca salts of CLA supplements that make CLA available for absorption in the intestine and deposition in tissues. Restricting feed intake of cattle during a growing phase resulted in decreased rate of growth, increased carcass leanness, and increased time needed during the finishing phase. However, research investigating the interaction of CLA supplementation and previous nutrition on fatty acid composition of the carcass is limited, particularly in beef cattle. The objective of this research was to determine the effects of supplemental Ca salts of CLA isomers, and previous rate of growth on fatty acid composition of beef.

Experimental Procedures

Thirty-five crossbreed steers (886.3 ± 66.1 lb initial BW) of predominantly Angus breeding were used from a previous growing study (Flórez-Díaz et al., 2006b) and maintained in dry-lot pens with 6 pens per dietary treatment. Dietary treatments (Table 1) consisted of: 1) control diet based on concentrate supplemented with 4% (DM basis) of rumen-protected Ca salts of palm fatty acid distillate (Table 2) and 2) concentrate diet with 4% rumen-protected Ca salts of mixed isomers of CLA. The steers had received Ca salts of CLA or palm oil during a 56-d growing phase with low (1.5 lb/d) or high (3.0 lb/d) rate of live weight gain. Steers in this study remained on the same fat source and in the same pen as they were in the growing study. Fat supplements were mixed with the concentrates and offered as part of the total ration to experimental animals. Diets were fed once daily at approximately 0800. Bunks were observed immediately prior to feeding, and an amount of feed was offered that allowed for ad libitum intake with minimal orts. This finishing phase lasted from 56 to 113 d. Growth performance and carcass characteristics have been previously reported (Flórez-Díaz et al., 2006a).

Sixteen steers (8/treatment) were harvested at the University of Arkansas abattoir. Steers were harvested in groups of 4, by harvesting the heaviest steer in each pen of each block, when their weights approximated 1,250 lb. The remaining steers (19 animals) were fed the treatment diets to reach 1,250 lb, which required an additional 27 d on the dietary treatments. These steers were harvested in a commercial abattoir (Tyson Foods, Emporia, Kan.). All steers were stunned via captive bolt pistol and exsanguinated. Following a 48-h chilling period, a rib section was removed and transported on ice to the Red Meat Abattoir, where rib sections were aged for 7 d at 36°F.

After 7 d, 1-in thick steaks were cut and at this time, samples of subcutaneous fat and *longissimus* muscle were removed and frozen at -4°F until analyses. Samples were freeze dried, then 35-mg samples of adipose tissue or 200-mg samples of *longissimus* muscle were subjected to transesterification. An internal standard (glyceryl tritridecanotate [13:0], 1 mg/mL) was prepared in hexane, and 1 mL was added to each 16 × 125-mm screw-cap tube. The hexane was evaporated leaving the internal standard, then samples were added to tubes and incubated in 2.0 mL of 0.2 M methanolic KOH at 122°F for 30 min with vortex-mixing 2 to 3 times/min until samples were dissolved (Murrieta et al., 2003). Tubes were allowed to cool to room temperature, and 1 mL of saturated NaCl was added to each tube. Two milliliters of hexane were added to the tubes, and tubes were vortexed and centrifuged for 5 min at 1,100 × g to separate the phases.

An approximate 1-mL portion of the hexane layer, containing the fatty-acid methyl esters, was transferred to gas-liquid chromatography vials that contained a 1.0-mm bed of anhydrous sodi-

[1] Present address: Centro de Investigación la Libertad, Corpoica, Km. 17 vía Puerto López, Villavicencio, Meta, Colombia
[2] Department of Animal Science, Fayetteville

um sulfate. Separation of fatty-acid methyl esters was achieved by gas-liquid chromatography (HP model 6890 Series II with HP 7673 automatic injector [Agilent Technologies, Inc., Wilmington, Del.]) with a 100-m capillary column (Supelco 2560 Fused Silica Capillary column; Supelco Park, Bellefonte, Pa.) and He as a carrier gas at 0.5 mL/min with a 1:50 split ratio. Oven temperature was maintained at 302°F for 5 min, ramped at 39.2°F/min to 381.2°F for 15 min, and then ramped at 36.5°F/min to 455°F for 16.25 min. Injector and detector temperatures were 482°F, and identification of fatty-acid methyl esters peaks was accomplished using purified standards (Supelco; Nu-Chek Prep, Elysian, Minn.; and Matreya, Pleasant Gap, Pa.).

Data from each tissue were analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). The model included the effects of previous rate of live weight gain, fat source, and their interaction. Block (original BW block) was a random effect. Before analyses, pen means for each fatty acid were calculated and pen was the experimental unit. Least squares means and the PDIFF option in SAS were used to compare any fat source × gain interactions.

Results and Discussion

Subcutaneous fat. There were no ($P \geq 0.09$) interactions of previous rate of gain × fat source on fatty acid composition of the subcutaneous fat (Table 3). Previous rate of gain during the growing period had minimal impacts on fatty acid composition of the subcutaneous fat. A greater rate of gain during the growing phase decreased ($P = 0.05$) the percentage of margaric acid (17:0) in the subcutaneous fat; and increased ($P = 0.03$) the percentage of CLA*cis9trans*11.

Source of rumen protected supplemental fat had a greater impact on the fatty acid composition of the subcutaneous fat. Feeding Ca salts of CLA increased ($P \leq 0.01$) the percentages of myristic acid (14:0), palmitelaidic acid (16:1trans), total 18:1trans fatty acids, CLA*cis9trans*11, CLA*trans10cis*12, CLA*cis9cis*11, total CLA, and total diunsaturated fatty acids. However, feeding Ca salts of CLA decreased ($P \leq 0.04$) the percentages of palmitoleic acid (16:1cis), oleic acid (18:1cis9), total monounsaturated fatty acids, linoleic acid (18:2), dihomo-γ-linolenic acid (20:3omega-6), and total unsaturated fatty acids. In addition, feeding Ca salts of CLA tended to increase ($P \leq 0.08$) the percentages of capric acid (10:0), vaccenic acid (18:1cis11), and CLAtrans9trans11. Feeding Ca salts of CLA also increased ($P < 0.001$) the amount of unidentified fatty acid peaks and the total trans fatty acids from the subcutaneous fat.

Longissimus muscle. In general, dietary treatments had a much greater impact on the percentages of fatty acids in the *longissimus* muscle (Table 4). While there were many main effects of previous rate of gain and fat source on percentages of fatty acids, 17:0 was the only fatty acid for which there was a previous rate of gain × fat source interaction ($P = 0.05$). Margaric acid was lowest in *longissimus* muscle from steers fed Ca salts of palm oil and the high rate of gain diet (1.185%) vs. the *longissimus* muscle of steers fed the other diets (1.302, 1.314, 1.328% for high rate of gain with CLA, low rate of gain with CLA, and low rate of gain with palm oil, respectively).

A greater rate of gain during the growing phase increased ($P \leq 0.03$) percentages of 14:0, arachidic acid (20:0), myristoleic acid (14:1), heptadecenoic acid (17:1), CLA*cis9trans*11, and total unidentified fatty acid peaks in the *longissimus* muscle. However, a greater rate of gain decreased ($P \leq 0.03$) percentages of 18:2, linolenic acid (18:3omega-3), 20:3omega-6, arachidonic acid (20:4), eicosapentaenoic acid (20:5), docosapentaenoic acid (22:5), total polyunsaturated fatty acids, and total omega-3 and omega-6 fatty acids. The greater rate of gain tended to increase ($P \leq 0.08$) the percentages of lauric acid (12:0), 16:1*cis*, and the total CLA, but tended to decrease ($P = 0.07$) the total diunsaturated fatty acids.

Feeding Ca salts of CLA increased ($P \leq 0.01$) the percentage of C16:1*trans*, total 18:1*trans*, 18:1*cis*11, CLA*cis9trans*11, CLA*trans10cis*12, CLA*cis9cis*11, total CLA, total *trans* fatty acids, and total unidentified fatty acid peaks. Yet, feeding Ca salts of CLA decreased ($P \leq 0.03$) the percentages of 14:1, 16:1*cis*, 18:1*cis*9, 20:3omega-6, and the omega-6:omega-3 ratio. Feeding Ca salts of CLA tended to decrease ($P \leq 0.07$) the total monounsaturated fatty acids and percentage of 20:4, but tended to increase ($P \leq 0.08$) the percentages of pentadecanoic acid (15:0) and 20:5.

Compared to the subcutaneous fat, the *longissimus* muscle fatty acid composition was impacted to a much greater extent by the different growing phase diets. Margaric acid was decreased and CLA*cis9trans*11 was increased in both tissues by the high rate of gain diet in the growing phase, and these were the only fatty acids still impacted in the subcutaneous fat. However, in the *longissimus* muscle the higher rate of gain in the growing phase resulted in numerous alterations in fatty acid composition, even though the cattle had been fed for a common rate of gain for the 56 to 113 d finishing phase. Feeding the high rate of gain diet in the growing phase decreased linoleic acid and all measured polyunsaturated fatty acids (> 2 double bonds) in the *longissimus* muscle. In addition, the high rate of gain growing diet decreased both the total omega-3 and the total omega-6 fatty acids in the *longissimus* muscle without altering the omega-6:omega-3 ratio. This is at least in part due to these higher rate of gain in the growing phase cattle having more fat within the *longissimus* muscle (5.45 vs. 3.6% fatty acids on a wet tissue basis; SE = 0.4, $P = 0.001$). That increased amount of fat would decrease the impact of cell membrane fatty acids, which tend to be more unsaturated. In muscle, an important proportion of lipids are phospholipids, which are component of cellular membranes, and their quantity remains fairly constant or increases slightly as the animal increases in fatness (Wood et al., 2008). This increased fat deposition in the *longissimus* muscle in the high rate of gain cattle is further supported by a decreased moisture in the *longissimus* muscle (71.7%) vs. moisture in the *longissimus* muscle from cattle fed for low rate of gain during the growing phase (73.0% SE = 0.342; $P < 0.05$). Typically moisture content of a tissue is inversely related to fat content. In addition, there were numerical differences in marbling scores with high rate of gain cattle having higher marbling scores than low rate of gain cattle upon carcass evaluation (Flórez-Díaz et al., 2006a).

Feeding the Ca salts of CLA compared to the Ca salts of palm oil dramatically altered the fatty acid composition of both tissues. Cattle were fed these different sources of rumen protected fats for both the growing and the finishing phases, therefore cattle were fed these fats for 112 to 169 d. Feeding the Ca salts of CLA decreased the total percentage of monounsaturated fatty acids; however, it appreciably increased the percentage of total *trans* fatty acids. Feeding the Ca salts of CLA increased the total CLA content of both tissues by over 2.7-fold. Feeding the rumen protected Ca salts of palm oil, which were 34 to 36% 18:1*cis*9 increased that fatty acid in both tissues.

Feeding the Ca salts of CLA increased total 18:1*trans* fatty acid by over 2.2-fold in both tissues. The majority of these fatty acids are probably *trans*-vaccenic acid (18:1*trans*11). This would represent an alteration in the rate of complete biohydrogenation of other

dietary fats within the rumen, or some availability and biohydrogenation of the rumen protected CLA within the rumen. The percentage of CLA in ruminant tissues is dependent on the ruminal formation of both vaccenic acid and CLA (De la Torre et al., 2006). Desaturation of vaccenic acid is the main source of CLA in the muscle lipids by the action of the enzyme Δ^9-desaturase (Knight et al., 2003).

Implications

Alterations in rate of gain during the growing phase more dramatically changed the fatty acid composition of the *longissimus* muscle than the subcutaneous fat. By feeding rumen protected CLA, percentages of total CLA in both *longissimus* muscle and subcutaneous fat were increased.

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Table 1. Ingredient composition (% of DM) of experimental diets during the finishing phase.

	Treatments[1]	
Ingredient	Palm oil	CLA
Corn, cracked	55.6	55.5
Cottonseed hulls	13.5	13.5
Soybean meal	5.2	5.2
Wheat middlings	14.6	14.6
Molasses, cane	5.0	5.0
Limestone	0.91	0.91
Salt	0.25	0.25
Urea	0.77	0.77
Ca salts of palm oil[2]	4.0	-
Ca salts of CLA[3]	-	4.1
Monensin[4]	+	+
Vitamin premix[5]	+	+
Trace mineral premix[6]	+	+

[1]Concentrate diet with Ca-salts of palm oil or Ca-salts of CLA.
[2]Ener GII (96.5% DM, 82 to 85% fat, and 9 to 11% Ca), Virtus Nutrition, LLC, Corcoran, CA.
[3]Calcium salts of CLA (96.5% DM, 80 to 84% fat, 9 to 11% Ca), Virtus Nutrition, LLC, Corcoran, CA.
[4]Rumensin 80 (Elanco, Indianapolis, IN), 10 mg of monensin/lb of diet DM
[5]Premix supplied per lb of diet: 386 IU of vitamin A, 77 IU of vitamin D_3, and 0.15 IU vitamin E.
[6]Premix supplied per lb of diet: 6 mg of Zn as $ZnSO_4$, 1.8 mg of Cu as $CuSO_4$, 0.03 mg of Se as Na_2SeO_3, 0.09 mg of I as $CaIO_4$, and 0.02 mg of Co as $CoCO_3$.

Table 2. Fatty acid profiles of calcium salts of palm oil and calcium salts of conjugated linoleic acid (CLA) supplements (g/100 g of fatty acids).[1]

Fatty acid	Ca-salts of palm oil	Ca-salts of CLA
Myristic (14:0)	1 to 2	0.5 to 1
Palmitic (16:0)	43 to 50	20 to 25
Stearic (18:0)	4 to 8	2 to 4
Oleic (18:1*cis*9)	34 to 36	28 to 32
Linoleic (18:2*cis*9*cis*12)	7 to 10	5 to 7
CLA*cis*9*trans*11	-	5 to 8
CLA*trans*10*cis*12	-	6 to 11
CLA, other	-	5 to 10

[1]Fatty acid composition provided by Virtus Nutrition LLC, Corcoran, CA. Palm oil supplement contained 82 to 85% fat and CLA supplement contained 80 to 84% fat.

Table 3. Effects of previous rate of weight gain and Ca salts of conjugated linoleic acid (CLA) on the fatty acid (FA) composition of beef subcutaneous fat.

	Growing phase gain[1]			Fat source[2]			Pr > F[3]		
Fatty acid, %	Low	High	SE	Palm oil	CLA	SE	GAIN	FAT	GAIN × FAT
Total saturated FA	49.29	49.87	0.578	48.94	50.22	0.578	0.50	0.17	0.90
Capric acid (10:0)	0.054	0.052	0.002	0.050	0.055	0.002	0.57	0.08	0.96
Lauric acid (12:0)	0.073	0.078	0.007	0.072	0.080	0.007	0.29	0.10	0.09
Myristic acid (14:0)	3.75	3.98	0.211	3.48	4.25	0.211	0.33	0.01	0.67
Pentadecanoic acid (15:0)	0.733	0.698	0.047	0.687	0.744	0.047	0.56	0.36	0.71
Palmitic acid (16:0)	28.76	28.91	0.520	28.69	28.98	0.520	0.84	0.70	0.99
Margaric acid (17:0)	1.538	1.342	0.061	1.445	1.436	0.061	0.05	0.91	0.31
Stearic acid (18:0)	14.35	14.78	0.664	14.49	14.65	0.664	0.66	0.87	0.90
Arachidic acid (20:0)	0.021	0.034	0.005	0.025	0.030	0.005	0.10	0.50	0.14
Total monounsaturated FA	45.59	44.86	0.572	46.82	43.64	0.572	0.40	0.01	0.96
Myristoleic acid (14:1)	0.64	0.70	0.108	0.74	0.60	0.108	0.54	0.21	0.28
Palmitelaidic acid (16:1*trans*)	0.277	0.290	0.016	0.23	0.336	0.016	0.60	0.003	0.59
Palmitoleic acid (16:1*cis*)	3.31	3.49	0.244	3.73	3.06	0.244	0.51	0.04	0.23
Heptadecenoic acid (17:1*trans*)	0.002	0.003	0.002	0.002	0.003	0.002	0.26	0.51	0.37
Total 18:1*trans* FA	6.53	6.37	0.348	3.78	9.12	0.348	0.64	<0.001	0.29
Oleic acid (18:1*cis*9)	33.12	32.32	0.554	36.70	28.74	0.554	0.35	<0.001	0.78
Vaccenic acid (18:1*cis*11)	1.666	1.633	0.056	1.569	1.730	0.056	0.67	0.07	0.45
Gadoleic acid (20:1)	0.048	0.052	0.015	0.063	0.037	0.015	0.83	0.27	0.36
Total diunsaturated FA	2.43	2.57	0.087	2.04	2.96	0.087	0.29	<0.001	0.52
Linoleic acid (18:2omega-6)	1.377	1.409	0.056	1.518	1.268	0.056	0.70	0.02	0.63
Total CLA	1.052	1.162	0.048	0.524	1.691	0.048	0.15	<0.001	0.54
CLA*cis*9*trans*11	0.595	0.699	0.035	0.524	0.770	0.035	0.03	<0.001	0.23
CLA*trans*10*cis*12	0.078	0.078	0.008	n.d.[4]	0.156	0.008	0.98	<0.001	0.97
CLA*trans*9*trans*11	0.017	0.010	0.009	n.d.	0.027	0.009	0.56	0.06	0.56
CLA*cis*9*cis*11	0.362	0.375	0.021	n.d.	0.737	0.021	0.68	<0.001	0.68
Total polyunsaturated FA	0.360	0.371	0.019	0.385	0.346	0.019	0.69	0.19	0.68
Linolenic acid (18:3omega-3)	0.346	0.362	0.020	0.362	0.346	0.020	0.54	0.58	0.85
Dihomo-γ-linolenic acid (20:3omega-6)	0.014	0.008	0.005	0.022	n.d.	0.005	0.39	0.02	0.39
Arachidonic acid (20:4omega-6)	n.d.	0.001	0.001	0.001	n.d.	0.001	0.36	0.36	0.36
Total unsaturated FA	48.38	47.80	0.568	49.25	46.94	0.568	0.50	0.03	0.97
Total unidentified FA peaks	2.33	2.32	0.112	1.81	2.84	0.112	0.95	<0.001	0.61
Total *trans* FA[5]	6.81	6.67	0.344	4.02	9.46	0.344	0.68	<0.001	0.32
Total omega-3 FA[6]	0.346	0.362	0.020	0.362	0.346	0.020	0.55	0.57	0.85
Total omega-6 FA[7]	1.470	1.496	0.062	1.542	1.424	0.062	0.78	0.23	0.71
Omega-6:omega-3[8]	4.39	4.41	0.427	4.56	4.23	0.427	0.97	0.59	0.54
Iodine value[9]	44.09	43.71	0.499	44.46	43.34	0.499	0.61	0.16	0.98

[1]Cattle were fed during the growing phase to obtain an ADG of 1.5 lb (low) or 3.0 lb (high). This was followed by a 56 to 113 d finishing phase where diets only differed in fat source.
[2]Cattle were fed 4% of diet DM as Ca salts of palm oil or as Ca salts of CLA.
[3]Probability values of F-tests for the main effects of previous rate of weight gain (GAIN) and source of supplemental fat (FAT) as well as the previous rate of weight gain × fat source interaction (GAIN × FAT).
[4]n.d. = not detectable.
[5]Total *trans* FA = {[16:1*trans*] + [17:1*trans*] + [total 18:1*trans*]}, where the brackets indicate concentration.
[6]Total omega-3 FA = [18:3omega-3].
[7]Total omega-6 FA = {[18:2omega-6] + [CLA*trans*10*cis*12] + [20:3omega-6] + [20:4omega-6]}, where the brackets indicate concentration.
[8]Σomega-6 ÷ Σomega-3.
[9]Iodine value = {0.95 × [16:1]} + {0.86 × [18:1]} + {1.732 × [18:2]} + {2.616 × [18:3]} + {0.785 × [20:1]}, where the brackets indicate concentration (AOCS, 1998).

Table 4. Effects of previous rate of weight gain and Ca salts of conjugated linoleic acid (CLA) on the fatty acid (FA) composition of beef longissimus muscle.

	Growing phase gain[1]			Fat source[2]			Pr > F[3]		
Fatty acid, %	Low	High	SE	Palm oil	CLA	SE	GAIN	FAT	GAIN × FAT
Total saturated FA	47.59	47.62	0.409	47.53	47.68	0.406	0.96	0.78	0.38
Capric acid (10:0)	0.049	0.055	0.004	0.053	0.051	0.004	0.34	0.77	0.53
Lauric acid (12:0)	0.059	0.070	0.006	0.063	0.066	0.006	0.06	0.53	0.75
Myristic acid (14:0)	2.95	3.29	0.113	3.03	3.21	0.113	0.03	0.18	0.94
Pentadecanoic acid (15:0)	0.529	0.520	0.020	0.504	0.546	0.020	0.68	0.08	0.24
Palmitic acid (16:0)	28.21	28.43	0.356	28.56	28.08	0.356	0.47	0.14	0.58
Margaric acid (17:0)	1.321	1.244	0.028	1.257	1.308	0.028	0.03	0.10	0.05
Stearic acid (18:0)	14.45	13.96	0.241	14.03	14.38	0.241	0.20	0.34	0.15
Arachidic acid (20:0)	0.013	0.041	0.003	0.025	0.030	0.003	<0.001	0.25	0.11
Total monounsaturated FA	43.95	44.50	0.487	44.81	43.64	0.487	0.34	0.07	0.40
Myristoleic acid (14:1)	0.438	0.544	0.037	0.545	0.437	0.037	0.02	0.02	0.22
Palmitelaidic acid (16:1*trans*)	0.269	0.270	0.024	0.212	0.326	0.024	0.96	<0.001	0.86
Palmitoleic acid (16:1*cis*)	2.96	3.28	0.106	3.32	2.91	0.106	0.08	0.03	0.17
Heptadecenoic acid (17:1*trans*)	0.001	0.019	0.005	0.010	0.010	0.005	0.01	0.95	0.63
Total 18:1*trans*	4.31	4.68	0.284	2.77	6.21	0.284	0.34	<0.001	0.22
Oleic acid (18:1*cis*9)	34.21	33.86	0.519	36.23	31.84	0.519	0.57	<0.001	0.33
Vaccenic acid (18:1*cis*11)	1.687	1.731	0.062	1.620	1.798	0.062	0.36	0.01	0.11
Gadoleic acid (20:1)	0.079	0.116	0.039	0.088	0.107	0.039	0.15	0.42	0.28
Total diunsaturated FA	4.48	3.90	0.213	3.98	4.41	0.213	0.07	0.15	0.83
Linoleic acid (18:2omega-6)	3.90	3.10	0.165	3.60	6.40	0.165	0.01	0.38	0.61
Total CLA	0.579	0.800	0.070	0.375	1.004	0.070	0.07	<0.001	0.60
CLA*cis*9*trans*11	0.363	0.467	0.032	0.332	0.498	0.032	0.02	0.002	0.50
CLA*trans*10*cis*12	0.040	0.063	0.014	0.012	0.091	0.014	0.28	0.006	0.98
CLA*trans*9*trans*11	n.d.[4]	0.012	0.006	0.002	0.010	0.006	0.18	0.38	0.38
CLA*cis*9*cis*11	0.176	0.258	0.031	0.029	0.405	0.031	0.11	<0.001	0.60
Total polyunsaturated FA	2.10	1.46	0.109	1.83	1.72	0.109	0.001	0.39	0.47
Linolenic acid (18:3omega-3)	0.313	0.265	0.018	0.272	0.306	0.018	0.03	0.10	0.12
Dihomo-γ-linolenic acid (20:3omega-6)	0.311	0.207	0.013	0.296	0.223	0.013	0.001	0.01	0.43
Arachidonic acid (20:4omega-6)	0.946	0.626	0.055	0.846	0.726	0.055	0.001	0.07	0.65
Eicosapentaenoic acid (20:5)	0.127	0.087	0.023	0.091	0.123	0.023	0.03	0.06	0.24
Docosapentaenoic acid (22:5)	0.401	0.269	0.033	0.326	0.345	0.033	0.003	0.49	0.33
Total unsaturated FA	50.53	49.85	0.359	50.62	49.77	0.359	0.23	0.15	0.27
Total unidentified FA peaks	1.88	2.53	0.164	1.86	2.55	0.164	0.002	0.002	0.46
Total *trans* FA[5]	4.58	4.96	0.293	3.00	6.55	0.293	0.34	<0.001	0.24
Total omega-3 FA[6]	0.842	0.622	0.048	0.688	0.775	0.048	0.004	0.12	0.15
Total omega-6 FA[7]	5.20	4.00	0.229	4.76	4.44	0.229	0.005	0.30	0.67
Omega-6: omega-3[8]	6.37	6.64	0.275	7.10	5.92	0.275	0.51	0.02	0.87

[1]Cattle were fed during the growing phase to obtain an ADG of 1.5 lb (low) or 3.0 lb (high). This was followed by a 56 to 113 d finishing phase where diets only differed in fat source.
[2]Cattle were fed 4% of diet DM as Ca salts of palm oil or as Ca salts of CLA.
[3]Probability values of F-tests for the main effects of previous rate of weight gain (GAIN) and source of supplemental fat (FAT) as well as the previous rate of weight gain × fat source interaction (GAIN × FAT).
[4]n.d. = not detectable.
[5]Total *trans* FA = {[16:1*trans*] + [17:1*trans*] + [total 18:1*trans*]}, where the brackets indicate concentration.
[6]Total omega-3 FA = {[18:3omega-3] + [20:5] + [22:5]}, where the brackets indicate concentration.
[7]Total omega-6 FA = {[18:2omega-6] + [CLA*trans*10*cis*12] + [20:3omega-6] + [20:4omega-6]}, where the brackets indicate concentration.
[8]Σomega-6 ÷ Σomega-3.

Near-infrared Spectroscopy, Warner-Bratzler Shear Force, and Meullenet-Owens Razor Shear as Predictors of Beef Ribeye Steak Consumer Panel Responses

J.W.S. Yancey[1], J.K. Apple[1], J.-F. Meullenet[2], and J.T. Sawyer[1]

Story in Brief

Beef ribeye rolls (n = 40) from Select, Choice, Certified Angus Beef (CAB), and Prime quality grade carcasses were used to determine the relationship of near-infrared spectroscopy (NIR) absorbance, Warner-Bratzler shear force (WBSF), and Meullenet-Owens razor shear (MORS) with consumer responses for tenderness and overall impression. One-inch steaks were cut and assigned to either 14 or 28 d aging (n = 4/each). Absorbance in the NIR spectrum was measured 1 d from the pack-date no less than 30 min after cutting, before steaks were aged to designated time and frozen. Steaks were thawed and cooked to 160°F for WBSF and MORS measurement, whereas 3 adjacent steaks were cooked to 160°F for evaluation by a consumer panel (n = 240 members). Steaks from the Select quality grade had the highest ($P = 0.06$) WBSF and lower ($P < 0.05$) overall impression scores than those from CAB and Prime quality grades. Consumer panelists evaluated steaks aged 28 d as more tender ($P < 0.05$) than those aged 14 d. The relationship of mechanical tenderness measurements was higher for consumer panel responses for tenderness than for overall impression, and those relationships were stronger for the Select quality grade than for grades with higher degrees of marbling. The 2nd derivatives of NIR measurements were more successful at predicting consumer panel responses of tenderness and overall impression than WBSF and MORS; thus, NIR methodology was less invasive and more predictive than other tenderness measurements.

Introduction

Predicting beef tenderness has become one of the most extensively researched areas in meat science. The gold-standard Warner-Bratzler shear force (WBSF) method was developed in 1930 (Bratzler, 1932) and is still the most widely used objective measure of beef tenderness in research. In spite of the success of WBSF, the protocol requires that a steak be cut from the carcass, aged, cooked, and destroyed (Savell et al., 1994).

Near-infrared spectroscopy (NIR) uses measurements of the absorption of electromagnetic radiation at wavelengths in the 780 to 2,500 nm range and has been widely used in the meat industry to determine fat, moisture, and protein level in raw and cooked products. Mitsumoto et al. (1991) found that WBSF correlated with regression models developed from NIR models (r = 0.80 to 0.82). Shackelford et al. (2005) used absorbance values of 10 wavelengths in the visual and NIR spectrum to calculate a regression equation that accounted for 38% of the tenderness variation in slice shear force of USDA Select steaks. Those researchers expressed concern that higher degrees of marbling would interfere with the ability to predict tenderness.

Previous research (Sawyer et al., 2006) has shown that 2 NIR technologies (NIRSystems and ASD Field Spec Pro) were successful in predicting variation in WBSF ($R^2 = 0.85$ and 0.61, respectively) and Meullenet-Owens razor shear (MORS; $R^2 = 0.88$ and 0.67, respectively) on *semimembranosus* steaks. However, when those same technologies were used on biceps femoris and semitendinosus steaks, the prediction equations were not as successful ($R^2 = 0.19$ to 0.45 for WBSF and 0.46 to 0.68 for MORS).

Several publications have studied the ability of NIR technologies to predict tenderness as assessed by other instrumental tenderness methodologies, such as WBSF. Others have used NIR technologies to predict tenderness as assessed by trained sensory panels. Nevertheless, there has yet to be a trial to validate the use of NIR technologies to predict tenderness according to untrained consumers. Therefore, the objective of this study was to analyze and compare the ability of NIR to predict the overall impression and tenderness of beef *longissimus* as evaluated by untrained consumers.

Experimental Procedures

Forty beef ribeye rolls (IMPS #112A) from USDA Prime, Certified Angus Beef (CAB), Choice, and Select carcasses (n = 10/quality grade category) were purchased from a commercial processor, delivered to the University of Arkansas Red Meat Abattoir, and stored at 34°F. After 1 d of storage, ribeye rolls were removed from their vacuum-packages, faced on the posterior end, and eight 1-in steaks were cut. The first 4 steaks cut were assigned randomly to either 14 or 28 d aging at 34°F from arrival date, and the second 4 steaks cut were assigned to the remaining aging treatment. Within the group of 4 steaks, 1 was assigned to instrumental evaluation and 3 were assigned to consumer panel evaluation. Steaks assigned to consumer panel evaluations were immediately vacuum-packaged.

Near-infrared spectrophometry. Steaks assigned to instrumental evaluation were placed on foam trays and allowed to bloom for no less than 30 min before being scanned from 400 to 2,400 nm with the NIRSystems spectroradiometer (NIR; model 6500; Perstorp Analytical, Silver Springs, Mass., USA). After NIR evaluation, the steaks were vacuum-packaged for Warner-Bratzler and Meullenet-Owens shear force determinations. After 2 d of aging, all vacuum-package bags were checked, and those that had lost their seal were re-packaged. After specified storage period, steaks were frozen at -4°F until analysis.

[1] Department of Animal Science, Fayetteville
[2] Department of Food Science, Fayetteville

Shear force measurements. Steaks were thawed overnight at 34°F and cooked to 160°F on a Presto Cool Touch Electric Griddle (National Presto Industries, Inc.) set at 400°F. Temperature was monitored by inserting a hand-held probe into the geometric center of each steak using a Comark Foodcheck Thermometer (Comark Instruments, Inc.). After cooking, steaks were allowed to cool to room temperature.

To determine MORS, the surface of the *longissimus* muscles was penetrated in 4 separate locations with the Muellenet-Owens razor blade attached to a Texture Analyzer (Model TA-XT2i; Texture Technologies) with an 11-lb load cell. The blade penetrated to a depth of 0.79 in and traveled at a speed of 0.4 in/sec. The maximum force incurred (MORSpf) and the total energy used (area under the curve; MORSta) were recorded for analysis. Within each steak, the 4 shears were averaged for analysis.

For WBSF determination, no less than six 0.5-in cores were removed from the *longissimus* muscle, parallel to the fiber direction. Each core was sheared once with a Warner-Bratzler shear attachment on an Instron Universal Testing Machine (Model No. 4466; Instron) with a 110-lb. compression load cell. Peak force for the cores from an individual steak was averaged for analysis.

Consumer panel evaluation. Steaks for consumer panel analysis were thawed overnight and cooked as discussed previously for shear force determination. Immediately after cooking, the spinalis dorsi was removed from each steak and the *longissimus* was cut into uniform, bite-size pieces, which were held in food warmers until presented to consumers.

Consumers (n = 240) were selected from a pool of over 4,000 based on an e-mail questionnaire requesting consumers who ate beef 4, or more, times in 1 week. Consumers were scheduled for 20-min sessions, in which 8 consumers were seated in climate-controlled booths with lighting adjusted so that the degree of doneness of the steak-pieces could not be seen. Pieces from 8 steaks (1 from each grade and aging combination) were presented to the consumers in random order, 2 pieces from each steak at a time on a small, clean, paper plate. Consumers rated samples on 9-point scales for overall impression and tenderness. The final question on each questionnaire asked the consumers to consider a steak with ideal tenderness and mark the score that would best describe it. An example of the panelists' ballot is shown below.

Data were analyzed in a split-plot design to determine differences in consumer panel scores, WBSF, and MORS according to quality grade and age. Quality grade was the whole-plot factor, and aging period was the sub-plot factor. For consumer panel evaluation, the session was included in the model as a random effect. These data were analyzed using the mixed-models procedure in SAS (SAS Inst., Inc., Cary, N.C.). Simple correlations of WBSF, MORS, and consumer responses were determined using the correlation procedure in SAS, and prediction equations were calculated in the regression procedure.

Data from the NIR, WBSF, MORS, and consumer panel responses were compared using partial least squares (PLS) regression, with the PLS 1 option of the multivariate regression software Unscrambler (version 7.5; CAMO, Oslo, Norway). This software allows the multi-data point output from the NIR to be successfully related to the single-data-point output from the WBSF, MORS, and consumer responses. Regression equations were calculated using the NIR data (in addition to the 2nd derivative of the NIR data) to predict WBSF, MORS, and consumer panel responses. Each observation was removed one at a time from the sample set, a new model calculation performed and a predicted score calculated for the sample removed. This procedure was repeated until all samples have been removed from the sample set once.

Results and Discussion

Quality grade and aging time did not ($P > 0.05$) have an effect on MORSpf or MORSta (Table 1). For WBSF, values from Select steaks tended to be higher ($P = 0.06$) than those from Choice, CAB, or Prime, indicating that steaks with less marbling were tougher. Postmortem aging also did not have an effect ($P > 0.05$) on WBSF. Steaks aged 28 d postmortem had higher ($P < 0.05$) consumer responses for tenderness than those aged 14 d, and, although steaks from Select ribs had numerically lower consumer responses for tenderness, the differences were not significant ($P > 0.05$). Steaks from Prime and CAB ribs had similar ($P > 0.05$) consumer responses for overall impression and had higher ($P < 0.05$) scores than those from Select, whereas Choice steaks were intermediate ($P > 0.05$). Aging time did not affect ($P > 0.05$) consumer responses for overall impression.

It is not surprising that Select steaks had higher WBSF and lower scores for overall impression that higher quality grades, because beef cuts with less marbling are more susceptible to tough-

SAMPLE # _____

Check (✓) Your Responses

1. Please observe and taste this sample. All things considered, which statement best describes your ***OVERALL IMPRESSION*** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

2. Which statement best describes your impression of the ***TENDERNESS*** of this product?

Extremely Tough	Very Tough	Moderately Tough	Slightly Tough	Neither Tender Nor Tough	Slightly Tender	Moderately Tender	Very Tender	Extremely Tender
☐	☐	☐	☐	☐	☐	☐	☐	☐

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1. Thinking of a steak that you would consider to have an ***IDEAL TENDERNESS***, which of the below statements would best describe it?

Extremely Tough	Very Tough	Moderately Tough	Slightly Tough	Neither Tender Nor Tough	Slightly Tender	Moderately Tender	Very Tender	Extremely Tender
☐	☐	☐	☐	☐	☐	☐	☐	☐

ening during cooking (Wheeler et al., 1999). In our study, differences in tenderness, even when significant, were minimal because this muscle is considerably tender and had been aged at least 14 d to increase tenderness. The increase in tenderness with aging also minimizes differences between tough and tender steaks.

For the complete dataset, the MORSpf, MORSta, and WBSF were highly correlated with consumer panel responses for both overall impression and tenderness (Table 2). Peak force measurements from the MORS instrument were more closely related to both consumer responses than the total area under the curve, and WBSF had the weakest relationship with consumer responses of the 3 instrumental methods. Consumer responses for tenderness were highly related to those for overall impression for the complete dataset (r = 0.75), but this was especially evident within the Select grade (r = 0.93). Furthermore, with increasing quality grade, the relationship between consumer responses for overall impression and tenderness grew weaker. Similarly, consumer responses for tenderness from steaks aged 14 d were more closely related to overall impression (r = 0.70) than those aged 28 d (r = 0.81).

The relationship of instrumental measures of tenderness to consumer responses varied according to quality grade. Within the Select grade, measurements from instrumental tenderness methods were highly related to consumer responses for overall impression and tenderness, especially those from the MORSta and MORSpf (r = -0.74 to -0.82, respectively). Nevertheless within the higher quality grades, the relationship of instrumental tenderness with consumer responses for overall impression was not ($P > 0.05$) significant. The relationship of MORS peak force and total area under the curve measurements with consumer responses for tenderness was stronger within the Select (r = -0.82 and -0.78) and Choice (r = -0.76 and -0.69) than those relationships within CAB (r = -0.63 and -0.61) and Prime (r = -0.65 and -0.59). The relationship was less consistent for WBSF with consumer responses for tenderness, with the highest correlation within Choice (r = -0.77) and Prime (r = -0.69), and the two were moderately related in Select (r = -0.57) and CAB (r = -0.46).

Consumer responses for steaks aged 28 d were more strongly correlated with MORSpf, MORSta, and WBSF than those aged 14 d. Within the 14-d aged samples, instrumental measurements of MORSpf, MORSta, and WBSF were more highly correlated with consumer responses for tenderness (r = -0.72, -0.60, and -0.59, respectively) than overall impression (r = -0.53, -0.34, and -0.35, respectively). Moreover, the relationships of MORSpf with consumer responses for overall impression and tenderness (r = -0.53 and -0.72, respectively) were stronger than those of MORSta (r = -0.34 and -0.60) or WBSF (r = -0.35 and -0.59) for 14-d aged steaks. For 28-d aged steaks, the relationship of MORSpf and MORSta with consumer responses for overall impression (r = -0.70 and -0.63) was not as closely related as that for tenderness (r = -0.80 and -0.77), but the differences between relationships for MORSpf and MORSta were less pronounced.

Predictive models were developed from NIR absorbance data to predict consumer panel responses for tenderness and overall impression, as well as objective tenderness measurements of MORSpf, MORSta, and WBSF (Table 3). Equations using NIR measurements were somewhat successful at predicting MORS and WBSF from the original data (Rcal = 0.42 to 0.56), and were more successful when the 2nd derivative was used (Rcal = 0.80 to 0.86). Consumer responses for tenderness were moderately fitted by the absorbance data (Rcal = 0.47) and were well fitted by the 2nd derivative (Rcal = 0.86). Furthermore, the tenderness model for the 2nd derivative was validated (Rval = 0.70) with a smaller RMSEP and larger discrimination index (RPD) than the model from the absorbance.

When the NIR regression equations for predicting consumer panel responses for tenderness and overall impression were compared to regression equations using the peak force and total area under the curve of the MORS and WBSF, the NIR equations were superior (Table 4). Equations from the NIR data had higher R^2 values for predicting consumer responses for tenderness and overall impression (R^2 = 0.74 and 0.79, respectively) than the shear methods. While, the NIR equations were equally successful at predicting tenderness and overall impression, the MORS and WBSF methods were more successful at predicting tenderness (R^2 = 0.38 to 0.58) than overall impression (R^2 = 0.15 to 0.37).

Implications

The non-invasive method of near-infrared spectroscopy predicts consumer responses for tenderness and overall impression of rib steaks relatively well and was more successful than WBSF and MORS methods, which require a steak to be cooked and destroyed. Within the mechanical tenderness measures (WBSF and MORS), the peak force of the MORS was the most successful at predicting consumer responses. These data also demonstrated that consumers relate tenderness more closely with overall impression when sampling ribeye steaks with lower degrees of marbling (Select).

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Table 1. Effect of Quality Grade and aging time on Meullenet-Owens razor shear peak force (MORSpf) and total area under the curve (MORSta), Warner-Bratzler shear force (WBSF), and consumer panel responses for tenderness and overall impression of beef longissimus steaks.

	Quality Grade					Aging Time		
Item	Prime	CAB	Choice	Select	SE	14 d	28 d	SE
MORSpf, N.mm	21.55	20.52	21.87	24.85	1.36	22.57	21.82	0.73
MORSta, N	265.00	246.34	267.41	281.28	13.10	269.38	260.63	7.33
WBSF, kg	3.15[a]	3.20[a]	3.29[a]	3.86[b]	0.20	3.41	3.34	0.12
Tenderness[1]	6.46	6.55	6.52	5.99	0.22	6.20[y]	6.56[z]	0.12
Overall Impression[1]	6.94[y]	6.80[y]	6.64[yz]	6.37[z]	0.14	6.65	6.73	0.08

[a,b] Means, within USDA grade or aging time, with different superscripts differ ($P = 0.06$).

[y,z] Means, within USDA grade or aging time, with different superscripts differ ($P < 0.05$).

[1] Tenderness and overall impression were determined on 9-point scales where 1 = extremely tough, dislike extremely and 9 = extremely tender and like extremely.

Table 2. Correlation coeffecients of Meullenet-Owens razor shear peak force (MORSpf) and total area under the curve (MORSta) and Warner-Bratzler shear force (WBSF) with consumer observations of overall impression[1] and tenderness[1] for beef longissimus steaks from Prime, Certified Angus Beef, Choice, and Select ribs aged 14 or 28 days.

Item	MORSpf	MORSta	WBSF	Tenderness
Complete Data Set				
Overall Impression	-0.61**	-0.48**	-0.39**	0.75**
Tenderness	-0.75**	-0.68**	-0.62**	
Select				
Overall Impression	-0.80**	-0.74**	-0.49*	0.93**
Tenderness	-0.82**	-0.78**	-0.57*	
Choice				
Overall Impression	-0.44	-0.37	-0.35	0.73**
Tenderness	-0.76**	-0.69**	-0.77**	
Certified Angus Beef				
Overall Impression	-0.39	-0.28	0.02	0.59*
Tenderness	-0.63*	-0.61*	-0.46*	
Prime				
Overall Impression	-0.27	-0.19	-0.33	0.51*
Tenderness	-0.65*	-0.59*	-0.69**	
14 d Aged				
Overall Impression	-0.53**	-0.34*	-0.35*	0.81**
Tenderness	-0.72**	-0.60**	-0.59*	
28 d Aged				
Overall Impression	-0.70**	-0.63**	-0.42*	0.70**
Tenderness	-0.80**	-0.77**	-0.66**	

** $P < 0.001$.
* $P < 0.05$.
[1] Tenderness and overall impression were determined on 9-point scales where 1 = extremely tough, dislike extremely and 9 = extremely tender and like extremely.

Table 3. Partial least squares regression model results of absorbance spectra and its second derivative for predicting consumer panel responses for tenderness and overall impression, Meullenet-Owens razor shear peak force (MORSpf) and total area under the curve (MORSta), and Warner-Bratzler shear force (WBSF) of beef longissimus steaks.

Item	SD[1]	Derivative	PC[2]	Rcal[3]	RMSEC[4]	Rval[5]	RMSEP[6]	RPD[7]	Robust[8]
Tenderness[9]	0.78	none	1	0.47	0.69	0.40	0.71	1.10	1.03
		2nd	4	0.86	0.39	0.70	0.57	1.38	1.46
Overall Impression	0.55	none	2	0.43	0.49	0.33	0.52	1.06	1.06
		2nd	3	0.89	0.25	0.70	0.39	1.40	1.56
MORSpf, N	4.71	none	2	0.56	3.86	0.47	4.15	1.13	1.08
		2nd	3	0.86	2.37	0.74	3.15	1.50	1.33
MORSta, N.mm	46.7	none	1	0.49	40.5	0.43	41.9	1.11	1.03
		2nd	4	0.86	23.2	0.69	33.9	1.38	1.46
WBSF, kg	0.77	none	1	0.42	0.69	0.31	0.73	1.05	1.06
		2nd	3	0.80	0.46	0.53	0.65	1.18	1.41

[1] SD = Standard deviation of the independent variable.
[2] PC = Optimal number of principle components.
[3] Rcal = Calibration coefficient of determination.
[4] RMSEC = Root mean square error of calibration.
[5] Rval = Full-cross validation coefficient of determination.
[6] RMSEP = Root mean square error of prediction (full-cross validation).
[7] RPD = discrimination index (standard deviation ÷ RMSEP).
[8] Robust = RMSEP ÷ RMSEC.
[9] Tenderness and overall impression were determined on 9-point scales where 1 = extremely tough, dislike extremely and 9 = extremely tender and like extremely.

Table 4. Values for R^2 and root mean square error (RMSE) for regression equations predicting consumer panel responses for tenderness and overall impression from Meullenet-Owens razor shear peak force (MORSpf) and total area under the curve (MORSta), Warner-Bratzler shear force (WBSF), and near-infrared reflectance (NIR) values.

	Dependent variables			
	Tenderness[1]		Overall Impression[1]	
Independent variables	R^2	RMSE	R^2	RMSE
MORSpf, N	0.58	0.52	0.37	0.44
MORSta, N.mm	0.46	0.58	0.23	0.48
WBSF, kg	0.38	0.62	0.15	0.51
NIR	0.74	0.39	0.79	0.25

[1] Tenderness and overall impression were determined on 9-point scales where 1 = extremely tough, dislike extremely and 9 = extremely tender and like extremely.

Fabrication Method of the *Infraspinatus* Muscle Affects Warner-Bratzler Shear Force

C.A. Ahrens, J.W.S. Yancey, and J.K. Apple[1]

Story in Brief

The objective of this study was to determine if fabrication method of the *infraspinatus* muscle (flat-iron vs. traditional) affected Warner-Bratzler shear force (WBSF) when cooked to "medium-rare" and "medium" degrees of doneness, and to determine differences between anatomical location of flat-iron steaks. *Infraspinatus* (INF) muscles (n = 30) were randomly assigned to a combination of age (7 or 21 d) and endpoint temperature (150 or 160°F). After aging, each muscle was fabricated into 2 traditional (top-blade) and 2 flat-iron steaks, then frozen. Flat-iron steaks were identified for their anatomical location: the medial portion was closest to the scapula, whereas the lateral portion was covered with subcutaneous fat. Steaks were cooked on a clam-shell griddle, and internal temperature was monitored with thermocouples. After cooling to room temperature, 6 cores were removed parallel to the fiber direction and sheared with a WBSF attachment using the Instron Universal testing machine. Traditional steaks had greater ($P < 0.05$) WBSF values and within-steak standard deviation than flat-iron steaks. Endpoint temperature did not have an effect on the WBSF of either traditional or flat-iron steaks. Medial flat-iron steaks had lower ($P < 0.05$) WBSF values after 7 d of aging; however, the medial and lateral sides had similar ($P > 0.05$) WBSF after 21 d of aging. Results of this study indicated that flat-iron steaks were more tender, with less within-steak variation, than traditional top-blade steaks.

Introduction

Recently discovered to be the second most tender muscle in the beef carcass (Calkins and Sullivan, 2007), the *infraspinatus* (INF) muscle is underutilized due to the large connective tissue that runs through the center. The INF muscle was previously used as part of chuck roasts or ground beef. In order to increase the palatability and marketability of the INF muscle, different methods of fabrication have been developed. The flat-iron is a new method of fabrication where steaks are cut parallel to the length of the muscle, and the connective tissue is removed using a fillet technique. This fabrication method has improved palatability and marketability of this tender muscle. Currently, the INF muscle is marketed as the flat-iron, seen on restaurant menus, in grocery stores, and as part of recipes to promote beef. There is limited research to determine the differences due to anatomical location of the INF muscle and none on flat-iron fabrication.

Most tenderness research protocols require end-point cooking temperatures to be 160°F, which is a "medium" degree of doneness. Nevertheless, the developers of the flat-iron and chefs that have worked with this cut recommend a "medium-rare" degree of doneness (150°F). The objective of our study was to determine if fabrication method (flat-iron vs traditional) affected Warner-Bratzler Shear Force (WBSF) of the *infraspinatus* steaks cooked to "medium-rare" (150°F) or "medium" (160°F) degree of doneness and to determine differences between anatomical locations of flat-iron steaks.

Experimental Procedures

Thirty INF muscles were purchased from a commercial processor and aged 7 or 21 d from the box date. Each muscle was fabricated into 2 flat-iron steaks and 2 traditional steaks paying close attention to the anatomical location of the muscle. Medial flat-iron steaks were closest to the scapula (Figure 1), whereas the lateral steaks were covered with subcutaneous fat. After fabrication, steaks were vacuumed packaged and frozen at -22°F.

Steaks were thawed overnight at 35.6°F and cooked to 150 or 160°F on a Star Pro-Max 2-sided griddle. Thermocouples were inserted into the geometric center of each steak to monitor the internal temperature. After cooking, steaks were cooled to room temperature, and 5 to 6 half-inch cores were removed parallel to the fiber direction. With a Warner-Bratzler shear force attachment on an Instron Universal testing machine, each core was sheared once and means and standard deviation (SD) were calculated for each steak.

To determine differences between fabrication styles, data were analyzed in a split-plot design, where temperature and postmortem age were the whole-plot and fabrication style was the sub-plot. Differences of anatomical location, within the flat-iron steaks, were determined in a split-plot design with temperature and aging in the whole-plot and anatomical location in the sub-plot. The MIXED procedure in SAS (SAS Inst., Inc., Cary, N.C.) was used to analyze the data, and means were separated using a probability of 0.05.

Results and Discussion

Traditional steaks had higher WBSF values than flat-iron steaks (Figure 2, $P < 0.05$) and higher within-steak SD ($P < 0.05$). Endpoint temperature and postmortem aging did not have an effect ($P > 0.05$) on the WBSF on either the traditional or flat-iron steaks. Previous research has not compared flat-iron to traditionally cut INF steaks; however, our results indicate that the new fabrication method created not only more tender steaks, but also less within-steak variation. According to these results, fabrication method can affect the outcome of WBSF data and should be considered when conducting tenderness research on this muscle.

Medial flat-iron steaks had lower WBSF values (Figure 3, $P <$

[1] Department of Animal Science, Fayetteville

0.05) than lateral steaks after 7 d of aging; however, the medial and lateral sides had a similar ($P > 0.05$) WBSF after 21 d of aging. These results indicate that after 7 d of aging, the medial side of the INF was more tender than the lateral side, and the lateral side required an additional 14 d of aging to produce steaks with WBSF comparable to the medial side. In contrast to this study, Searls et al. (2005) aged traditionally-fabricated INF steaks to 14 d and found that there were no differences due to anatomical location. Had they aged the steaks less than 14 d, there may have been differences due to anatomical location in the INF. Although the medial side was more tender after 7 d of aging, in our study, both sides were equally tender after 21 d of aging.

Implications

This study showed that when fabricating the *infraspinatus* muscle, the more tender steak will be the one fabricated as a flat-iron. The flat-iron method of fabrication would also be more suitable to the consumer since not only is it more palatable and more tender than the traditional method of fabrication, but it does not have the large connective tissue running through the middle of the steak. Thus, the flat-iron would be more marketable to consumers and would not be as underutilized.

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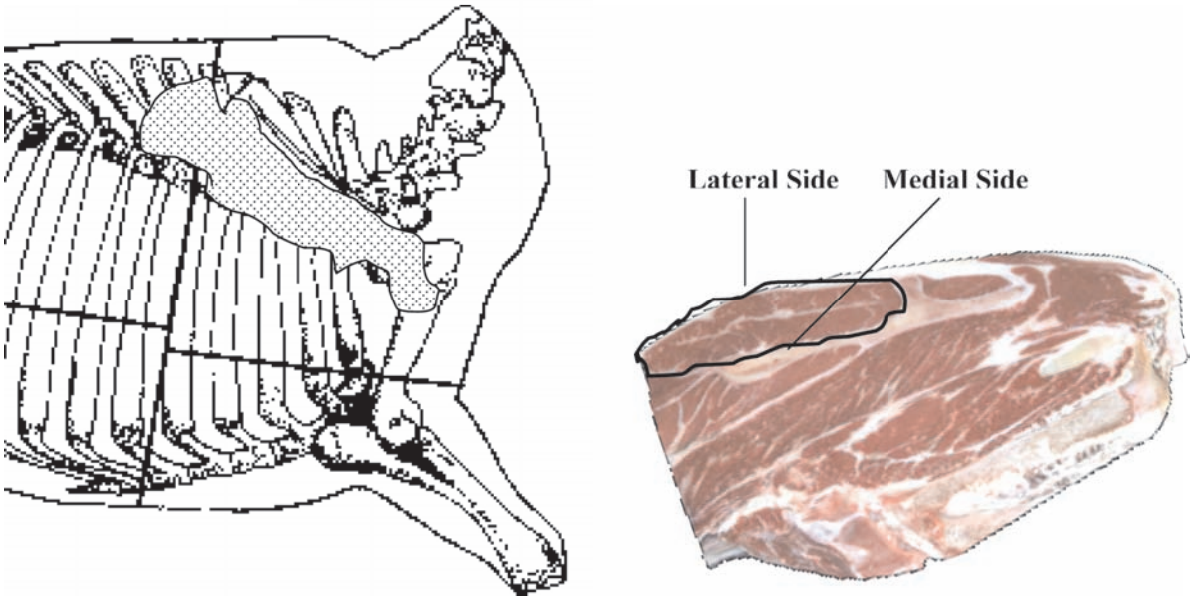

Fig. 1. Diagram of the *infraspinatus* muscle.

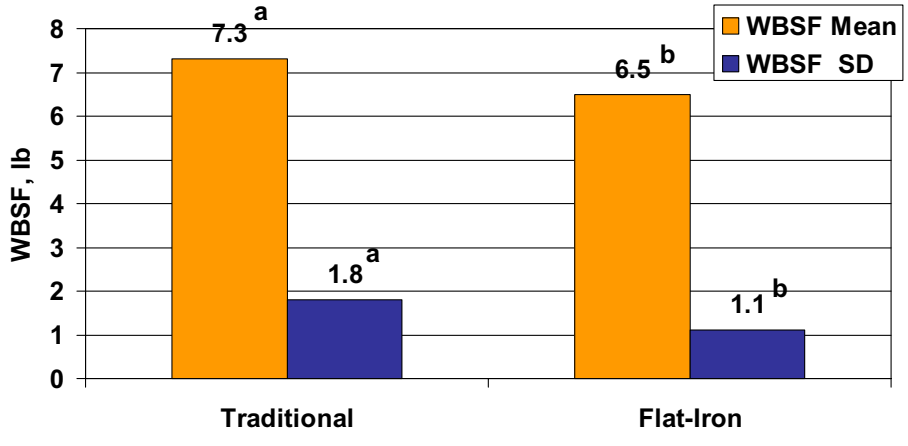

Fig. 2. Warner-Bratzer shear force (WBSF) mean and standard deviation (SD) of *infraspinatus* fabricated into flat-iron or traditional top-blade steaks.
[a, b] Means and SD with different letters differ ($P < 0.05$).

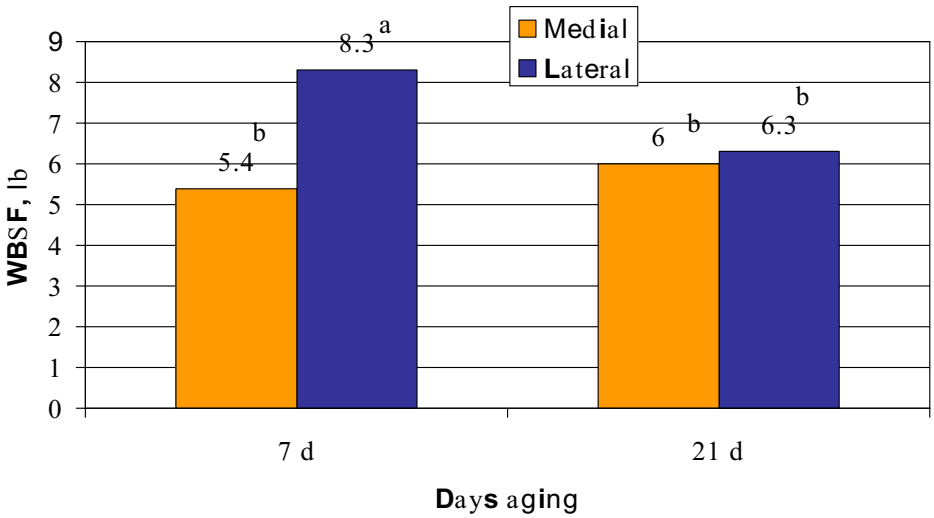

Fig. 3. Mean Warner-Bratzler shear force (WBSF) of flat-iron steaks from the medial and lateral portions of the *infraspinatus* aged 7 and 21 days. [a, b] Means with different letters differ ($P < 0.05$).

Internal Color and Tenderness of the *Semimembranosus* Are Affected by Cooking Method and Degree of Doneness

M.D. Wharton, J.K. Apple, J.W.S. Yancey, J.T. Sawyer, and M.S. Lee[1]

Story in Brief

Semimembranosus (SM) steaks (n = 360) from USDA Select top/inside rounds aged 0 to 35 d at 35.6°F were used to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force (WBSF) and cooked beef color. Steaks were cooked to 3 different endpoint temperatures (150, 160, or 170°F) using: 1) an air-impingement oven (IMP); 2) clam-shell griddle (PANI); 3) forced-air convection oven (BLOD); 4) counter-top electric griddles (GRID); and 5) gas-fired, open-hearth char-grill (CHAR). Steaks cooked to 170 and 150°F had the greatest ($P < 0.05$) and lowest ($P < 0.05$) cooking loss percentages. Steaks cooked in the PANI had the lowest ($P < 0.05$) cooking losses, and GRID-cooked steaks had lower ($P < 0.05$) cooking losses than steaks cooked in BLOD, CHAR or IMP. Shear force (WBSF) values increased with increasing endpoint temperature, and steaks cooked on CHAR had greater ($P < 0.05$) WBSF values than those cooked in BLOD, GRID, IMP and PANI at 150 and 170°F. Internal color of steaks cooked in the BLOD was lighter ($P < 0.05$) and less yellow ($P < 0.05$) than steaks cooked on CHAR, GRID or PANI. Internal color of steaks cooked to 150°F was redder ($P < 0.05$) and more yellow ($P < 0.05$) than steaks cooked to 170°F. Obviously, cooking SM steaks to 170°F produced tougher steaks, with less internal red cooked beef color, especially when cooked on CHAR; however, grilling SM steaks on GRID produced the most tender steaks, regardless of endpoint temperature.

Introduction

Cooking method and endpoint temperature/degree of doneness are important factors in determining the overall desirability of beef steaks. Neely et al. (1999) and Behrends et al. (2005) found that consumers in metropolitan cities (Chicago, Houston, Philadelphia, and San Francisco) prefer to grill top round (*semimembranosus*) steaks to "medium well" or greater degrees of doneness. Moreover, Belk et al. (1993) reported that sensory panel scores for juiciness and tenderness of top round roasts decreased with increasing endpoint temperature.

When cooking beef from "rare" to "very well done," obvious changes occur to the internal color of cooked meat. Myoglobin is the primary heme pigment responsible for fresh meat color, and, during cooking, myoglobin is denatured to varying degrees, thereby influencing the appearance of meat color (Gracía-Segovia et al., 2006); however, there is limited information concerning the effects of cookery method and/or degree of doneness on internal cooked beef color, especially in top round steaks. Therefore, the objective of this research study was to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force and cooked beef color of the *semimembranosus* steaks.

Experimental Procedures

USDA Select inside (top) rounds were aged 0, 7, 14, 21, 28, or 35 d at 35.6°F (10 inside rounds/aging period) to develop a wide range in possible tenderness differences. After the aging period, the *adductor* and *gracilis* muscles were removed before six 1-in-thick *semimembranosus* (**SM**) steaks (n = 360) were cut from each primal, labeled, vacuum-packaged, and frozen at -22°F for approximately 60 d before cooking. Then, frozen SM steaks were randomly assigned to 1 of 15 treatments in a 3 × 5 factorial arrangement, with 3 endpoint temperatures (150, 160, or 170°F) and 5 cookery methods. Steaks were thawed overnight at 35.6°F, removed from vacuum–packages, and weighed. Steaks were then cooked to their assigned endpoint temperature in/on either: 1) an air-impingement oven (**IMP**); 2) a clam-shell griddle (**PANI**); 3) electric, counter-top griddle (**GRID**); 4) forced-air, convection oven (**BLOD**); or 5) gas-fired, open-hearth char-grill (**CHAR**). All cookery methods were preheated to 360°F before cooking, and internal temperature was monitored in steaks cooked in PANI, BLOD, GRID and CHAR by placing copper-constantan thermocouples in the geometric-center of each steak. Additionally, SM steaks cooked in the BLOD, PANI and CHAR were turned when the internal temperatures had reached 95, 100, and 105°F for 150, 160 and 170°F endpoint temperatures, respectively, whereas steaks cooked on GRID were turned every 4 min until reaching the appropriate endpoint temperature. Finally, belt speeds of the IMP were set at 20, 25 and 30 min to produce endpoint temperatures of 150, 160 and 170°F, respectively, and endpoint temperature of each IMP-cooked steak was confirmed at the completion of cooking with a hand-held thermometer.

Cooking times were recorded for each SM steak cooked, and after a 1-h cooling period at room temperature, steaks were weighed to calculate cooking loss percentages. Then, each steak was sliced perpendicular to the cut surface, and instrumental color (L*, a* and b* values), as well as reflectance values from 400 to 740 nm, was measured immediately after cutting with a Hunter Miniscan XL equipped with a 9-mm aperture and illuminant A.

Immediately after cooked color data collection, six 0.5-in-diameter cores were removed parallel with the muscle fiber orientation, and each core was sheared once with a Warner-Bratzler shear force (**WBSF**) device attached to an Instron Universal Testing machine with a 110-lb compression load cell and a crosshead speed of 250 mm/min. The average peak shear force of the 6 cores was used for statistical analyses.

[1] Department of Animal Science, Fayetteville

Data were analyzed as an incomplete block design with inside round (subprimal) as the block and individual SM steak as the experimental unit. Analysis of variance was generated with the mixed model procedure of SAS (SAS Inst., Inc., Cary, N.C.) with cookery method, endpoint temperature, and the 2-way interaction included in the model as fixed effects and subprimal as the random effect in the model. Least squares means were calculated and separated statistically using pair-wise t-tests (PDIFF option) when a significant ($P \leq 0.05$) F-test was identified.

Results and Discussion

An endpoint temperature by cookery method interaction was found for WBSF ($P < 0.05$) (Figure 1). Steaks cooked to 170°F on the CHAR had the greatest ($P < 0.05$) WBSF of any other endpoint temperature and cookery method combination. Furthermore, SM steaks cooked to 150°F on the CHAR had greater ($P < 0.05$) WBSF than any other cookery method at that temperature. Other than the CHAR, steaks cooked to 150°F were similar ($P > 0.05$) in WBSF regardless of cookery method and lower ($P < 0.05$) than those cooked on the CHAR. Steaks cooked to 170°F in the BLOD had greater ($P < 0.05$) WBSF than steaks cooked to 170°F on the GRID, IMP or PANI. Steaks cooked to 160°F on the CHAR had greater ($P < 0.05$) WBSF than those cooked to 160°F in the BLOD, GRID, or PANI, but CHAR steaks were similar ($P > 0.05$) to those cooked in the IMP at 160°F. Within the BLOD, CHAR, and GRID cooking methods, steaks cooked to 150 and 160°F had similar ($P > 0.05$) WBSF, but steaks cooked to150°F had lower ($P < 0.05$) WBSF than those cooked to 160°F in the IMP and PANI. Steaks cooked to 170°F in the BLOD and CHAR had greater ($P < 0.05$) WBSF than those cooked to 150 or 160°F, but on the GRID and IMP, steaks cooked to 170°F were similar ($P > 0.05$) to those cooked to 150 and 160°F. When cooked on the PANI, the WBSF of steaks cooked to 160 and 170°F were similar ($P > 0.05$) and greater ($P < 0.05$) than those cooked to 150°F. In the IMP, steaks cooked to 160°F had greater ($P < 0.05$) WBSF than those cooked to 150°F, but steaks cooked to 170°F were intermediate ($P > 0.05$).

As expected, SM steaks cooked to 150°F had the least ($P < 0.05$) cooking loss, and those cooked to 170°F had the greatest ($P < 0.05$) (Table 1). Steaks cooked on the PANI had the lowest ($P < 0.05$) cooking loss, and those cooked on the GRID had less ($P < 0.05$) cooking loss than those cooked on the BLOD, CHAR, or IMP, which were similar ($P > 0.05$). Cooking SM muscles in the BLOD and IMP to 170°F took longer ($P < 0.05$) than cooking to 170°F using other cookery methods. In the BLOD, steaks had longer ($P < 0.05$) cooking times to 160°F than other methods, and the steaks took longer ($P < 0.05$) in the IMP to cook to 160°F than on the GRID or PANI (Figure 2). When cooking SM steaks to 150°F, the BLOD had longer ($P < 0.05$) cooking times than the CHAR and GRID, and the IMP was intermediate ($P > 0.05$). The PANI method had the shortest ($P < 0.05$) cooking times at each endpoint temperature. Within the BLOD and IMP cookery methods, cooking SM steaks to 150°F had the shortest ($P < 0.05$) cooking times, and cooking steaks to 170°F had the longest ($P < 0.05$). On the CHAR and GRID, steaks cooked to 150°F had shorter ($P < 0.05$) cooking times than those cooked to 170°F, and steaks cooked to 160°F were intermediate ($P > 0.05$). When cooking on the PANI, cooking time was similar ($P > 0.05$) regardless of end-point temperature.

Endpoint cooking temperature had no effect ($P > 0.067$) on internal lightness (L* values) (Table 1). Although the differences in L* were small and inconsequential (total difference less than 2 units), steaks cooked on the BLOD had greater ($P < 0.05$) L* values than those cooked on the CHAR, GRID, and PANI, and those cooked on the IMP had greater ($P < 0.05$) L* values than those cooked on the CHAR and PANI. As expected, SM steaks cooked to 150°F were reddest ($P < 0.05$; higher a*), and those cooked to 170°F were least red ($P < 0.05$). Cooking method did not affect ($P > 0.05$) redness of SM steaks. Similarly, SM steaks cooked to 150°F had the most yellow ($P < 0.05$) internal color, and those cooked to170°F were the least yellow ($P < 0.05$). As with L*, the differences in b* due to cookery method were statistically significant but irrelevant. Steaks cooked on the GRID were more yellow ($P < 0.05$) than those cooked on the BLOD, IMP, and PANI, whereas those cooked on the CHAR were more yellow ($P < 0.05$) than those cooked on the BLOD.

Implications

Cooking top/inside round (*semimembranosus*) steaks to 170°F resulted in greater cooking losses and reductions in mechanical measures of tenderness, especially when cooked upon a gas-fired, open-hearth char-grill. And, even though cooking steaks in the clam-shell griddle, where the steak is in contact with the griddle on both sides, greatly reduced cooking times, grilling upon inexpensive electric, counter-top griddles produced the most tender steaks, regardless of endpoint temperature.

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Table 1. Main effects of endpoint temperature and cookery method on characteristics of cooked *semimembranosus* steaks.

	Endpoint temperature				Cookery method[1]					
Trait	150°F	160°F	170°F	SEM	BLOD	CHAR	GRID	IMP	PANI	SEM
Cook loss, %	29.4^{c}	35.1^{b}	39.6^{a}	0.42	38.3^{a}	38.1^{a}	30.8^{b}	37.1^{a}	29.2^{c}	0.57
L*[2]	58.4	57.9	57.0	1.05	58.9^{a}	57.1^{c}	57.3^{bc}	58.7^{ab}	56.9^{c}	1.30
a*[2]	17.4^{a}	13.7^{b}	11.0^{c}	0.36	14.2	14.1	14.5	13.0	14.4	0.46
b*[2]	17.5^{a}	16.7^{b}	15.7^{c}	0.25	16.0^{c}	16.9^{ab}	17.5^{a}	16.1^{bc}	16.6^{bc}	0.32

[1]BLOD = forced-air convection oven; CHAR = gas-fired, open-hearth char-grill; GRID = counter-top electric griddles; IMP = air-impingement oven; and PANI = clam-shell griddle.
[2]L* = a measure of darkness to lightness (greater number indicates a lighter color); a* = a measure of redness (greater number indicates a redder color); and b* = a measure of yellowness (greater number indicates a more yellow color).
[a,b,c]Within a row and main effect, least squares means lacking common superscript letters differ ($P < 0.05$).

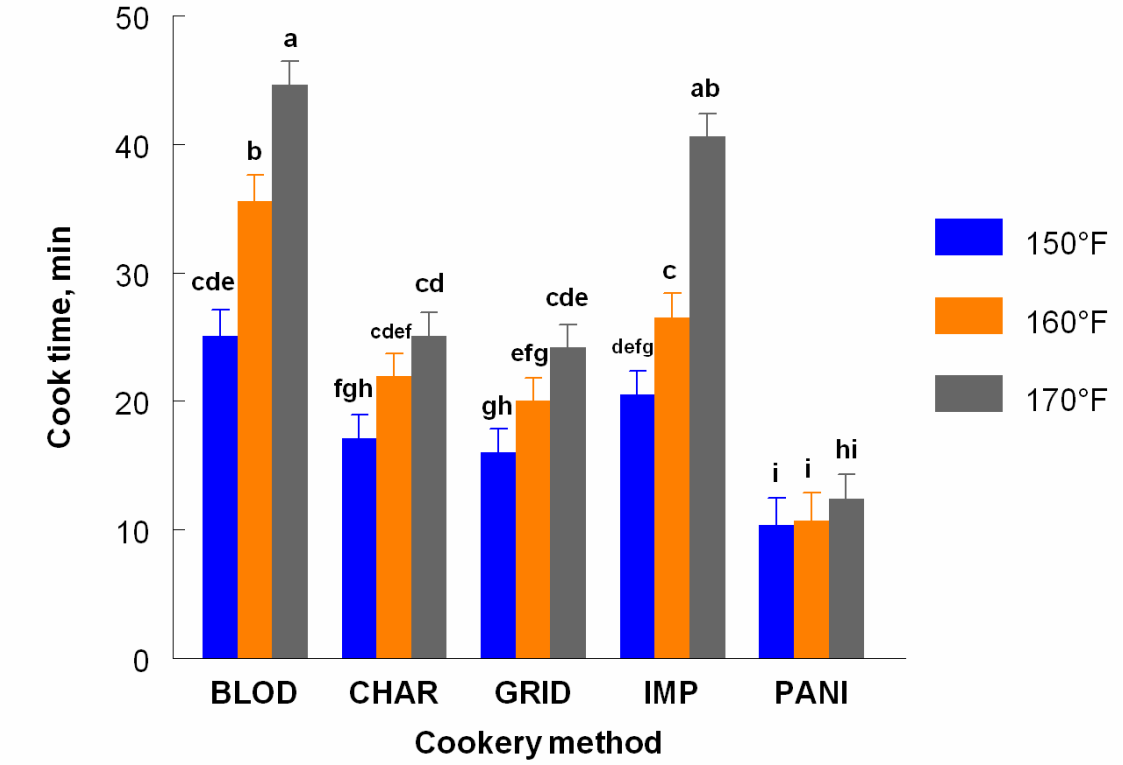

Fig. 1. Interactive effect of cookery method and endpoint temperature on shear force values of *semimembranosus* steaks. Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).

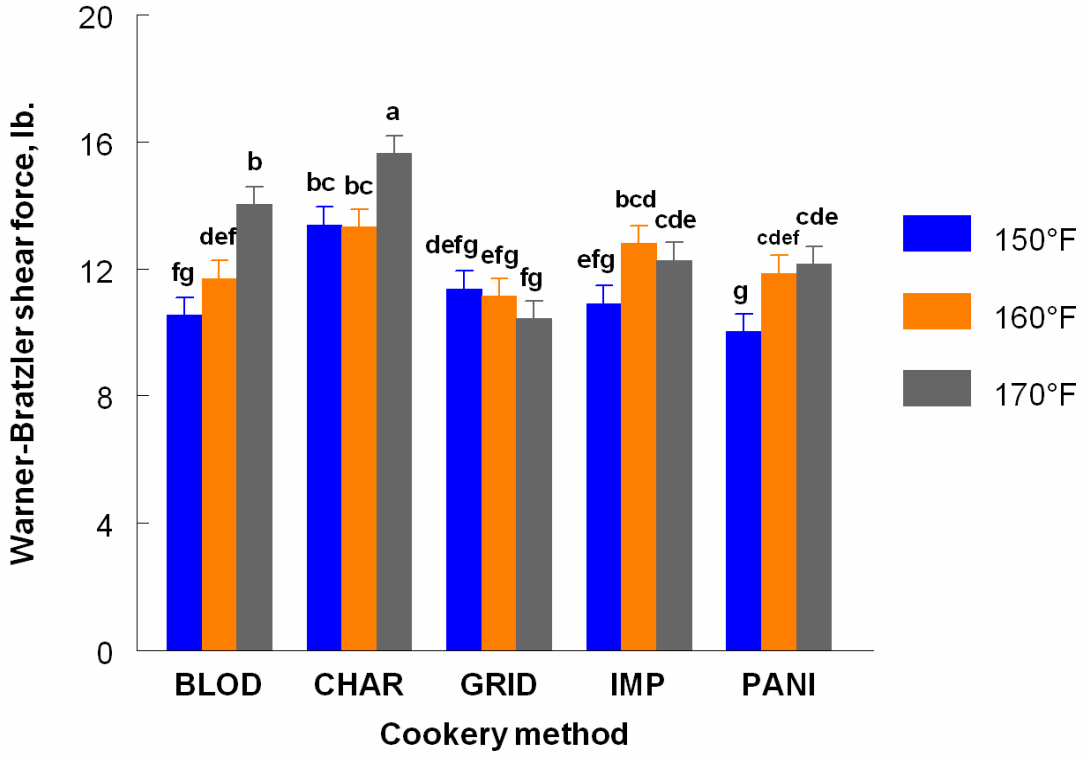

Fig. 2. Interactive effect of cookery method and endpoint temperature on cook time of *semimembranosus* steaks. Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).

Internal Color and Tenderness of the *Infraspinatus* Are Affected by Cooking Method and Degree of Doneness

M.D. Wharton, J.K. Apple, J.W.S. Yancey, J.T. Sawyer, and M.S. Lee[1]

Story in Brief

Infraspinatus (IF) steaks (n = 360) from USDA Select clods aged 0 to 35 d at 35.6°F were used to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force (WBSF) and cooked beef color. Steaks were cooked to 3 different endpoint temperatures (150, 160, or 170°F) using: 1) an air-impingement oven (IMP); 2) clam-shell griddle (PANI); 3) forced-air convection oven (BLOD); 4) counter-top electric griddles (GRID); and 5) gas-fired, open-hearth char-grill (CHAR). Cooking loss percentage was greatest ($P < 0.05$) in steaks cooked to 170°F, and lowest ($P < 0.05$) in steaks cooked to 150°F, whereas steaks cooked on CHAR and PANI had the highest ($P < 0.05$) and lowest ($P < 0.05$) cooking losses, respectively. Steaks cooked in the BLOD to 170°F cooked the longest ($P < 0.05$), and steaks cooked on the PANI to 150°F had the shortest ($P < 0.05$) cook time. Steaks cooked to 150 and 170°F had the least ($P < 0.05$) and greatest ($P < 0.05$) WBSF, respectively, and steaks cooked on the PANI and in the BLOD had the least ($P < 0.05$) and greatest ($P < 0.05$) WBSF values, respectively. Steaks cooked on the PANI to 150°F had the reddest ($P < 0.05$) internal cooked color, whereas those cooked on the PANI to 170°F were the least ($P < 0.05$) red internally. Results of this experiment suggest that endpoint temperature has a greater impact on cook losses and mechanical tenderness than cookery method.

Introduction

Different cooking methods and endpoint temperatures have always been used when cooking steaks. According to AMSA (1995) guidelines, broiling is the most common cookery method for steaks. Tenderness of beef tends to decrease as end point temperature increases, and research has shown that the degree of doneness to which beef is cooked varies among U.S. consumers, with 64 to 82% of beef consumers cooking their steaks to "medium" to "very well done" (Wheeler et al., 1999).

When cooking beef from "rare" to "very well done," obvious changes occur to the internal color of cooked meat. Myoglobin is the primary heme pigment responsible for fresh meat color, and, during cooking, myoglobin is denatured to varying degrees, thereby influencing the appearance of meat color (Gracía-Segovia et al., 2006). Therefore, the objective of this research study was to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force and cooked beef color of the *infraspinatus* steaks.

Experimental Procedures

USDA Select clods were aged 0, 7, 14, 21, 28, or 35 d at 35.6°F (10 clods/aging period) to develop a wide range in possible tenderness differences. After the aging period, six 1-in-thick *infraspinatus* (IF) steaks (n = 360) were cut from each primal, labeled, vacuum-packaged, and frozen at -22°F for approximately 60 d before cooking. Then, frozen steaks were randomly assigned to 1 of 15 treatments in a 3 × 5 factorial arrangement, with 3 endpoint temperatures (150, 160, or 170°F) and 5 cookery methods. Steaks were thawed overnight at 35.6°F, removed from vacuum–packages, and weighed. Steaks were then cooked to their assigned endpoint temperature in/on either: 1) an air-impingement oven (IMP); 2) a clam-shell griddle (PANI); 3) electric, counter-top griddles (GRID); 4) forced-air, convection oven (BLOD); or 5) gas-fired, open-hearth char-grill (CHAR). All cookery methods were preheated to 360°F before cooking, and internal temperature was monitored in steaks cooked in PANI, BLOD, GRID and CHAR by placing copper-constantan thermocouples in the geometric-center of each steak. Additionally, steaks cooked in the BLOD, PANI and CHAR were turned when the internal temperatures had reached 95, 100, and 105°F for 150, 160, and 170°F endpoint temperatures, respectively, whereas steaks cooked on GRID were turned every 4 min until reaching the appropriate endpoint temperature. Finally, belt speeds of the IMP were set at 20, 25, and 30 min to produce endpoint temperatures of 150, 160, and 170°F, respectively, and endpoint temperature of each IMP-cooked steak was confirmed at the completion with a hand-held thermometer.

Cooking times were recorded for each steak cooked, and after a 1-h cooling period at room temperature, steaks were weighed to calculate cooking loss percentages. Then, each steak was sliced perpendicular to the cut surface, and instrumental color (L*, a* and b* values), as well as reflectance values from 400 to 740 nm, was measured immediately after cutting with a Hunter Miniscan XL, equipped with a 9-mm aperture, and illuminant A.

Immediately after cooked color data collection, six 0.5-in.-diameter cores were removed parallel with the muscle fiber orientation, and each core was sheared once with a Warner-Bratzler shear force (WBSF) device attached to an Instron Universal Testing machine with a 110-lb compression load cell and a crosshead speed of 200 mm/min. The average peak shear force of the 6 cores was used for statistical analyses.

Data were analyzed as an incomplete block design with subprimal as the block and individual steak as the experimental unit. Analysis of variance was generated with the mixed model procedure of SAS (SAS Inst., Inc., Cary, N.C.), with cookery method, endpoint temperature, and the 2-way interaction included in the model as fixed effects and subprimal as the random effect in the

[1] Department of Animal Science, Fayetteville

model. Least squares means were calculated and separated statistically using pair-wise t-tests (PDIFF option) when a significant ($P \leq 0.05$) F-test was identified.

Results and Discussion

No interaction existed ($P > 0.05$) between endpoint temperature and cooking method for WBSF, cooking loss, L* (lightness), or b* (yellowness), whereas cooking time and a* (redness) had interactions ($P < 0.05$) between endpoint temperature and cooking method.

Steaks cooked to 150°F had lower ($P < 0.05$) WBSF (Table 1) than those cooked to 160 or 170°F, which were similar ($P > 0.05$). Wheeler et al. (1999) confirms these results stating that higher endpoint temperatures lead to an increased WBSF and a less tender steak. Cooking method did not affect ($P = 0.324$) WBSF.

Not surprisingly, steaks cooked to 150°F had the lowest ($P < 0.05$) cooking losses (Table 1), and those cooked to 170°F had the greatest ($P < 0.05$). It is generally understood that higher endpoint temperatures result in greater cooking losses. Cooking steaks on the CHAR resulted in the greatest ($P < 0.05$) cooking loss, and the conduction cooking methods of GRID and PANI resulted in the least amount ($P < 0.05$) of losses during cooking. Cooking with air, as with the CHAR, BLOD, and IMP, apparently led to greater evaporation of intramuscular moisture.

Steaks cooked on the PANI had the shortest ($P < 0.05$) cook time (Figure 1), regardless of temperature. Surprisingly, when cooked on the PANI, steaks cooked to 150°F had similar ($P > 0.05$) cook times to those cooked to 170°F, whereas those cooked to 160°F had shorter ($P < 0.05$) cooking times than those cooked to 170°F. Steaks cooked in the BLOD had longer ($P < 0.05$) cook times than those cooked on any other cooking method, with the exception of the IMP ($P > 0.05$). Furthermore, steaks cooked on the IMP were similar ($P > 0.05$) in cooking time to those cooked on the GRID. The GRID had longer ($P < 0.05$) cooking times than the CHAR when steaks were cooked to 160 and 170°F; however, when cooking steaks to 150°F, the IMP and GRID were similar ($P > 0.05$) to CHAR. Within each cooking method, cooking steaks to 170°F took longer ($P < 0.05$) than cooking to 150 or 160°F, and cooking to 160°F had numerically longer ($P < 0.05$) cook times than to 150°F, but the differences were only significant for steaks cooked on the GRID ($P < 0.05$).

Neither cooking method ($P = 0.109$) nor endpoint temperature ($P = 0.461$) affected lightness (L* values) of *infraspinatus* steaks (Table 1). When cooking to 150°F, all 5 cooking methods had similar ($P < 0.05$) redness (a*) values (Figure 2). Moreover, when cooking to 170°F, all cooking methods had similar ($P > 0.05$) redness (a*) values, and, not surprisingly, the steaks cooked to 150°F were redder ($P < 0.05$) than those cooked to 170°F for each method. Steaks cooked at a lower temperature tend to have a higher redness (a*) value than those steaks cooked at a higher temperature indicating more myoglobin degradation (Gracía-Segovia et al., 2006). When cooked in the BLOD and on the CHAR, *infraspinatus* steaks cooked to 160°F were similar ($P > 0.05$) in redness to those cooked to 150°F and were greater ($P < 0.05$) than those cooked to 170°F. It was interesting that the convection-type cooking methods of BLOD and CHAR had redness values for "medium" steaks that were similar to those of "medium rare." In contrast, when cooking on the GRID, IMP, or PANI, steaks cooked to 160°F were less red ($P < 0.05$) than those cooked to 150°F and were similar ($P > 0.05$) to those cooked to 170°F. These methods produced internal redness in "medium" steaks similar to those of "medium well." Steaks cooked to 150°F were more yellow (higher b*; $P < 0.05$) (Table 1) than those cooked to 170°F, whereas those cooked to 160°F were intermediate ($P > 0.05$). Cooking method did not affect ($P > 0.05$) yellow (b*) values.

Implications

Even though cooking in a clam-shell grill resulted in *infraspinatus* steaks with the lowest cooking losses and shear force values, information from this study indicates that endpoint temperature has a greater impact on cooking losses, cook time, shear force measured tenderness, and internal color than any cookery method.

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Table 1. Main effects of endpoint temperature and cookery method on characteristics of cooked *infraspinatus* steaks.

	Endpoint temperature				Cookery method[1]					
Trait	150°F	160°F	170°F	SEM	BLOD	CHAR	GRID	IMP	PANI	SEM
Cook loss, %	26.1[c]	29.2[b]	34.4[a]	0.36	31.0[b]	33.5[a]	27.0[c]	30.5[b]	27.7[c]	0.45
WBSF[2], lb	6.39[b]	7.10[a]	7.20[a]	0.189	6.65	7.06	6.80	7.05	6.93	0.212
L*[3]	53.5	53.6	54.1	0.46	53.1	53.7	53.0	54.8	53.9	0.57
b*[3]	17.1[a]	16.4[ab]	15.8[b]	0.37	15.8	17.0	16.0	16.9	16.5	0.48

[1]BLOD = forced-air convection oven; CHAR = gas-fired, open-hearth char-grill; GRID = counter-top electric griddles; IMP = air-impingement oven; and PANI = clam-shell griddle.
[2]Warner-Bratzler shear force.
[3]L* = a measure of darkness to lightness (greater number indicates a lighter color) and b* = a measure of yellowness (greater number indicates a more yellow color).
[a,b,c]Within a row and main effect, least squares means lacking common superscript letters differ ($P < 0.05$).

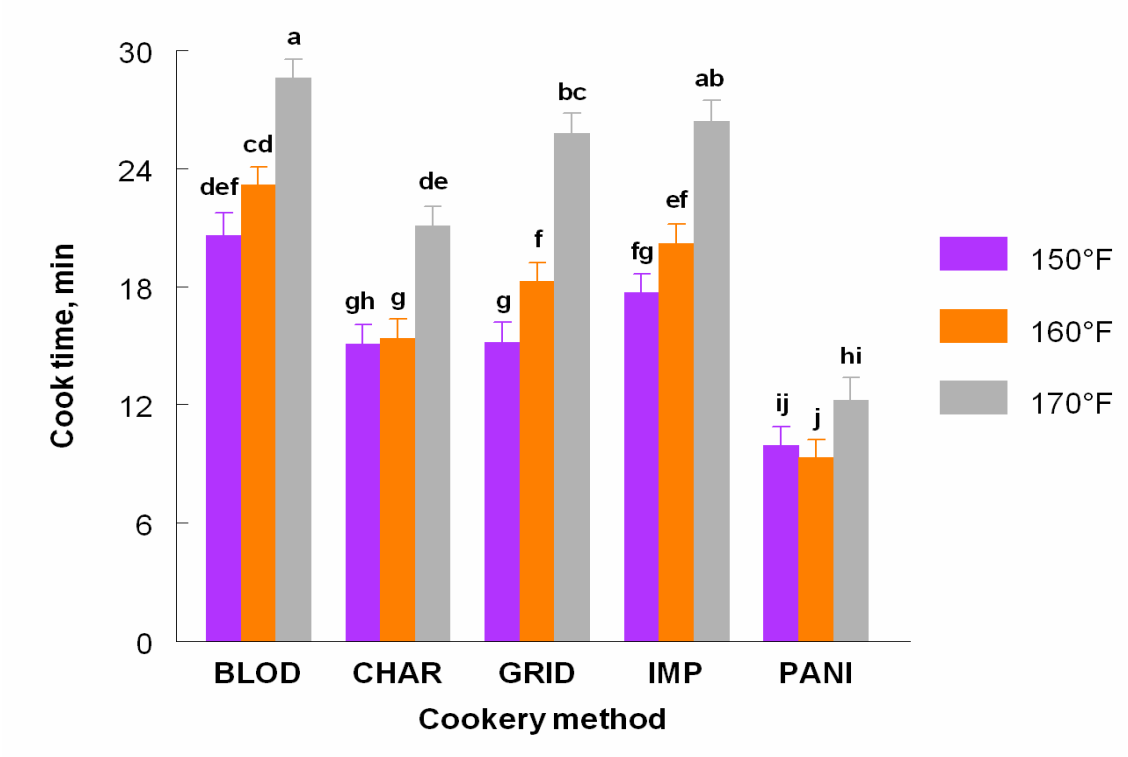

Fig. 1. Interactive effect of cookery method and endpoint temperature on cook time of *infraspinatus* steaks. Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).

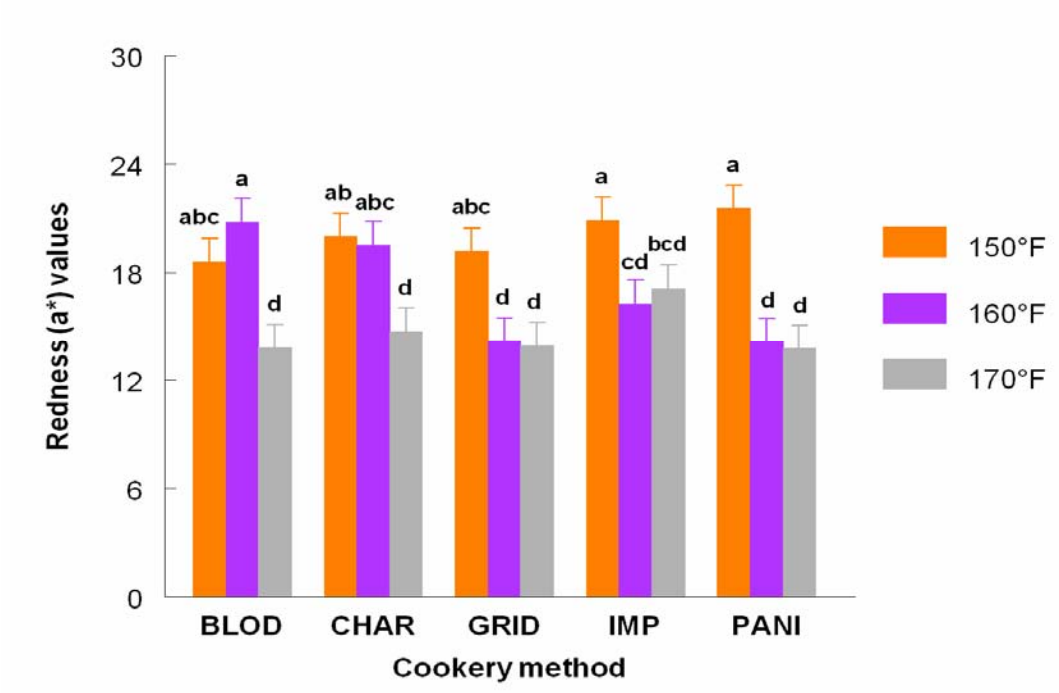

Fig 2. Interactive effect of cookery method and endpoint temperature on redness (a* values) of internal cooked color of *infraspinatus* steaks (greater a* values indicates a redder color). Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).

Internal Color and Tenderness of the *Longissimus Thoracis* Are Affected by Cooking Methods and Degree of Doneness

M.D. Wharton, J.K. Apple, J.W.S. Yancey, J.T. Sawyer, and M.S. Lee[1]

Story in Brief

Longissimus thoracis (LT) steaks (n = 360) from USDA Select ribeye rolls aged 0 to 35 d at 35.6°F were used to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force (WBSF) and cooked beef color. Steaks were cooked to 3 different endpoint temperatures (150, 160 or 170°F) using: 1) an air-impingement oven (IMP); 2) clam-shell griddle (PANI); 3) forced-air convection oven (BLOD); 4) counter-top electric griddles (GRID); and 5) gas-fired, open-hearth char-grill (CHAR). Cooking steaks to 170°F took longer ($P < 0.05$) than cooking to 150°F, regardless of cookery methods, and, even though cooking losses were similar ($P = 0.09$) among cookery methods, cooking loss percentages for steaks cooked to 170°F were greater ($P < 0.05$) than steaks cooked to 150 and 160°F. The greatest ($P < 0.05$) and least ($P < 0.05$) WBSF values were in steaks cooked to 170 and 150°F, respectively, whereas steaks cooked in the BLOD had lower ($P < 0.05$) shear force values than steaks cooked on CHAR, GRID and PANI. Internal cooked color of LT steaks cooked to 150°F was the reddest ($P < 0.05$), and steaks cooked on CHAR were redder ($P < 0.05$) than steaks cooked on GRID, IMP and PANI. Cooking LT steaks to 150°F produced more tender steaks, with an obviously redder internal cooked color, than cooking to 170°F. Moreover, broiling LT steaks in the BLOD resulted in lower WBSF values, but internal cooked color was intermediate to other cookery methods.

Introduction

The *longissimus* muscle (LM) is probably the most studied muscle, especially in meat science, and, because LM steaks are more tender than other steaks from the sirloin and round (Neely et al., 1998; Lorenzen et al., 2003), it is the "gold standard" to which the palatability attributes of other cuts of meat are routinely compared (Savell and Shackelford, 1992). Cookery guidelines for research (AMSA, 1995) specify broiling/grilling steaks to 160°F, based on the finding that most consumers prepare LM steaks by grilling and broiling (Lorenzen et al., 1999). However, Lorenzen et al. (1999) reported that degrees of doneness for LM steaks were equally distributed among "rare to medium rare," "medium," "medium well" and "well done," or greater, by consumers in Chicago, Houston, Philadelphia and San Francisco, whereas Wheeler et al. (1999) noted that 64 to 82% of beef consumers cooked beef between "medium" and "very well done" degrees of doneness. Moreover, research has demonstrated that shear force values increase (Lorenzen et al., 2003), and consumer ratings for tenderness decrease (Neely et al., 1998; Lorenzen et al., 1999) with increasing endpoint temperature.

Although a number of studies have tested the effects of cookery method and/or degree of doneness on the palatability attributes of beef LM steaks, little is known about the internal color changes associated with increasing degrees of doneness from "rare" to "well done" nor is there information concerning cookery method on internal color changes. Therefore, the objective of this research study was to test the effect of various cookery methods and internal endpoint temperature on Warner-Bratzler shear force and cooked beef color of *longissimus thoracis* steaks.

Experimental Procedures

USDA Select ribeye rolls were aged 0, 7, 14, 21, 28, or 35 d at 35.6°F (10 ribeye rolls/aging period) to develop a wide range in possible tenderness differences. After the aging period, six 1-in-thick *longissimus thoracis* (LT) steaks (n = 360) were cut from each primal, labeled, vacuum-packaged, and frozen at -22°F for approximately 60 d before cooking. Then, frozen steaks were randomly assigned to 1 of 15 treatments in a 3 × 5 factorial arrangement, with 3 endpoint temperatures (150, 160 or 170°F) and 5 cookery methods. Steaks were thawed overnight at 35.6°F, removed from vacuum–packages, and weighed. Steaks were then cooked to their assigned endpoint temperature in/on either: 1) an air-impingement oven (IMP); 2) a clam-shell griddle (PANI); 3) electric, counter-top griddles (GRID); 4) forced-air, convection oven (BLOD); or 5) gas-fired, open-hearth char-grill (CHAR). All cookery methods were preheated to 360°F before cooking, and internal temperature was monitored in steaks cooked in PANI, BLOD, GRID and CHAR by placing copper-constantan thermocouples in the geometric-center of each steak. Additionally, LT steaks cooked in the BLOD, PANI and CHAR were turned when the internal temperatures had reached 95, 100, and 105°F for 150, 160 and 170°F endpoint temperatures, respectively, whereas steaks cooked on GRID were turned every 4 min until reaching the appropriate endpoint temperature. Finally, belt speeds of the IMP were set at 20, 25 and 30 min to produce endpoint temperatures of 150, 160 and 170°F, respectively, and endpoint temperature of each IMP-cooked steak was confirmed at the completion with a hand-held thermometer.

Cooking times were recorded for each steak cooked, and, after a 1-h cooling period at room temperature, LT steaks were weighed to calculate cooking loss percentages. Then, each steak was sliced

[1] Department of Animal Science, Fayetteville

perpendicular to the cut surface, and instrumental color (L*, a* and b* values), as well as reflectance values from 400 to 740 nm, was measured immediately after cutting with a Hunter Miniscan XL, equipped with a 9-mm aperture, and illuminant A.

Immediately after cooked color data collection, six 0.5-in-diameter cores were removed parallel with the muscle fiber orientation, and each core was sheared once with a Warner-Bratzler shear force (WBSF) device attached to an Instron Universal Testing machine with a 110-lb compression load cell and a crosshead speed of 200 mm/min. The average peak shear force of the 6 cores was used for statistical analyses.

Data were analyzed as an incomplete block design with subprimal as the block and individual steak as the experimental unit. Analysis of variance was generated with the mixed model procedure of SAS (SAS Inst., Inc., Cary, N.C.), with cookery method, endpoint temperature, and the 2-way interaction included in the model as fixed effects and subprimal as the random effect in the model. Least squares means were calculated and separated statistically using pair-wise t-tests (PDIFF option) when a significant ($P \leq 0.05$) F-test was identified.

Results and Discussion

There was no cooking method by endpoint temperature interactive effect on WBSF, cooking loss, L*, a*, chroma, hue angle or the ratio of reflectance values at 630 over 580; however, an interaction existed for cooking time and b* values.

As expected, steaks cooked to 150°F had the lowest ($P < 0.05$) WBSF, and those cooked to 170°F had the greatest ($P < 0.05$) WBSF (Table 1). This agrees with Wheeler et al. (1999) and Lorenzen et al. (2003), who reported that increasing endpoint temperature also increases meat toughness. Steaks cooked in the BLOD had lower ($P < 0.05$) WBSF values than those cooked on the CHAR, GRID, or PANI, whereas those cooked on the IMP were intermediate ($P > 0.05$). The BLOD and IMP both use convection heating, whereas the GRID and PANI use conduction heating and the CHAR uses a combination of convection and conduction, heating by both direct contact with the hot grills and hot air from the gas burners.

Not surprisingly, steaks cooked to 170°F had the greatest ($P < 0.05$) cooking loss (Table 1); however, those cooked to 160°F had numerically, but not statistically ($P > 0.05$), greater cooking losses than those cooked to 150°F. Cooking method did not affect ($P > 0.05$) cooking loss in the LT. The BLOD had the longest ($P < 0.05$) and the PANI had the shortest ($P < 0.05$) cooking time at all 3 endpoint temperatures (Figure 1). When cooking to 150°F, steaks cooked on the IMP had longer ($P < 0.05$) cook times than those cooked on the CHAR, whereas the GRID method was intermediate ($P > 0.05$). Steaks cooked on the CHAR to 160°F took less time ($P < 0.05$) than those cooked to 160°F on the GRID, which in turn, took less time ($P < 0.05$) than those cooked to 160°F on the IMP. When cooking to 170°F, the CHAR and GRID methods had similar ($P > 0.05$) cooking times, which were shorter ($P < 0.05$) than cooking to 170°F on the IMP. In the BLOD, cooking to 150 and 170°F had the shortest ($P < 0.05$) and longest ($P < 0.05$) cooking times, respectively. Cooking steaks to 150 and 160°F on the CHAR resulted in similar ($P > 0.05$) cooking times, which were shorter ($P < 0.05$) than those cooked to 170°F on the CHAR. On the GRID and PANI, cooking steaks to 170°F took longer ($P < 0.05$) than cooking to 150°F, and cooking to 160°F had intermediate ($P > 0.05$) cooking times. Using the IMP, cooking to 150°F resulted in a shorter ($P < 0.05$) cooking time than cooking to 160 or 170°F, which were similar ($P > 0.05$).

Internal lightness (L* values) of the cooked steaks was not affected by end-point cooking temperature or cooking method (Table 1). Steaks cooked to 150°F had the reddest (highest a* value; $P < 0.05$) internal cooked color, and those cooked to 170°F were the least red ($P < 0.05$). Steaks cooked on the CHAR were redder ($P < 0.05$) than those cooked on the GRID, IMP, or PANI, whereas those cooked in the BLOD were intermediate ($P > 0.05$). Differences in yellowness were significant ($P < 0.05$) (Figure 2), but were numerically irrelevant as the largest b* difference was just over 4 units. Steaks cooked to 150°F in the BLOD or on the CHAR were more yellow (higher b* values; $P < 0.05$) than steaks from any other cooking method and endpoint temperature combination. Steaks cooked to 160 and 170°F had similar ($P > 0.05$) b* values for all cookery methods, and on the GRID and PANI b* values were similar ($P > 0.05$) regardless of end-point temperature. When cooked on the IMP, steaks cooked to 150°F were more yellow ($P < 0.05$) than those cooked to 170°F, and steaks cooked to 160°F were intermediate ($P > 0.05$).

Implications

As expected, shear force values, cooking losses and cook times increased, and internal cooked color became less red, with increasing endpoint temperatures, regardless of cookery method. Moreover, although char-grilling produced steaks with a redder internal cooked color than the other cookery methods, cooking steaks in a forced-air convection oven resulted in more tender steaks, especially when compared to steaks cooked on the char-grill, electric, counter-top griddles, and in the clam-shell griddle.

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Table 1. Main effects of endpoint temperature and cookery method on characteristics of cooked *longissimus thoracis* steaks.

	Endpoint temperature				Cookery method[1]					
Trait	150°F	160°F	170°F	SEM	BLOD	CHAR	GRID	IMP	PANI	SEM
Cook loss, %	26.2^{b}	29.3^{b}	35.2^{a}	1.30	31.5	32.6	30.7	29.9	26.2	1.67
WBSF, lb.	7.04^{c}	7.50^{b}	8.27^{a}	0.225	7.17^{b}	7.67^{a}	7.75^{a}	7.49^{ab}	7.93^{a}	0.24
L*[3]	59.1	58.6	57.7	0.53	57.8	58.0	59.1	58.8	58.8	0.65
a*[3]	20.1^{a}	15.1^{b}	12.2^{c}	0.57	16.4^{ab}	17.5^{a}	14.9^{b}	15.5^{b}	14.7^{b}	0.73

[1]BLOD = forced-air convection oven; CHAR = gas-fired, open-hearth char-grill; GRID = counter-top electric griddles; IMP = air-impingement oven; and PANI = clam-shell griddle.
[2]Warner-Bratzler shear force.
[3]L* = a measure of darkness to lightness (greater number indicates a lighter color); and a* = a measure of redness (greater number indicates a redder color).
[a,b,c]Within a row and main effect, least squares means lacking common superscript letters differ ($P < 0.05$).

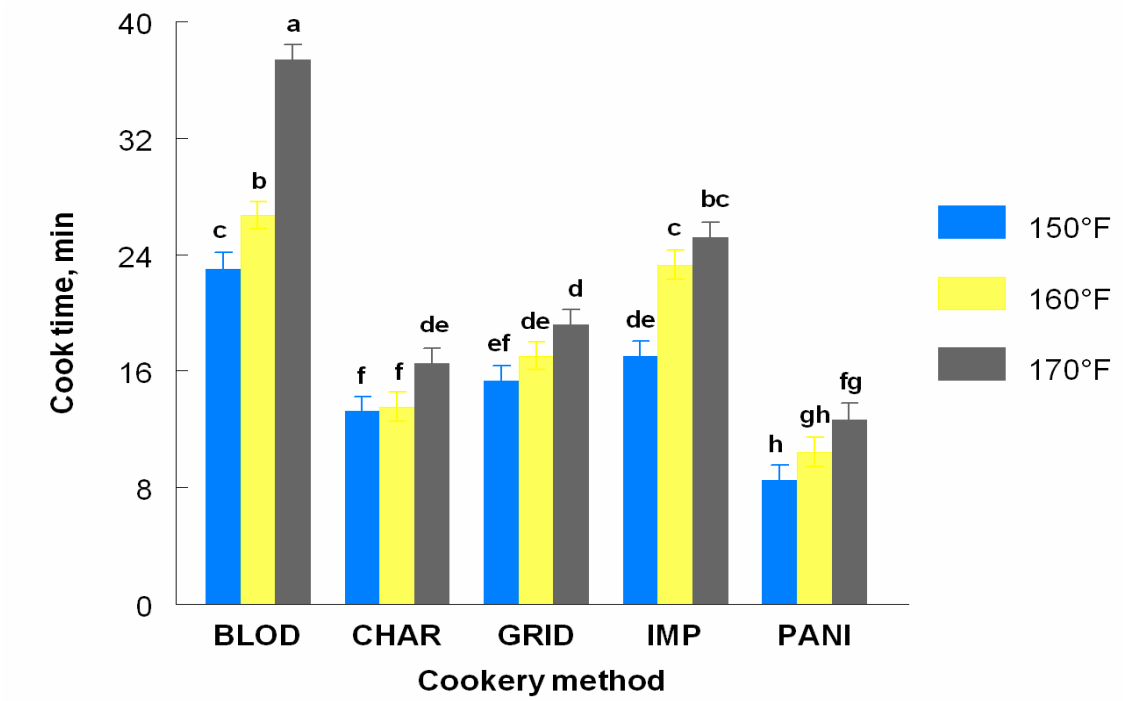

Fig. 1. Interactive effect of cookery method and endpoint temperature on cook time of *longissimus thoracis* steaks. Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).

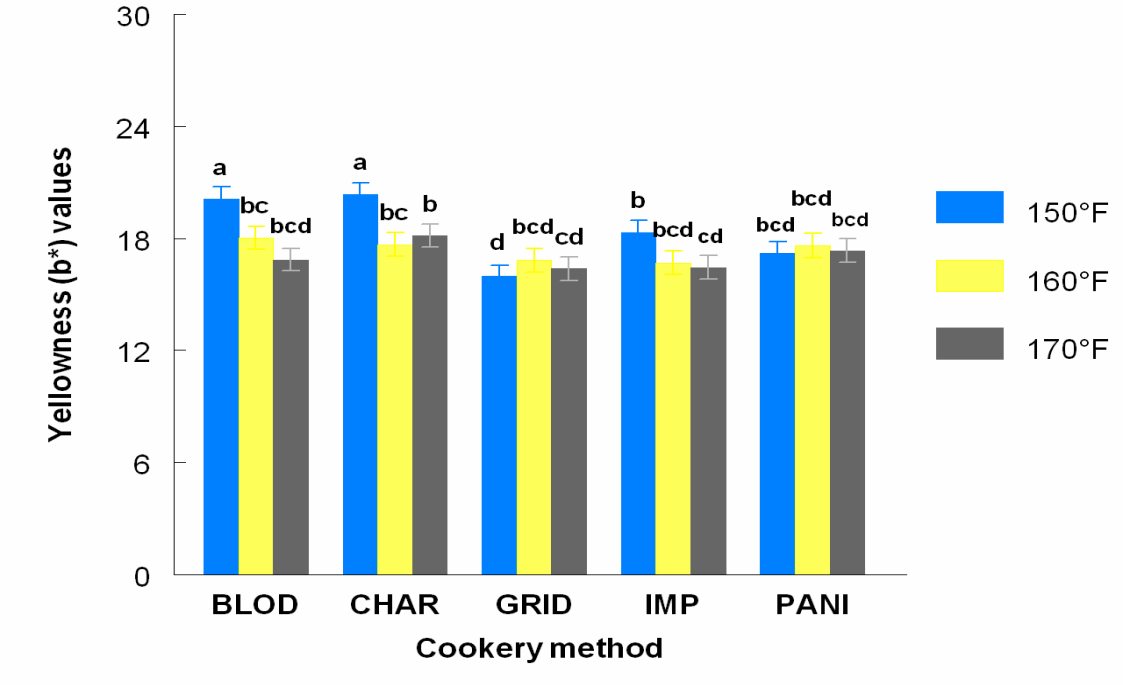

Fig. 2. Interactive effect of cookery method and endpoint temperature on yellowness (b* values) of internal cooked color of *longissimus thoracis* steaks (larger b* values indicates a more yellow color). Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).

Physical, Chemical, and Sensory Properties of Surface-Decontaminated Beef Steaks Using Potassium Lactate, Sodium Metasilicate, Cetylpyridinium Chloride or Trisodium Phosphate as Single Antimicrobial Interventions Prior to Packaging

F.W. Pohlman[1], P.N. Dias-Morse[1], B.L. Gupton[2], C.W. Rowe[3], and L.M. McKenzie[1]

Story in Brief

Steaks from strip loins were placed in a meat tumbler with 500 ml of 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 0.5% cetylpyridinium chloride (CPC), or 10% trisodium phosphate (TSP) as a single microbial intervention and tumbled for 2 min prior to packaging. Packaged steaks were sampled on days 0, 1, 2, 3, and 7 of retail display for instrumental color, sensory color, and lipid oxidation. In addition, the shear force and cooking loss values of steaks were evaluated. These properties were compared with an untreated control to understand impacts of treatments on the quality characteristics of the decontaminated steaks. The results indicate that TSP and NMS treatments may enhance and retain meat color compared to other treatments. The use of NMS treatment also showed lower lipid oxidation, cooking loss and shears force values and outperformed the other treatments.

Introduction

Single or multiple antimicrobial interventions to improve microbiological quality in fresh meat have been intensely researched and have shown promising results in decontaminating meat products. However, a substantial need exists to identify the antimicrobial agents that improve shelf life and reduce or eliminate microbial growth while maintaining a pleasing appearance for consumers. Particularly, consumers consider the color of meat as an indicator of meat quality and freshness and often discriminate against discolored meat products. Thus, any deleterious effects on color attributes lead to negative economic impact. There are only a limited number of antimicrobial products that can be used without causing adverse effects on appearance and taste of the product (Mermelstain, 2001). According to Jimenez-Villarreal et al. (2003) and Pohlman et al. (2005) the use of 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 0.5% cetylpyridinium chloride (CPC), or 10% trisodium phosphate (TSP) may not adversely affect color characteristics when used in a ground beef system. Therefore, the objective of this study is to evaluate the impact of CPC, TSP, NMS and KL when used as a single antimicrobial intervention on physical, chemical and sensory properties of beef steaks.

Experimental Procedures

Antimicrobial treatment and processing. A total of 90 steaks (2 cm) were obtained from 15 strip loins (IMPS = 180). The antimicrobial treatments used in this study were 0.5% (w/v) CPC (Zeeland, Inc, Zeeland, Mich.), 0.3 % (v/v) KL (Purasal®, Purac America Inc., Lincolnshire, Ill.), 4% NMS (Avgard®, Rhodia Inc., Cranbury, N.J.), and 10 % (w/v) TSP (Rhone Poulenc, Cranbury, N.J.). For treatment application, 10 steaks were placed into a meat tumbler (Model 4Q, Lyco Inc. Janesville, Wis.) and 500 ml of the selected antimicrobial agent was added and tumbled at 60 rpm for 2 min as a single antimicrobial intervention. Each antimicrobial treatment was repeated 3 times. Next, decontaminated and untreated control (CON) steaks were placed individually on styrofoam trays with absorbent pads and overwrapped with polyvinyl chloride film with an oxygen transmission rate of 14,020 $cm^3O_2/m^2/24$ h/atm-6 (Koch Supplies, Inc., Kansas City, Mo.). The steaks were stored under simulated retail conditions (4˚C ; deluxe warm white fluorescent lighting, 1630 lux, Phillips Inc., Somerset, N.J.). The treated steak samples were diluted with de-ionized water at 1:18 ratio. An Orion model 420A pH meter with Ross electrode (Model 8165 BN, Orion Research Inc., Beverly, Mass.) was used to measure the pH of homogenized samples.

Instrumental color. Steaks were sampled on days 0, 1, 2, 3, and 7 of simulated display, and a Hunter-Lab MiniScan XE Spectrocolorimeter, Model 4500L (Hunter Associates Laboratory, Reston, W.Va.) was used to evaluate instrumental color. Samples were assessed for CIE (L*, a*, and b*) color values, hue angle ($\tan^{-1}(b^*/a^*)$, which describes the hue or color of steaks, and saturation index $(a^{*2}+ b^{*2})^{0.5}$, which describes the brightness or vividness of color (Hunt et al., 1991). Reflectance measurements were also taken in the visible spectrum from 580 to 630 nm and reflectance ratio (630/580 nm) was calculated to estimate the oxymyoglobin proportion of the myoglobin pigment (Hunt et al., 1991). Each sample was measured 5 times using Illuminant A/10° observer, and the Spectrocolorimeter was standardized using white tile, black tile and working standards before use in measurements.

Sensory evaluation. Experienced panelists were selected through screening and trained according to AMSA *Research Guidelines for Cookery, Sensory Evaluation and Instrumental Measurements* (1995). Sensory evaluation of steaks treated with antimicrobial agents was carried out on 0, 1, 2, 3 and 7 d of simulated retail display. Panelists (n = 8) evaluated overall color and worst point color using modified 5-point scales of Hunt et al. (1991) (5 = bright purplish red to 1 = brown). Percent discol-

[1] Department of Animal Science, Fayetteville
[2] Formerly, College of the Ozarks, Missouri
[3] Auburn University, Alabama

oration was evaluated on a 7-point scale ((7 = no discoloration (0%) to 1 = total discoloration (96 to 100%)).

Warner–Bratzler shear force (WBS) and cooking loss. Steaks were removed from foam trays prior to cooking and cooked for evaluation using a Blodgett forced air convection oven (Blodgett Oven., Burlington, Vt.) to an internal temperature of 70° C (AMSA, 1995). An Internal Teflon-coated copper constantan thermocouple (Omega Engineering Inc., Stamford, Conn.) attached to a Doric multichannel data logger (VAS Engineering Inc., San Diego, Calif.) was used to monitor the internal temperature of each steak. Then, steaks were allowed to cool to room temperature (25˚C) and six 1.27-cm diameter cores were taken parallel to the muscle fibers from each steak for WBS (AMSA, 1995). Each core was sheared with a Warner–Bratzler shear attachment using an Instron Universal Testing Machine (Instron Corp., Canton, Mass.) equipped with a 490 N load cell and 250-mm/min crosshead speed. After steaks were removed from the foam trays, each steak was weighed prior to cooking. Upon completion of cooking and after allowing the steaks to cool at room temperature (25°C), a final weight was obtained. Cooking loss was determined by dividing the weight difference between the fresh and cooked weight by the fresh weight and multiplying by 100.

Thiobarbituric Acid Reactive Substances (TBARS). On day 0, 3, and 7 of simulated retail display a sample of steak from each treatment and replicate were analyzed for TBARS as described by Baublits et al. (2007).

Analysis of data. Instrumental color and sensory color were arranged in a completely randomized 5 x 5 factorial design; whereas, TBARS data were arranged in a completely randomized 5 × 3 factorial design. The experiment was replicated 3 times. Treatments were analyzed for the main effects of antimicrobial treatment, days of displays, and treatment by day interactions using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). A panelist term was added to the model to account for sensory panelist variation. Means were generated using LSMEANS and separated with the PDIFF option of SAS.

Results and Discussion

The results indicate that sensory panelists did not find differences ($P > 0.05$) among TSP, NMS, and CON treatments for worst point color and overall color on day 1 of retail display (Table 1). Further, they found only modest discoloration in TSP treated-steaks that was similar ($P > 0.05$) to the control steaks on day 1 (Table 1). The panelists also identified that NMS and TSP treated steaks had similar or better performances ($P < 0.05$) compared to the control for worst point color and overall color on day 2 and 3 of display. Although CON, NMS and TSP treatments had similar ($P > 0.005$) percent discoloration on day 2, only NMS and TSP treatments continued to maintain a small or modest discoloration on day 3. The NMS treated steaks had a greater ($P < 0.05$) worst point color, overall color, and percent discoloration scores compared to all the other treatments on day 7.

The CPC treatment had similar ($P > 0.05$) lightness (L*) values to untreated steaks on day 0 to 7 (Table 2). Steaks from NMS and TSP treatments were similar in lightness ($P > 0.05$), and both were darker ($P < 0.05$) than control steaks on days 0 to 2. However, no differences ($P > 0.05$) in lightness were found among CON, NMS, and TSP treatments on day 7. The TSP-treated steaks and CON-steaks had similar ($P > 0.05$) redness (a*) and both had greater redness values ($P < 0.05$) compared to other treatments on day 1 (Table 2). A study by Abril et al. (2001) confirms that ultimate meat pH affects the color development in meat surface and therefore influences the reflectance spectra. As Seideman et al. (1984) stated, in meat of high pH, proteins will associate with more water and create a tightly packed surface that will not scatter light to same extent as surface of meat with low pH. Therefore, steaks with higher ultimate pH tend to be darker. Correspondingly, in our study the NMS (pH = 6.7) and TSP (pH = 6.5) treated steaks were darker compared to KL (pH = 5.7), CPC (pH = 5.9), and CON (pH = 6) steaks. According to Young et al. (2001), hue angle is a good indicator of discoloration and as discoloration in meat progresses, hue angle increases. Our results show that steaks from NMS and TSP treatments had lower ($P > 0.05$) hue angle values compared to all the other treatments on day 0 to 3 (Table 3), thus, confirming less discoloration of these steaks compared to the other treatments. The TSP-treated steaks had similar saturation index ($P > 0.05$) compared to the control steaks on days 2 and 3 of display (Table 3). These steaks, along with NMS-treated steaks, maintained a similar or higher oxymyoglobin to myoglobin ratio compared to the control steaks during day 0 to 3 of display (Table 3). The NMS treatment had the lowest lipid oxidation ($P < 0.05$) on day 0, 3, and 7 of display and possessed the lowest ($P < 0.05$) cooking loss value and shear force value compared to all the other treatments (Table 5).

Implications

Since consumer meat purchasing decisions largely depend on meat color, it is important to select decontamination agents that maintain or enhance the product color. In this context, sodium metasilicate and trisodium phosphate will be better candidates for improving and retaining meat color for a prolonged time.

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Table 1. Day of display by antimicrobial treatment interaction effect on least squares means for overall color, worst point color and percentage discoloration of beef steaks treated with different antimicrobials.

		Days of display				
Attribute[x]	Treatment[y]	0	1	2	3	7
Worst point color						
	CON	4.58[a]	4.04[a]	3.05[b]	2.40[b]	1.55[b]
	CPC	2.79[c]	2.00[c]	2.00[c]	1.80[b]	1.77[b]
	KL	3.25[bc]	3.25[b]	3.61[ab]	2.47[b]	1.33[bc]
	NMS	3.75[b]	3.70[ab]	3.94[ab]	3.80[a]	2.48[a]
	TSP	3.58[b]	3.66[ab]	4.16[a]	3.47[a]	1.15[c]
	SE	0.18	0.18	0.21	0.25	1.55
Overall color						
	CON	4.83[a]	4.25[a]	3.72[b]	2.93[c]	2.11[b]
	CPC	3.33[c]	2.66[c]	2.72[c]	2.93[c]	2.18[b]
	KL	3.50[c]	3.54[b]	3.94[b]	3.33[bc]	1.55[c]
	NMS	4.13[b]	3.96[ab]	4.50[a]	4.46[a]	3.15[a]
	TSP	4.00[b]	4.08[ab]	4.55[a]	3.93[ab]	1.33[c]
	SE	0.15	0.16	0.16	0.21	0.14
Percent discoloration						
	CON	6.62[a]	5.37[a]	4.55[a]	2.60[c]	2.37[bc]
	CPC	4.45[b]	3.33[c]	3.38[b]	3.40[bc]	2.77[b]
	KL	4.91[b]	4.58[b]	5.38[a]	3.73[bc]	2.00[cd]
	NMS	5.29[b]	4.17[b]	4.50[a]	5.26[a]	3.74[a]
	TSP	5.00[b]	4.62[ab]	5.50[a]	4.20[ab]	1.63[d]
	SE	0.30	0.28	0.37	0.48	0.19

[abc]Least squares means within a column with different superscripts are different ($P < 0.05$).

[x]Worst point color and overall color scale was 5 = bright purplish red, 4 = dull purple red, 3 = slightly brownish red, 2 = moderately brownish red and 1 = brown. Percentage surface discoloration was evaluated on a 1 to7 scale (7 = no discoloration (0%), 6 = slight discoloration (1to20%), 5 = small discoloration (20 to39%), 4 = modest discoloration (40 to 59%), 3 = moderate discoloration (60 to79%), 2 = extensive discoloration (80-95%), 1 = total discoloration (96 to 100%) .

[y]Treatments: CON = untreated control CPC = 0.5% cetylpyridinium chloride, K-L = 3% potassium lactate, NMS = 4% sodium metasilicate, TSP = 10% trisodium phosphate.

Table 2. Day of display by antimicrobial treatment interaction effect on least squares means for L*, a*, b* values of beef steaks treated with different antimicrobials.

Attribute[x]	Treatment[y]	Days of display				
		0	1	2	3	7
Lightness (L*)						
	CON	44.18[b]	42.88[a]	42.51[a]	30.10[c]	37.26[b]
	CPC	45.66[b]	44.07[a]	42.41[a]	40.58[ab]	38.09[b]
	KL	50.38[a]	42.49[a]	42.13[a]	42.25[a]	41.50[a]
	NMS	36.62[c]	36.23[b]	36.60[b]	41.52[a]	36.43[b]
	TSP	39.29[c]	37.64[b]	38.77[b]	33.60[c]	35.52[b]
	SE	1.13	1.16	0.80	1.82	1.05
Redness (a*)						
	CON	30.23[a]	31.50[a]	26.55[a]	20.42[b]	16.02[ab]
	CPC	26.57[c]	26.07[b]	22.98[b]	22.94[ab]	17.88[a]
	KL	28.05[b]	27.55[b]	26.64[a]	22.77[ab]	15.08[b]
	NMS	23.41[d]	25.65[b]	23.55[b]	24.94[a]	17.81[a]
	TSP	25.70[c]	30.02[a]	25.30[ab]	24.38[a]	10.12[c]
	SE	0.51	0.71	0.88	0.96	0.86
Yellowness (b*)						
	CON	22.62[a]	25.47[a]	20.95[a]	17.74[b]	16.57[a]
	CPC	21.23[a]	22.18[b]	19.38[ab]	20.06[a]	16.11[a]
	KL	21.79[a]	22.49[b]	21.14[a]	19.52[ab]	16.87[a]
	NMS	11.47[c]	15.00[c]	13.66[c]	15.02[c]	10.84[b]
	TSP	16.40[b]	22.27[b]	17..44[b]	16.81[bc]	10.24[b]
	SE	0.54	0.70	0.71	0.71	0.46

[abcd] Least squares means within a column with different superscripts are different ($P < 0.05$).
[x]L*: 0 = black and 100 = white; a*: -60 = green and +60 = red; b*: -60 = blue and +60 = yellow.
[y]Treatments: CON = untreated control, CPC = 0.5% cetylpyridinium chloride, K-L = 3% potassium lactate, NMS = 4% sodium metasilicate, TSP = 10% trisodium phosphate, UN= un-inoculated untreated control.

Table 3. Day of display by antimicrobial treatment interaction effect on least squares means for hue angle, saturation index and reflectance ratio values of beef steaks treated with different antimicrobials.

		Days of display				
Attribute	Treatment[z]	0	1	2	3	7
Hue angle[w]						
	CON	36.79^{b}	38.95^{b}	28.27^{d}	40.99^{a}	46.26^{ab}
	CPC	38.63^{a}	40.42^{a}	40.19^{a}	41.19^{a}	42.32^{b}
	KL	37.84^{ab}	39.23^{b}	38.46^{b}	40.63^{a}	48.56^{b}
	NMS	25.89^{d}	30.09^{d}	29.99^{d}	31.07^{c}	31.30^{c}
	TSP	32.49^{c}	36.47^{c}	34.46^{c}	34.55^{b}	45.59^{ab}
	SE	0.63	0.46	0.46	0.71	1.65
Saturation index[x]						
	CON	37.76^{a}	40.51^{a}	33.83^{ab}	27.08^{b}	23.13^{a}
	CPC	34.03^{b}	34.24^{c}	30.06^{b}	30.49^{a}	24.17^{a}
	KL	35.52^{b}	35.57^{bc}	34.01^{a}	29.99^{ab}	22.69^{ab}
	NMS	26.10^{d}	29.74^{d}	27.24^{c}	29.12^{ab}	20.86^{b}
	TSP	30.50^{c}	37.38^{b}	30.73^{b}	29.61^{ab}	14.47^{c}
	SE	0.67	0.96	0.32	1.15	14.47
Reflectance ratio[y]						
	CON	6.17^{a}	6.74^{b}	4.45^{bc}	3.28^{b}	1.87^{cd}
	CPC	4.70^{b}	4.47^{c}	3.56^{c}	3.61^{b}	2.31^{bc}
	KL	4.79^{b}	5.20^{c}	4.74^{b}	3.51^{b}	1.64^{d}
	NMS	5.83^{a}	6.63^{b}	5.42^{ab}	5.63^{a}	3.15^{a}
	TSP	5.63^{a}	7.85^{a}	5.13^{ab}	6.00^{a}	1.43^{c}
	SE	0.30	0.34	0.31	0.40	0.18

[abcd] Least squares means within a column with different superscripts are different ($P < 0.05$).
[w]Calculated as $\tan^{-1}(b^*/a^*)$.
[x]Calculated as $(a^{*2}+b^{*2})^{0.5}$.
[y]Calculated as (630nm/580nm).
[z]Treatments: CON= untreated control, CPC = 0.5% cetylpyridinium chloride, K-L = 3% potassium lactate, NMS = 4% sodium metasilicate, TSP = 10% trisodium phosphate.

Table 4. Day of display by antimicrobial treatment interaction effect on least squares means for thiobarbituric acid reactive substances (TBARS) values of beef steaks treated with different antimicrobials.

	Day of display		
Treatment[x]	0	3	7
CON	0.29[a]	0.29[a]	7.51[a]
CPC	0.20[bc]	0.10[c]	5.71[b]
KL	0.22[ab]	0.24[ab]	5.82[b]
NMS	0.15[c]	0.08[c]	2.62[c]
TSP	0.27[ab]	0.17[bc]	1.18[d]
SE	0.27	0.27	0.37

[abcd] Least squares means within a column with different superscripts are different ($P < 0.05$).
[x]Treatments: CON = untreated control CPC = 0.5% cetylpyridinium chloride, K-L = 3% potassium lactate, NMS = 4% sodium metasilicate, TSP = 10% trisodium phosphate.

Table 5. Day of antimicrobial treatment effect on least squares means for shear force and cooking loss values of beef steaks treated with different antimicrobials.

Treatment[x]	Cooking loss (%)	Shear force (N)
CON	40.16[a]	32.51[a]
CPC	43.93[a]	35.58[a]
KL	41.37[a]	29.74[a]
NMS	31.01[b]	22.30[b]
TSP	33.51[b]	30.48[a]
SE	1.72	2.03

[abcd] Least squares means within a column with different superscripts are different ($P < 0.05$).
[x]Treatments: CON = untreated control CPC = 0.5% cetylpyridinium chloride, K-L = 3% potassium lactate, NMS = 4% sodium metasilicate, TSP = 10% trisodium phosphate.

Effect of Replacing Fish Meal with Synthetic Amino Acids on Nursery Pig Growth Performance

J.W. Frank[1], C.L. Bradley[1], C.V. Maxwell[1], Z.B. Johnson[1], and J.L. Usry[2]

Story in Brief

The objective of this study was to determine if fish meal (FM) could be replaced with synthetic amino acids (AA) in Phase 1 and 2 nursery diets. Weaned pigs were used in a 34 d growth study. Pigs were fed 1 of 5 dietary treatments that contained decreasing levels of FM during Phases 1 and 2. All pigs were fed a common Phase 3 diet. There were no differences ($P > 0.12$) in ADG or ADFI during the study. There was a linear increase ($P < 0.01$) in F/G as FM was replaced with AA in the diet during Phases 1 and 2; however, there was no effect of dietary treatment on F/G during Phase 3 or overall ($P = 0.24$). Final BW was not different as FM was replaced with AA ($P = 0.27$). Although F/G increased as FM was replaced with AA during Phase 2, there were no effects on overall F/G. These results suggest that synthetic amino acids may be used to replace fish meal in nursery diets without compromising overall growth performance of the pigs.

Introduction

Rising feed costs are challenging producers to find alternative protein sources for swine rations. Complex ingredients such as spray dried plasma protein, whey protein, soy protein concentrate, and fish meal (FM) have been used in nursery diets to reduce the amount of soybean meal inclusion in an attempt to reduce the soybean meal hypersensitivity response that reduces growth performance (Li et al., 1990). The use of complex ingredients has clearly been shown to improve growth performance of nursery pigs; however, these feed ingredients are very expensive. A potential alternative to using these protein sources is to increase the inclusion rates of synthetic amino acids. Traditionally, the inclusion rate of synthetic lysine (L-lysine-HCl) has been limited to 0.15% of a corn-soy diet because methionine or threonine would become limiting. More recent research suggests that L-lysine-HCl can be included in Phase 3 nursery diets at much higher levels (0.45%), provided other synthetic amino acids are also supplemented to maintain the pig's minimum requirements (Kendall et al., 2008). Synthetic lysine, methionine, and threonine are currently used in swine rations to reduce feed costs, however their aggressive use in Phase 1 and 2 weaning pig diets has not been thoroughly investigated.

Experimental Procedures

Animals and housing. A total of 200 pigs (Monsanto GPK35 × EBU; 21.7 d of age; initial BW = 16.4 lb) were used in the study. The pigs were fed 1 of 5 dietary treatment regimes from weaning to approximately 52 lb. The pigs were individually weighed, sorted, and assigned to treatment. Pigs remained in the same pens throughout the experiment. There were 7 total replications per treatment (5 replicates at 6 pigs/pen and 2 replicates at 5 pigs/pen).

Diets and growth performance. The experiment consisted of 3 dietary phases: Phase 1 = 4 d, Phase 2 = 15 d, and Phase 3 = 15 d. Experimental diets for the study are presented in Tables 1 and 2. DL-methinoine, L-threonine, and L-valine were used in the formulations to maintain ideal ratios of methionine + cystine, threonine, and valine at minimums of 0.58, 0.60, and 0.65 to lysine, respectively. Pigs were fed a common corn-soy diet supplemented with 0.333% L-lysine, 0.154% DL-methionine, and 0.100% L-threonine in Phase 3 (1.47% total lysine). None of the diets were supplemented with L-tryptophan. All diets were formulated to meet or exceed nutrient requirements (NRC, 1998). Individual pig weights and pen feed intake were collected in order to calculate ADG, ADFI, and F/G by phase.

Statistical analysis. The data were analysed using the PROC GLM procedures of SAS (SAS Institute, Inc., Cary, N.C.) for a randomized block design. Fixed effect was treatment. Linear and quadratic contrasts comparing the different levels of fishmeal replacement were also analyzed.

Results and Discussion

There were no differences in growth performance in pigs fed decreasing levels of fishmeal during Phase 1 (Table 3). There was a linear increase in F/G ($P < 0.01$) as FM was replaced with AA in the diet during Phase 2. In addition, F/G increased linearly ($P < 0.01$) as FM was replaced with AA during Phases 1 and 2 combined. Although, F/G increased during Phase 2, this did not affect ADG or ADFI during this phase. Final BW was not different as FM was replaced with AA ($P = 0.27$).

Synthetic amino acids, specifically L-lysine, DL-methionine, L-threonine, and L-valine, were added to these nursery diets as FM was removed to maintain the minimum levels of these essential amino acids. The increase in F/G as FM was replaced with AA during Phase 2, suggesting that an amino acid (i.e. tryptophan or isoleucine) or other nutrient, was limiting. However, there were no effects on ADG or ADFI during Phase 2, nor were there any differences in overall ADG, ADFI, F/G, or BW at the conclusion of the study.

[1] Department of Animal Science, Fayetteville
[2] Ajinomoto Heartland LLC, Chicago, Ill.

Implications

Although it is not currently economically feasible to add L-valine to commercial swine feed, the use of L-lysine, DL-methionine, and L-threonine in nursery diets has become standard industry practice. This research demonstrates that fishmeal can be replaced with synthetic amino acids in early nursery diets without jeopardizing overall growth performance.

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Table 1. Composition of Phase 1 diets (as-fed).

	Fish Meal				
Ingredients, %	8%	6%	4%	2%	0%
Corn	34.87	36.26	37.62	38.97	40.31
Soybean meal - 48% CP	18.00	18.00	18.00	18.00	18.00
Fat (yellow grease)	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	0.000	0.319	0.639	0.958	1.278
Limestone	0.374	0.446	0.517	0.589	0.661
Salt	0.300	0.300	0.300	0.300	0.300
L-Lysine	0.075	0.193	0.310	0.426	0.544
DL-Methionine	0.103	0.151	0.200	0.248	0.296
L-Threonine	0.000	0.048	0.093	0.135	0.180
L-Valine	0.000	0.000	0.040	0.095	0.150
Whey	30.0	30.0	30.0	30.0	30.0
Spray dried plasma	3.50	3.50	3.50	3.50	3.50
Menhaden fish meal	**8.00**	**6.00**	**4.00**	**2.00**	**0.00**
Zinc oxide	0.300	0.300	0.300	0.300	0.300
Copper sulfate	0.050	0.050	0.050	0.050	0.050
Vitamin premix [a]	0.250	0.250	0.250	0.250	0.250
Trace mineral premix [b]	0.150	0.150	0.150	0.150	0.150
Ethoxyquin	0.030	0.030	0.030	0.030	0.030
Neo-terramycin 10/5	1.000	1.000	1.000	1.000	1.000
Calculated composition					
NRC ME, Mcal/lb	1.550	1.546	1.541	1.537	1.533
CP, %	23.07	22.08	21.11	20.14	19.18
Total lysine, %	1.601	1.598	1.594	1.589	1.585
TID[c] lysine, %	1.434	1.434	1.434	1.434	1.434
Total methionine. + cystine, %	0.953	0.950	0.947	0.942	0.939
TID methionine + cystine, %	0.834	0.834	0.835	0.834	0.834
Total threonine, %	1.034	1.031	1.025	1.017	1.011
TID threonine, %	0.863	0.865	0.865	0.863	0.863
Total tryptophan, %	0.281	0.272	0.263	0.253	0.244
TID tryptophan, %	0.237	0.229	0.221	0.212	0.204
Total isoleucine, %	0.990	0.940	0.890	0.839	0.789
TID isoleucine, %	0.870	0.822	0.775	0.727	0.680
Total valine, %	1.166	1.108	1.089	1.085	1.081
TID valine, %	1.005	0.950	0.935	0.935	0.934
Total P, %	0.724	0.727	0.730	0.732	0.735
Available P, %	0.524	0.524	0.524	0.524	0.524
Ca, %	0.875	0.875	0.875	0.875	0.875
Na, %	0.576	0.562	0.548	0.534	0.521
Lactose, %	20.1	20.1	20.1	20.1	20.1

[a] Supplied 5,000 IU vitamin A, 750 IU vitamin D_3 as D-activated animal sterol, 20 IU vitamin E, 2.0 mg vitamin K as menadione sodium bisulfite complex, 15 mg pantothenic acid as D-calcium pantothenate, 25 mg niacin, 4.5 mg riboflavin, and 20 µg vitamin B_{12} per lb of feed.
[b] Supplied 0.14 mg Se as sodium selenite, 18.1 mg Mn as manganous oxide, 75 mg Zn as zinc oxide, 75 mg Fe as ferrous sulfate, 7.7 mg Cu as copper sulfate, and 0.14 mg of I as calcium iodate per lb of feed.
[c] TID = true ileal digestible.

Table 2. Composition of Phase 2 diets (as-fed).

	Fish Meal				
Ingredients, %	6%	4.5%	3%	1.5%	0%
Corn	47.94	48.95	49.96	50.96	51.97
Soybean meal - 48% CP	27.00	27.00	27.00	27.00	27.00
Fat (yellow grease)	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	0.470	0.713	0.950	1.190	1.430
Limestone	0.389	0.443	0.498	0.550	0.605
Salt	0.400	0.400	0.400	0.400	0.400
L-Lysine	0.275	0.364	0.452	0.540	0.627
DL-Methionine	0.138	0.175	0.213	0.250	0.288
L-Threonine	0.105	0.140	0.175	0.210	0.243
L-Valine	0.000	0.033	0.075	0.116	0.158
Whey	7.50	7.50	7.50	7.50	7.50
Lactose	5.00	5.00	5.00	5.00	5.00
Menhaden fish meal	**6.00**	**4.50**	**3.00**	**1.50**	**0.00**
Zinc oxide	0.300	0.300	0.300	0.300	0.300
Copper sulfate	0.050	0.050	0.050	0.050	0.050
Vitamin premix [a]	0.250	0.250	0.250	0.250	0.250
Trace mineral premix [b]	0.150	0.150	0.150	0.150	0.150
Ethoxyquin	0.030	0.030	0.030	0.030	0.030
Neo-terramycin 10/5	1.000	1.000	1.000	1.000	1.000
Calculated composition					
NRC ME, Mcal/lb	1.558	1.554	1.551	1.548	1.544
CP, %	21.99	21.27	20.55	19.83	19.11
Total lysine, %	1.524	1.522	1.519	1.516	1.512
TID [c] lysine, %	1.392	1.392	1.392	1.392	1.392
Total methionine. + cystine, %	0.888	0.887	0.885	0.884	0.882
TID methionine + cystine, %	0.808	0.809	0.810	0.812	0.813
Total threonine, %	0.958	0.955	0.952	0.949	0.943
TID threonine, %	0.837	0.838	0.840	0.841	0.840
Total tryptophan, %	0.248	0.241	0.234	0.227	0.220
TID tryptophan, %	0.220	0.214	0.207	0.201	0.195
Total isoleucine, %	0.926	0.888	0.851	0.813	0.775
TID isoleucine, %	0.827	0.791	0.755	0.720	0.684
Total valine, %	1.037	1.025	1.023	1.020	1.017
TID valine, %	0.915	0.906	0.907	0.907	0.907
Total P, %	0.642	0.645	0.646	0.648	0.650
Available P, %	0.367	0.367	0.367	0.367	0.367
Ca, %	0.745	0.745	0.745	0.745	0.745
Na, %	0.289	0.278	0.268	0.258	0.247
Lactose, %	9.98	9.98	9.98	9.98	9.98

[a] Supplied 5,000 IU vitamin A, 750 IU vitamin D_3 as D-activated animal sterol, 20 IU vitamin E, 2.0 mg vitamin K as menadione sodium bisulfite complex, 15 mg pantothenic acid as D-calcium pantothenate, 25 mg niacin, 4.5 mg riboflavin, and 20 µg vitamin B_{12} per lb of feed.
[b] Supplied 0.14 mg Se as sodium selenite, 18.1 mg Mn as manganous oxide, 75 mg Zn as zinc oxide, 75 mg Fe as ferrous sulfate, 7.7 mg Cu as copper sulfate, and 0.14 mg of I as calcium iodate per lb of feed.
[c] TID = true ileal digestible.

Table 3. Growth performance of nursery pigs fed diet with decreasing levels of fish meal[1].

	Fish meal						
Phase 1	8%	6%	4%	2%	0%		
Phase 2	6%	4.5%	3%	1.5%	0%	SE	*P*-value
ADG, lb							
Phase 1	0.31	0.35	0.41	0.37	0.39	0.05	0.56
Phase 2	0.76	0.81	0.74	0.74	0.71	0.03	0.25
Phase 1 to 2	0.67	0.71	0.67	0.66	0.64	0.02	0.33
Phase 3	1.55	1.55	1.46	1.51	1.54	0.03	0.18
Phase 1 to 3	1.06	1.08	1.01	1.03	1.03	0.02	0.12
ADFI, lb							
Phase 1	0.41	0.41	0.47	0.47	0.45	0.03	0.55
Phase 2	0.99	0.99	1.03	1.00	1.01	0.04	0.96
Phase 1 to 2	0.87	0.87	0.91	0.89	0.89	0.03	0.86
Phase 3	2.35	2.32	2.28	2.28	2.29	0.06	0.85
Phase 1 to 3	1.52	1.50	1.51	1.50	1.49	0.03	0.96
Feed:gain							
Phase 1	1.88	1.30	1.23	1.90	2.11	0.49	0.64
Phase 2[a]	1.30	1.26	1.40	1.37	1.44	0.03	0.01
Phase 1 to 2[a]	1.30	1.25	1.35	1.36	1.40	0.03	0.01
Phase 3	1.51	1.50	1.60	1.51	1.48	0.04	0.24
Phase 1 to 3	1.44	1.41	1.50	1.45	1.45	0.03	0.24
Weight, lb							
Initial	16.4	16.4	16.4	16.4	16.4	0.01	0.88
Phase 1	17.6	17.8	18.0	17.9	17.9	0.20	0.57
Phase 2	29.1	29.9	29.1	28.9	28.5	0.46	0.36
Phase 3	52.4	53.1	50.9	51.6	52.1	0.71	0.27

[1] Phase 1 = 4 d, Phase 2 = 15 d, and Phase 3 = 15 d. Phase 1 diets contained 20% lactose and Phase 2 diets contained 10% lactose. All pigs were given a common Phase 3 diet. Data represent 7 replicates per treatment with 5 to 6 pigs/pen.

[a] Linear increase in F/G as fish meal was replaced with synthetic amino acids ($P < 0.01$).

Estimates of Heritability for Lifetime Productivity Traits and Longevity in Four Breeds of Swine

Z.B. Johnson[1] and R.A. Nugent, II[2]

Story in Brief

The objective of this study was to estimate heritability of lifetime productivity traits and a measure of longevity in 4 breeds of swine. Records were collected in a commercial swine operation from 1992 to 1999. For each litter, number of live born pigs and weight of litter at weaning were recorded. Number of litters (NL), mean number born alive (MBA), mean litter weaning weight (MWWL), total number born alive (TBA), and total litter weaning weight (TWWL) were calculated for each sow. Length of productive life (LPL) or longevity was measured as age of the sow at the birth of her last litter. Estimates of heritability were obtained for each of these traits for each breed. Heritability of NL ranged from 0.00 in Hampshire to 0.17 in Landrace. Estimates of heritability were 0.02, 0.13, 0.16 and 0.18 for MBA, and 0.19, 0.13, 0.25, and 0.03 for TBA for Landrace, Yorkshire, Duroc and Hampshire, respectively. For MWWL, estimates of heritability were moderate ranging from 0.18 for Yorkshire to 0.43 for Hampshire; while estimates of heritability for TWWL were smaller ranging from 0.08 for Hampshire to 0.29 for Duroc. Estimates of heritability of LPL ranged from 0.11 for Yorkshire to 0.19 for Duroc and Landrace. These estimates of heritability indicate that enough genetic variation does exist in these traits for selection to be effective.

Introduction

Prolificacy traits and longevity play an important role in efficient pig production (Serenius and Stalder, 2004); that is, the longer a sow remains in the herd, the more piglets she is likely to produce in her lifetime. Improving sow longevity would improve a pork producer's profitability by reducing replacement gilt expenses and associated development, isolation, and acclimation costs (Stalder et. al., 2004). Estimates of heritability are necessary if breeding values are to be estimated for these traits. The objective of this study was to obtain estimates of heritability for lifetime productivity traits of number of litters born; average and total number of live pigs born; average and total weaning weight of litter; and age at birth of last litter as a measure of longevity.

Experimental Procedures

Data for this study consisted of records of Landrace, Yorkshire, Duroc, and Hampshire sows collected in a commercial swine operation (The Pork Group, A Division of Tyson Foods, Inc., Rogers, Ark.) from 1992 to 1999. Management of gilts in each breed through performance test is described in Johnson and Nugent (2004).

Gilts were ranked on an overall index at the end of the test. Those ranking highest were examined for acceptable phenotype (leg structure, vulva, etc.) and then retained for great-grandparent replacements if of acceptable phenotype; the next tier was used for grandparent replacements. Approximately 16 % of the gilts were retained and bred to produce first parity litters. Gilts entered the breeding unit at 205 days of age, and received twice daily boar exposure. Any gilt not bred by day 250 was culled. Gilts were normally bred on their first heat after entering the barn. Beginning in 1997 gilts were given boar exposure prior to entering the breeding unit; before that time, they were not. Litter size, measured as number of pigs born alive, and total weaning weight of the litter (at an average of approximately 17 days of age) were recorded. Number of litters (NL), mean number born alive (MBA), mean litter weaning weight (MWWL), total number born alive (TBA), and total litter weaning weight (TWWL) were obtained for each sow. Litter weaning weight was adjusted to 17 d of age by linear regression before summing over all litters. Age at birth of the last recorded litter of each sow was calculated and used as a measure of longevity or length of productive life (LPL) of the sow. Data were somewhat truncated in that some sows were still producing litters when the study ended; however, all sows had the opportunity to produce at least 3 litters.

Contemporary group (CG) of the dam was defined as all females in the same house and started on test within a 6-mo period. Number of CG, along with number of sires, and range in number of observations for CG and sire, is shown in Table 1. For each breed, heritabilities were estimated for each lifetime productivity trait and longevity using an animal model and DFREML procedures (MTDFREML; Boldman et al., 1993). Contemporary group was included as a fixed effect. Number of individuals in the pedigree matrix (A^{-1}) was 761 for Landrace, 2,345 for Yorkshire, 727 for Duroc and 427 for Hampshire (Table 1).

Results and Discussion

Some description of the datasets is given in Table 1. Number of contemporary groups ranged from 16 in Hampshire to 29 in Yorkshire. Number of observations for each contemporary group ranged from 10 to 57 for Landrace, from 5 to 125 for Yorkshire, from 13 to 55 for Duroc, and from 11 to 40 for Hampshire. Number of sires ranged from 48 for Hampshire to 239 for Yorkshire.

[1] Department of Animal Science, Fayetteville
[2] The Pork Group, Tyson Foods, Inc., Springdale, Ark.

Number of observations for each sire ranged from 1 to 39 for Landrace, from 1 to 57 for Yorkshire, from 1 to 22 for Duroc, and from 1 to 22 for Hampshire.

Means and standard deviations for lifetime productivity traits and LPL are given in Table 2. Lifetime productivity traits were measured on 578 Landrace, 1,806 Yorkshire, 524 Duroc, and 332 Hampshire sows. Average number of litters per sow ranged from 2.19 in Yorkshire to 2.83 in Duroc. In a review article, Stadler et al. (2004) reported an average parity at culling of 3.2 to 5.8. Gou et al. (2001) reported an average sow herd life of 1.8 parities with 17 pigs produced during their productive life in a population of Landrace pigs. Rodriguez-Zas et al. (2006) reported that in US breeding herds, sows are culled on average near an optimal parity of 4. Total number born alive ranged from 20 in Landrace to 25 in Duroc. Serenius and Stalder (2004) reported TBA of 32.0 and 32.8 for Landrace and Large White populations, respectively.

Age at birth of last litter ranged from 656 d for Landrace to 746 d in Hampshire. Yazdi et al. (1999) reported an average length of productive life of 617 d in Swedish Landrace sows, which corresponds to an age of 2 yr and 8 mo at culling.

Estimates of heritability for lifetime productivity traits and LPL are shown in Table 3. Heritability of NL ranged from zero in Hampshire to 0.23 ± 0.09 in Duroc. Heritability of MBA ranged from near zero (0.02 ± 0.06) in Landrace to 0.18 ± 0.12 in Hampshire. Heritability of TBA ranged from near zero (0.03 ± 0.09) in Hampshire to 0.25 ± 0.09 in Duroc. Estimates of heritability of MWWL were moderate ranging from 0.18 ± 0.05 for Yorkshire to 0.43 ± 0.12 for Hampshire. Estimates for TWWL were slightly lower for Landrace, Yorkshire, and Duroc and not different from zero for Hampshire (0.08 ± 0.10). Estimates of heritability for age at birth of last litter were between 10 and 20 %, ranging from 0.11 ± 0.04 for Yorkshire to 0.19 ± 0.08 for Landrace and 0.19 ± 0.10 for Duroc. Stadler et al. (2004) reported estimates of heritability of LPL, defined as number of days from first service until culling, as 0.16 in Yorkshire and 0.13 in Landrace populations. Gou et al. (2001) reported a heritability of 0.25 for length of productive life in Landrace sows. Yazdi et al. (1999) reported estimates of heritabilities of longevity in Swedish Landrace sows ranging from 0.05 to 0.27, depending on the model used. Serenius and Stadler (2004) reported estimates of heritability of LPL of 0.16 and 0.17 for Landrace and 0.17 and 0.19 for Large White populations using a survival analysis, but lower estimates of 0.05 and 0.10, respectively, using a linear model.

Implications

Estimates of heritability of lifetime productivity traits (number of litters, mean number born alive, total number born alive, mean litter weight at weaning, total weaning weight at litter and age at birth of last litter) indicate that enough genetic variation does exist in these traits for selection to be effective.

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Table 1. Description of data sets used for estimation of heritabilities of lifetime productivity traits for four breeds of swine.

	Breed			
Item	Landrace	Yorkshire	Duroc	Hampshire
No. of contemporary groups	18	29	18	16
No. of observations /contemporary group	10 to 57	5 to 125	13 to 55	9 to 40
No. of sires	85	239	97	48
No. of observations/sire	1 to 39	1 to 57	1 to 22	1 to 22
No. of animals in pedigree (A^{-1}) matrix	761	2,345	727	427

Table 2. Means and standard deviations for lifetime productivity traits of sows in four breeds of swine.

Trait	N	Mean	SD
Landrace			
Number of litters	578	2.33	1.40
Mean number born alive	578	8.30	2.14
Mean litter weaning wt, lb	549	111.69	24.67
Total number born alive	578	19.67	13.22
Total litter weaning wt, lb	549	262.74	172.30
Age at birth of last litter, d	578	656.28	289.53
Yorkshire			
Number of litters	1,806	2.19	1.40
Mean number born alive	1,805	9.51	2.38
Mean litter weaning wt, lb	1,736	105.96	26.57
Total number born alive	1,805	21.48	15.60
Total litter weaning wt, lb	1,736	236.40	165.30
Age at birth of last litter, d	1,803	662.08	310.59
Duroc			
Number of litters	524	2.83	1.81
Mean number born alive	524	8.63	2.10
Mean litter weaning wt, lb	493	76.99	20.81
Total number born alive	524	25.32	18.31
Total litter weaning wt, lb	493	223.82	158.23
Age at birth of last litter, d	524	680.96	316.09
Hampshire			
Number of litters	332	2.75	1.72
Mean number born alive	332	8.29	2.10
Mean litter weaning wt, lb	314	88.64	24.73
Total number born alive	332	23.31	16.09
Total litter weaning wt, lb	314	239.82	164.28
Age at birth of last litter, d	323	745.73	353.44

Table 3. Estimates of heritability (± SE) for lifetime productivity traits for Landrace, Yorkshire, Duroc and Hampshire breeds of swine.

	Breed			
Trait	Landrace	Yorkshire	Duroc	Hampshire
Number of litters (NL)	0.17 ± 0.07	0.09 ± 0.04	0.23 ± 0.09	0.00 ± 0.09
Mean number born alive (MBA)	0.02 ± 0.06	0.13 ± 0.04	0.16 ± 0.09	0.18 ± 0.12
Mean litter weaning wt (MWWL)	0.22 ± 0.08	0.18 ± 0.05	0.32 ± 0.10	0.43 ± 0.12
Total number born alive (TBA)	0.19 ± 0.07	0.13 ± 0.04	0.25 ± 0.09	0.03 ± 0.09
Total litter weaning wt (TWWL)	0.17 ± 0.08	0.10 ± 0.04	0.29 ± 0.10	0.08 ± 0.10
Age at birth of last litter (LPL)	0.19 ± 0.08	0.11 ± 0.04	0.19 ± 0.10	0.15 ± 0.07

Relationships Between Performance Test Traits and Lifetime Productivity Traits in Four Breeds of Swine

Z.B. Johnson[1] and R.A. Nugent, III[2]

Story in Brief

The objective of this study was to examine relationships between performance test traits and subsequent measures of lifetime performance of sows in 4 breeds of swine. Performance test records were collected in a commercial swine operation from 1992 to 1999. All females were grown to 100 d of age. At this time pigs were weighed and selected for performance testing based on a combination of maternal and performance indexes which were different for each breed. Pigs were weighed at the end of the 77-d performance test and ADG calculated. Backfat, loin eye area, and body length were measured. Total number of litters produced, total number of live born pigs, and total litter weight at weaning for each sow were recorded. Number born alive, weaning weight of litter, and age of sow at first farrowing were also recorded. Age at birth of last litter as a measure of longevity or length of productive life was recorded. Canonical correlation procedures were used to examine relationships between performance test traits and lifetime productivity traits. Also examined were relationships between sow traits for first litter and lifetime productivity traits. Relationships between performance test data and subsequent lifetime productivity traits were non-significant or low for these populations of Landrace, Yorkshire, and Duroc sows, although a significant relationship was found for Hampshire sows. Canonical correlations indicated that productivity traits at first farrowing were related ($P < 0.01$) to lifetime productivity traits in all breeds, indicating that performance at the first farrowing may be a good indicator of lifetime performance.

Introduction

Lifetime production (number of litters, number born, and number weaned, as well as longevity) is an important economic component of sow productivity. It is important to know how selection for other traits may affect these traits. The objectives of this study was to examine relationships between performance test traits and lifetime productivity traits in Landrace, Yorkshire, Duroc, and Hampshire breeds of swine and to examine relationships between sow traits (number born alive, litter weight at weaning, and age at birth of first litter) recorded for her first farrowing and lifetime productivity traits in these breeds.

Experimental Procedures

Data for this study consisted of performance test records of Landrace, Yorkshire, Duroc, and Hampshire pigs collected in a commercial swine operation (The Pork Group, A Division of Tyson Foods, Inc., Rogers, Ark.) from 1992 to 1999. All females were grown to 100 d of age and weighed (WT100). Fifty to sixty percent were selected for performance testing based on a combination of maternal and performance indexes which were different for each breed. Two indexes (breeding values) for each animal were calculated. One was a maternal index based on number born alive, farrowing interval, and litter weaning weight. The other was based on growth rate, leanness, and feed efficiency (Grow-Fin). The maternal index was computed using a three-trait model that included terms for the additive genetic effect, litter effects, and maternal genetic effects along with appropriate fixed effects. The Grow-Fin index was computed using a model that included only additive genetic effects and appropriate fixed effects. These two indexes were combined into an overall ranking depending on the breed. For Landrace equal emphasis was given to both indexes; for Yorkshire more emphasis was given to the maternal index; for Duroc more emphasis was given to the Grow-Fin index; and for Hampshire the emphasis was totally on the Grow-Fin index.

Gilts were fed for ad libitum consumption a pelleted corn-soybean meal diet that was formulated to contain 1.14% lysine, 19% protein, and 3,344 mcal/kg ME, with each pig having an area of 1.2 m^2. Exact composition of the diet varied due to ingredient cost. Different size pens were available in different facilities, so pens in some barns held 8 pigs and in other barns 10 pigs. All pigs had ad libitum access to water. Barns were curtain-sided buildings that were tunnel ventilated in the winter. All pigs were weighed at the end of the 77-day performance test (WT177) and ADG was calculated. Backfat (BF), and loin eye area (LEA) were measured at approximately the 12^{th} rib using B-mode ultrasound equipment, and body length (LEN) was measured from the top of the tail to the point of the shoulder when the head is down.

Gilts were ranked on an overall index at the end of the test. Those ranking highest were examined for acceptable phenotype (leg structure, vulva, etc.) and then retained for great-grandparent replacements if of acceptable phenotype; the next tier was used for grandparent replacements. Approximately 16% of the gilts were retained and bred to produce first-parity litters. Gilts entered the breeding unit at 205 d of age, and received twice daily boar exposure. Any gilt not bred by d 250 was culled. Gilts were normally bred on their first heat after entering the barn. Beginning around 1997, gilts were given boar exposure prior to entering the breeding unit; before that time, they were not. Litter size, measured as number of pigs born alive (NBA1), total weaning weight of the litter (at an average of approximately 17 d of age, WWL1), and age at far-

[1] Department of Animal Science, Fayetteville
[2] The Pork Group, Tyson Foods, Inc., Springdale, Ark.

rowing (Age1) were recorded for the first farrowing of each sow. Total number of litters produced (NL), total number born alive (TBA), total litter weaning weight (TWWL), and age at farrowing of last litter as a measure of longevity or length of productive life (LPL) were obtained for each sow. Data were somewhat truncated in that some sows were still producing litters when the study ended; however, all sows had the opportunity to produce at least 3 litters.

Before analysis, WT100 was adjusted to 100 d of age; WT177, LEN, LEA, and BF were adjusted to 177 d of age; and weaning weight of litter was adjusted to 17 d by linear regression for each breed. Canonical correlation analyses of SAS (SAS Institute, Inc., Cary, N.C.) were used to examine relationships between performance test traits and lifetime productivity traits (Analysis I) for each breed. Also examined were relationships between traits measured at first farrowing and lifetime productivity traits (Analysis II). The objective of a canonical correlation analysis is to generate a linear combination of one set of traits that has maximum correlation with a second set of traits. Canonical variate scores can be generated from these linear combinations, and the canonical correlation coefficient is the correlation between these scores. Second linear combinations, independent of the first, and, therefore, a second canonical correlation are also generated. The number of these linear combinations and canonical correlations that can be generated is equal to the number of traits in the set with the fewest number of traits. Canonical correlation coefficients and correlations of the canonical variates with the original measured variables are presented. Number of observations for this study was 578 for Landrace, 1,806 for Yorkshire, 524 for Duroc, and 332 for Hampshire.

Results and Discussion

Means and estimates of heritability for the various traits have been previously reported for these populations of swine (Johnson and Nugent, 2004, 2008; Johnson et al., 2005). There were no significant canonical correlations ($P > 0.05$) for the Landrace or Duroc breeds (Table 1), and only one significant correlation (0.43; $P < 0.01$) for Hampshire (Table 1) for Analysis I. Correlations with the original measured variables indicated that sows with high values for canonical variate 1 had lower weights at both 100 and 177 d, but were longer and had larger LEA and greater BF, as well as being younger at birth of their last litter (i.e., did not stay in the herd as long). Correlations with NL, TBA, and TWWL were positive but low. All 4 canonical correlations for Yorkshire were significant ($P < 0.05$), even though they were low (≤0.15). Correlations of the original variables with canonical variate 1 indicated that Yorkshire sows with a high canonical variate 1 score were lighter at 177 d with smaller LEA, but longer with more BF and had a greater NL, TBA, TWWL, and LPL (Table 1). Correlations of the original variables with canonical variate 2 (data not shown) indicated that Yorkshire sows with a high canonical variate 2 score were heavier at 100 d, but lighter at 177 d, and were shorter with less BF than sows with a low canonical variate 2 score. These sows also had a greater NL, TBA, TWWL, and LPL.

All 3 canonical correlations from Analysis II were significant (0.54, 0.42, and 0.17; $P < 0.01$) for Landrace sows (Table 2). Correlations with canonical variate 1 indicated that sows with high values for canonical variate score 1 had larger first litters (NBA1 and WWL1) and higher lifetime values for these traits (TBA and TWWL). Correlations with canonical variate 2 indicated that sows with high values for this variate were younger and had higher weaning weights of their first litter than sows with low values for this variate. They also had higher lifetime weaning weights of their litters, but were younger at the birth of their last litter (r = -0.24). Correlations with canonical variate 3 indicated that sows with high values for this variate were older at the birth of their first litter and also older at the birth of their last litter. All other correlations with this variate were positive and moderate, indicating that sows with high values for this variate had a larger NBA1 and WWL1, as well as more NL and higher TBA and TWWL.

All 3 canonical correlations from Analysis II were significant (0.47, 0.43, and 0.13; $P < 0.01$) for Yorkshire sows also (Table 3). Correlations with canonical variate 1 indicated that sows with high values for canonical variate score 1 had larger NBA1 and higher TBA. Correlations with canonical variate 2 indicated that sows with high values for this variate had larger first litters that weighed more (r = 0.98), as well as larger TWWL (r = 0.41). Correlations with canonical variate score 3 indicated that sows that were older at birth of their first litter had fewer litters, fewer total number born alive and, therefore, less total weight of litters weaned as indicated by negative correlations for these traits.

For Duroc sows, only 2 canonical correlations were significant (0.46 and 0.35; $P < 0.01$) in Analysis II (Table 4). Correlations of the original measured variables with canonical variate 1 indicated that sows with high values for this variate had high weaning weights for their first litter (r = 0.79), as well as for total weaning weight of all litters produced (r = 0.44). Correlations of the original measured variables with canonical variate 2 indicated that sows with high values for variate 2 had larger litter sizes at first farrowing with larger weaning weights for the litter and a larger number of litters during their lifetime, with more total pigs produced and heavier total weaning weights.

For Hampshire sows, all 3 canonical correlations were significant (0.65, 0.58, and 0.45; $P < 0.01$) for Analysis II (Table 5). Correlations of variate 1 with the original measured variables indicated that sows with high values for this variate had a larger number born alive, higher weaning weight of litter, and were older at birth of the first litter. Correlations with the lifetime productivity traits were low and/or negative. Correlations of variate 2 with the original measured variables indicated that sows with high values for this variate had a heavier weaning weight of first litter (r = 0.86) and heavier total weaning weight (r = 0.37) of all litters produced. Correlations of the original measured variables with variate 3 indicated that sows with high values for this variate were older at birth of their first litter (r = 0.80), had smaller litter sizes (r = -0.48), a smaller number of litters during their lifetime, and fewer TBA (r = -0.47) as well as lower TWWL (r = -0.38).

In conclusion, relationships between performance test data and subsequent lifetime productivity traits were non-significant, or low, for these populations of Landrace, Yorkshire, and Duroc sows; although a significant relationship was found for Hampshire sows. Yet, productivity traits at first farrowing were related to lifetime productivity traits in all breeds, indicating that performance at the first farrowing may be a good indicator of lifetime performance. In a review article, Stalder et al. (2004) reported that for compositional traits, like growth, backfat, and loin muscle size (measured at or near selection), it appears that several may have some minimum and/or some maximum value that is necessary to maximize lifetime reproductive performance whether measured as a longevity trait or a lifetime production trait.

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Table 1. Results of canonical correlation analyses I – correlations between canonical variates and original measured variables for canonical variate 1.

	Breed			
Traits	Landrace	Yorkshire[a]	Duroc	Hampshire
Set one				
WT100[b]	-0.43	-0.11	-0.85	-0.54
WT177	-0.86	-0.40	-0.65	-0.50
Body length	-0.28	0.47	0.14	0.40
Loin eye area	0.02	-0.36	0.10	0.39
Backfat thickness	0.07	0.42	-0.42	0.21
Set two				
Number of litters	0.65	0.67	0.39	0.16
Total number born alive	0.36	0.75	0.48	0.11
Total wt of litters weaned	0.59	0.81	0.55	0.15
Age of sow at birth of last litter	0.50	0.28	0.00	-0.47
Canonical correlation	0.21+	0.15**	0.19	0.43**

[a]For Yorkshire, second, third, and fourth canonical correlations were 0.12 ($P < 0.01$), 0.07 ($P < 0.05$), and 0.07 ($P < 0.05$), respectively.
[b]WT100 and WT177 are weights of sows at 100 and 177 days of age, respectively.
** $P < 0.01$.
+ $P = 0.09$.

Table 2. Results of canonical correlation analysis II for Landrace sows – correlations between canonical variates and original measuredvariables for three canonical variates.

	Canonical variate		
Traits	1	2	3
Set one			
Number born alive in 1st litter	0.96	-0.14	0.24
Weaning wt of 1st litter	0.42	0.82	0.39
Age of sow at birth of 1st litter	-0.16	-0.21	0.96
Set two			
Number of litters	0.18	-0.07	0.32
Total number born alive	0.51	-0.07	0.34
Total weight of litters weaned	0.31	0.23	0.40
Age of sow at birth of last litter	0.03	-0.24	0.75
Canonical correlation	0.54 **	0.42**	0.17**

** $P < 0.01$.

Table 3. Results of canonical correlation analysis II for Yorkshire sows – correlations between canonical variates and original measured variables for three canonical variates.

	Canonical variate		
Traits	1	2	3
Set one			
Number born alive in 1st litter	0.88	0.47	0.05
Weaning wt of 1st litter	-0.19	0.98	-0.05
Age of sow at birth of 1st litter	-0.02	0.22	0.98
Set two			
Number of litters	0.19	0.07	-0.42
Total number born alive	0.45	0.18	-0.33
Total weight of litters weaned	0.10	0.41	-0.35
Age of sow at birth of last litter	0.09	0.06	0.25
Canonical correlation	0.47**	0.43**	0.13**

** $P < 0.01$.

Table 4. Results of canonical correlation analysis II for Duroc sows – correlations between canonical variates and original measured variables for three canonical variates.

	Canonical variate		
Traits	1	2	3
Set one			
Number born alive in 1st litter	-0.29	0.96	-0.01
Weaning wt of 1st litter	0.79	0.61	0.03
Age of sow at birth of 1st litter	-0.04	0.02	0.99
Set two			
Number of litters	0.10	0.30	0.45
Total number born alive	0.04	0.55	0.41
Total weight of litters weaned	0.44	0.45	0.32
Age of sow at birth of last litter	0.18	0.26	0.79
Canonical correlation	0.46**	0.35**	0.07 ($P = 0.35$)

** $P < 0.01$.

Table 5. Results of canonical correlation analysis for Hampshire sows – correlations between canonical variates and original measured variablesfor three canonical variates.

	Canonical variate		
Traits	1	2	3
Set one			
Number born alive in 1st litter	0.85	-0.21	-0.48
Weaning wt of 1st litter	0.49	0.86	-0.14
Age of sow at birth of 1st litter	0.59	-0.10	0.80
Set two			
Number of litters	-0.10	-0.02	-0.35
Total number born alive	0.18	-0.08	-0.47
Total weight of litters weaned	0.15	0.37	-0.38
Age of sow at birth of last litter	0.05	-0.03	-0.06
Canonical correlation	0.65**	0.58**	0.45**

** $P < 0.01$.

Effects of a Single Nucleotide Polymorphism in the Interleukin-8 Receptor on Susceptibility of Dairy Cattle to Mastitis

R.W. Rorie and M.D. Person[1]

Story in Brief

Mastitis costs about 2 billion dollars annually in the U.S., due to milk loss, increased culling, veterinary services, and treatment. There are genetic differences among cows in their susceptibility to mastitis, suggesting that marker-assisted selection might be effective in reducing the incidence of mastitis. The present study was conducted to investigate the effect of a polymorphism in the interleukin-8 (IL-8) receptor on mastitis susceptibility, milk yield, and quality. Blood samples were collected from 75 Holstein cows, DNA was recovered, and polymerase chain reaction procedures were used to amplify a 311 base pair segment of the IL-8 receptor, followed by digestion with a restriction enzyme and electrophoresis. Three IL-8 receptor genotypes (GG, GC and CC) were identified. Cows with the GG or GC genotypes for the IL-8 receptor had lower mean somatic cell counts ($P = 0.01$) than cows with the CC genotype. Genotype had no effect on 305-day adjusted milk ($P = 0.40$), protein ($P = 0.57$), or fat ($P = 0.84$) production. Results suggest selection based on genotypes for the IL-8 receptor polymorphism would be effective in reducing the incidence of mastitis in dairy cattle.

Introduction

Mastitis is an inflammatory response of the mammary system to an infection, commonly caused by various strains of Staphylococcus and by E. coli. In response to this inflammation, neutrophils migrate to the mammary gland and become predominant. Interleukin-8 (IL-8) is a chemokine produced by a number of cell types, including mammary epithelial cells, that is critical in regulating the inflammatory response of neutrophils by inducing their migration to the site of infection and then, enhancing their killing ability (Barber and Yang, 1998).

There are genetic differences among cows in their susceptibility to mastitis. Considering the importance in the IL-8 in the immune response, it would be a good candidate for a gene marker to select cows that are less susceptible to mastitis infection. A single nucleotide polymorphism (SNP) has been reported in the IL-8 receptor (CXCR2) resulting in genotypes with increased or decreased susceptibility of Holstein and Jersey cows to mastitis (Youngerman et al., 2004b). Of the 3 genotypes associated with the IL-8 receptor, GG and CC are associated with low and high somatic cell counts, respectively, while GC is intermediate for somatic cell count. The present study was conducted to further investigate the effect of IL-8 genotypes on mastitis susceptibility, as well as, milk quantity and quality

Experimental Procedures

Blood samples were collected from 75 Holstein cows at a local dairy in which Dairy Herd Improvement (DHI) records were available for somatic cell count (SCC) and milk production. DNA was recovered from each blood sample, quantified and frozen at -20°C until use. The polymerase chain reaction-restriction length polymorphism (PCR-RFLP) procedures were based on those reported by Youngerman et al. (2004a). Forward (5'-CTTCCGTGAGGCCTATCAAC-3') and reverse (5'-AGGTCTCAGCAATCAC-ATGG-3') primers were used to amplify a 311 base pair segment of the bovine IL-8 receptor locus.

The reaction mixture consisted of 2 µl of 10x buffer, 1.5 mM MgCl2, 200 µM of each deoxynucleotide triphosphate (dNTP), 10 pmoles of each primer, 2 units of DNA polymerase and 50 ng of DNA in a total volume of 20 µl. Thermal cycler conditions were an initial DNA denaturing of 95°C for 2 min, followed by 35 cycles of denaturing at 95°C for 1 min, annealing at 55°C for 30 sec and extension at 68°C for 1 min. After the last thermal cycle, one-half (10 µl) of each product was placed in a separate pcr tube with 5 units of Bme1580I restriction endonuclease and digested at 37°C.

The digested and undigested product for each sample were loaded side-by-side into a 1.5% agarose gel, and DNA fragments in each sample separated by electrophoresis inTris (hydroyxmethyl) aminomethane - boric acid - EDTA (TBE buffer). The GG genotype was recognized by the presence of 19 and uncut 292 base pair (bp) DNA fragments. With the CC genotype, the restriction endonuclease recognizes a G to C polymorphism at position 777 of the IL-8 receptor locus, resulting in 19, 103, and 189 bp DNA fragments. The heterozygous (GC) genotype was recognized by the presence of all four (19, 103, 189, and 292 bp) DNA fragments. Cows were grouped by genotype, and analysis of variance was used to compare mean somatic cell count, 305-day milk, protein, and fat data obtained from monthly DHI records.

Results and Discussion

The frequency of GG, GC, and CC genotypes of the 75 Holstein cows evaluated in this study were 0.33, 0.47 and 0.20, respectively. The allele frequency was 0.57 and 0.43 for G and C, respectively. This allele frequency was the same as previously reported for Holstein cows (Youngerman et al., 2004a). In order to select for or against a polymorphism, it must occur at a high

[1] Department of Animal Science, Fayetteville

enough frequency in a given population. With over half of the Holstein cows in the current study having the G allele for this IL-8 receptor polymorphism, selection should be effective. The allele frequency appears to vary with breed of dairy cattle. Jerseys are reported to have an allele frequency of 0.87 and 0.13 for G and C, respectively (Youngerman et al., 2004a).

The inflammation caused by mastitis infection causes large numbers of leukocytes (somatic cells) to be shed into the udder to kill bacteria. Therefore, somatic cell counts are used as an indicator of the presence and severity of mastitis. A somatic count of 200,000 or greater is considered the threshold for mastitis infection. Cows with the GG or GC genotypes for the IL-8 receptor had lower mean somatic cell counts (P = 0.01) than cows with the CC genotype (Table 1). Genotype had no effect on 305-day adjusted milk (P = 0.40), protein (P = 0.57), or fat (P = 0.84) production.

According to the DHI Dairy Records Management System website (http://www.drms.org/dhia.htm), there is increasing milk loss during lactation with increasing somatic cell count. Cow with a somatic cell count between 284,000 and 565,000 (as is the case for the cows with the CC genotype in the present study) would be expected to produce about 1,200 pounds less milk during their lactation than cows with very low somatic cell counts. In the present study, cows with the CC genotype produced 1,234 pounds less milk that the average for cows with the GG and GC genotypes.

The National Mastitis Council (www.nmconline.org) estimates the annual cost in milk loss, increased culling, veterinary services, and treatment averages about $180 per cow per year, or about 2 billion dollars annually in the U.S. Antibiotic resistance of strains of bacteria responsible for most incidences of mastitis has increased for several years making treatment less effective (Rajala-Schultz et al., 2004). Results of the present study suggest selection based on genotypes for the IL-8 receptor polymorphism would be effective in reducing the incidence of mastitis in dairy cattle.

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Table 1. Effects of Interleukin-8 receptor polymorphism on somatic cell count, milk yield and quality.

IL-8 receptor genotype	No. of cows	Mean SCC (thousands)	305-d avg milk, lb	305-d avg milk protein, lb	305-d avg milk fat, lb
GG	25	81 ± 14[b]	27,427 ± 691	789 ± 22	1,007 ± 29
GC	35	114 ± 24[b]	26,328 ± 505	773 ± 15	995 ± 23
CC	15	374 ± 147[a]	25,643 ± 948	751 ± 22	983 ± 43

[a,b]Mean somatic cell count differed among genotypes (P = 0.01). Genotype had no effect on 305-day average milk (P = 0.40), protein (P = 0.57), or fat (P = 0.84) production.

DairyMetrics for Arkansas Herds in May, 2008

Jodie A. Pennington[1]

Story in Brief

DairyMetrics, a benchmarking tool from Dairy Records Management Systems (DRMS), was used to obtain the average and standard deviation of the dairy herd traits, minimum and maximum herd values for each trait, and number of herds in the comparison for Holstein herds and all dairy herds in Arkansas on the Dairy Herd Improvement (DHI) program. This year was unusual as rolling herd average for milk decreased 225 lb to 16,086 lb for all herds and 790 lb to 16,617 lb for Holstein herds in the last year. For Holstein herds, average fat was 3.4%, average protein was 3.1%, and herd size averaged 145.9 cows with 89.9% in milk on test day. Overall, 35% of cows left the Holstein herds; major reasons for leaving the herds were 7.4% due to death, 5.1% for reproduction, and 3.1% for mastitis. Actual calving interval for Holsteins was 14.6 months. Services per pregnancy averaged 2.8, and 27.9% of heats were reported as observed. Holstein herd sires were 57.5% proven AI bulls, 9.7% young AI bulls, and 34.3% young non-AI bulls. Financially, the Holstein herds averaged $11.70/day of milk per milking cow with costs of $4.80/day to feed; income-over-feed costs averaged $7.00/day for milking cows. Feed costs per cwt of milk were $8.00 (values are rounded). Milk averaged $19.80/cwt, which was a record high price. The difference in milk/cow/year of 4,000 lb between herds on the DHI program and those not on the program would affect income by over $700/cow, or approximately $84,000 in a 120-cow herd. Only about 30% of the state's cows are enrolled in the DHI record-keeping program; therefore, opportunities exist for raising the level of milk production and profitability in the state by encouraging more producers to use DHI or similar records.

Introduction

DairyMetrics is a benchmarking tool that allows producers on the Dairy Herd Improvement (DHI) program to compare 72 variables concerning general herd traits, such as milk production, reproduction, udder health, and genetics on their DHI records to other herds in the state or region. Data obtained from DairyMetrics can show individual dairy producers their herd's average and percentile for any of the 72 variables compared to other herds, which can indicate where they might improve the herd. DairyMetrics also can be used to compare these variables among groups of herds to illustrate how the various traits affect efficiency of producing milk

Experimental Procedures

DairyMetrics was used to obtain the average and standard deviation, as well as low and high values for herds for various general, production, reproduction, udder health, and genetic variables. These values are presented in Table 1 for Holstein herds in the state (n = 21) and in Table 2 for herds of all breeds (n = 30 or 9 additional herds) in Arkansas on May 12, 2008. Previously designated ranges of variables can be selected for comparison; however, each category must have had at least 6 herds to assure anonymity of individual herds. If an individual herd comparison is conducted, the means for the herd for each trait and percentile are displayed. The percentile of each variable is relative to the variables that are selected for comparison (e.g., the cohort herds or selected group of herds).

Results and Discussion

As illustrated by the comparisons of Table 1 and Table 2, Holstein herds were the predominant herds on tests in Arkansas. Compared to last year, one of the most significant changes in the parameters is that milk blend price for all Holsteins improved to $19.60, a record high price. Milk price for Holsteins was $15.61/cwt in 2007, after it had decreased to $13.18/cwt in 2006 from $15.62/cwt in 2005 (compared to $11.68, $11.60, and $14.00/cwt in 2002, 2003, and 2004, respectively). This increase in milk prices helped maintain a reasonable daily income-over-feed costs per Holstein cow of $7.00 in 2008 compared to $6.92 in May, 2007. In 2006, daily income-over-feed costs were $5.51 compared to $5.23 in 2005 (compared to $3.61, $3.71, and $5.07 per day in 2002, 2003, and 2004, respectively). Feed costs/cwt of milk from Holsteins increased dramatically this year ($8.00), when compared to the feed costs of previous years ($5.00/cwt in 2007; $4.71/cwt in 2006). Daily feed costs/Holstein milk cow were $4.80, an increase from $4.04 in 2007. This compares to daily feed costs/cow of $3.15 in 2002, $3.24 in 2003, $3.35 in 2004, $3.23 in 2005, and $3.56 in 2006.

The Arkansas average for milk/cow was 12,941 lb/year on all cows in 2007, which indicates that non-DHI herds averaged less than 12,000 lb/cow/year as herds on DHI averaged 16,086 lb/cow. This difference in milk/cow/year of 4,000 lb would affect income by over $700/cow, or approximately $84,000 in a 120-cow herd. As about 30% of the state's cows are enrolled in the DHI record-keeping program, opportunities exist for raising the level of milk production and profitability in the state by encouraging more producers to use DHI or similar records.

[1] Department of Animal Science, Little Rock

Implications

Many factors in milk production are interrelated and can affect herd profitability. Records from the Dairy Herd Improvement program can provide management information to help producers increase profits. Data from these records show general, production, udder health, reproduction, and genetics of the herd that can enhance the intensity of managing the dairy herd. DairyMetrics also can be used effectively either by individual producers to compare their herds to other herds throughout the region or can be used in an educational activity to illustrate the importance of specific management practices on profitability and efficiency of milk production, as indicated by daily income-over-feed costs.

Table 1. DairyMetrics for Holstein herds in Arkansas, May, 2008.

Trait	Number of herds	Average	SD	Minimum	Maximum
General					
Number of cows-All lactation	21	145.9	98.6	40	376
Number of cows-1st lactation	21	51.2	47.9	2	161
Number of cows-2nd lactation	21	38.4	27.4	9	115
Number of cows-3rd lactation	21	56.2	28.9	19	112
Number of cows-Year change, %	21	1.4	14.8	-27	27
In milk on test day, %	21	89.9	5.9	78	100
Days in milk, mo	21	196.8	21.1	168	255
Age of 1st lactation cows	21	27.8	2.7	23	34
Cows eft Herd-All lactation, %	21	35	15	17	74
Cows lLeft Herd-1st lactation, %	21	27.2	29.4	2	108
Cows left Herd-2nd lactation, %	21	22.2	22.6	1	81
Cows left Herd-3rd lactation, %	21	33.4	18.3	5	78
Cows died-All lactation, %	21	7.4	4.4	3	18
Cows died-1st lactation, %	21	4.4	4.2	0	14
Cows died-2nd lactation, %	21	5.5	4.6	0	17
Cows died-3rd lactation, %	21	12.4	9.7	2	37
Cows left herd for reproduction-All lactation, %	21	5.1	4.9	0	18
Cows left herd for reproduction-1st lactation, %	21	4	5	0	16
Cows left herd for reproduction-2nd lactation, %	21	4.8	5.4	0	17
Cows left herd for reproduction-3rd lactation, %	21	6.2	6.7	0	26
Daily value produced-milk cows, $	21	11.7	2.3	7.8	16.6
Daily feed cost-milk cows, $	16	4.8	1.2	2.5	7.3
Daily feed cost/Cwt milk, $	16	8.0	2.1	5.3	12.3
Daily income minus feed-Milk cows, $	16	7.0	1.9	3.7	11.5
Milk blend price, $	21	19.6	2.4	17.5	26

Table 1. DairyMetrics for Holstein herds in Arkansas, May, 2008 (Continued).

Trait	Number of herds	Average	SD	Minimum	Maximum
Production					
Rolling milk, lb	21	16,617	4,409	10,076	24,079
Rolling milk-Year change, lb	21	-790.1	1,091.6	-2,402.5	1,418
Rolling fat, lb	21	586.7	147.5	379	878
Rolling protein, lb	21	513.7	134.2	292	739
Daily milk 1-40 d-1st lactation, lb	17	52.6	9.6	31	70
Daily milk 1-40 d-2nd lactation, lb	16	77.4	18.8	39	104
Daily milk 1-40 d-3rd+ lactation, lb	14	75.1	19	45	103
Daily milk-Milk cows, lb	21	60.4	10.7	45.3	77.8
Daily milk-All cows, lb	21	54.5	11.6	39.3	77.8
Daily fat, %	21	3.4	0.3	3.1	3.9
Daily protein, %	21	3.1	0.1	2.9	3.4
Summit milk 1st lactation, lb	21	56.8	12.8	34	80
Summit milk 2nd lactation, lb	21	71.2	16	41	94
Summit milk 3rd+ lactation, lb	21	77.2	16.7	52	106
Peak milk 1st lactation, lb	20	60.8	14.4	33	86
Peak milk 2nd lactation, lb	21	74.9	16.7	42	103
Peak milk 3rd+ lactation, lb	21	79.8	17.8	51	108
Projected 305 day ME milk, lb	21	19,109.8	4,009.1	12,578	25,664
Standardized150 day milk, lb	21	64.1	11.1	46.1	80.6
Fat:protein 1-40 d-1st lactation	17	1.1	0.1	0.8	1.2
Fat:protein1-40 d-2nd lactation	16	1.1	0.2	0.8	1.7
Fat:protein 1-40 d-3rd+ lactation	14	1.2	0.2	0.8	1.4
Fat:protein 41-100 d-1st lactation	18	1.1	0.2	0.7	1.3
Fat:protein 41-100 d-2nd lactation	19	1.1	0.1	0.8	1.4
Fat:protein 41-100 d-3rd+ lactation	21	1.2	0.2	0.9	1.6
Fat:protein 100-199 d-1st lactation	16	1.1	0.1	1	1.2
Fat:protein 100-199 d-2nd lactation	21	1.1	0.2	0.7	1.5
Fat:protein 100-199 d-3rd+ lactation	21	1.1	0.1	0.8	1.3
Fat:protein 200-305 d-1st lactation	20	1.1	0.1	0.9	1.4
Fat:protein 200-305 d-2nd lactation	21	1.1	0.1	0.9	1.3
Fat:protein 200-305 d-3rd+ lactation	20	1.1	0.1	1	1.3
Fat % 1-40 d-1st lactation	17	3.4	0.3	2.9	3.9
Fat % 1-40 d-2nd lactation	16	3.4	0.6	2.4	4.4
Fat % 1-40 d-3rd+ lactation	14	3.7	0.8	2.6	5
Fat % 41-100 d-1st lactation	18	3.1	0.5	2.1	3.9
Fat % 41-100 d-2nd lactation	19	3.1	0.4	2.5	4
Fat % 41-100 d-3rd+ lactation	21	3.3	0.4	2.6	4.2
Fat % 100-199 d-1st lactation	16	3.4	0.2	3.1	3.8
Fat % 100-199 d-2nd lactation	21	3.4	0.5	2.3	4.6
Fat % 100-199 d-3rd+ lactation	21	3.3	0.5	2.3	4
Fat % 200-305 d-1st lactation	20	3.7	0.4	3	4.7
Fat % 200-305 d-2nd lactation	21	3.5	0.4	2.7	4.1
Fat % 200-305 d-3rd+ lactation	20	3.5	0.3	2.9	3.9
Udder Health					
Somatic cell count (X1000) actual	21	353.4	95.4	188	538
Somatic cell score	21	3.4	0.5	2.2	4.3
Somatic cell score for 1st lactation cows	21	2.9	0.6	1.6	4.1
Somatic cell score for 2nd lactation cows	21	3.3	0.6	2.3	4.5
Somatic cell score for 3rd+ lactation cows	21	3.7	0.5	2.4	4.8
Somatic cell score for cows in milk 41-99 days	21	2.8	0.9	1.3	4.4
Somatic cell score for cows in milk 100-199 days	21	3.1	0.6	1.9	4.2
Somatic cell score for cows in milk 200-305 days	21	3.6	0.6	2	4.8
Somatic cell score for cows in milk 306+ days	21	3.9	0.6	2.8	5.2
Cows (somatic cell score of 0-3), %	21	55.8	10.1	35	78
Cows (<41d with somatic cell score>4), %	20	38.7	24.9	0	100
1st lactation (somatic cell score of 0-3), %	21	66	14.9	40	100
2nd lactation (somatic cell score of 0-3), %	21	57.2	16.1	13	81
3rd lactation (somatic cell score of 0-3), %	21	49.6	12.3	26	74
Cows culled for mastitis, %	21	3.1	3.3	0	9
Value product lost from somatic cell count, %	21	3.1	1.6	0	6

Table 1. DairyMetrics for Holstein herds in Arkansas, May, 2008 (Continued).

Trait	Number of herds	Average	SD	Minimum	Maximum
Reproduction					
Pregnancy rate-Current, %	18	18.1	7.8	6	34
Days open-Projected min-Total herd	21	180.1	37.8	134	280
Projected calving interval, mon	21	15.1	1.2	13.6	18.4
Actual calving interval, mon	21	14.6	1.2	12.6	17.5
Cows calving-Current test, %	21	6.6	3.8	0	14
Births 4+ calving difference-1st lactation, %	14	5.1	6.3	0	21
Days open-projected minimum-1st lactation	21	200.6	67.1	117	409
Days open-projected min-2nd lactation	21	177	51.6	98	329
Days open-projected min-3rd+ lactation	21	173.8	38.6	118	249
Voluntary waiting period(VWP), d	21	50.5	7.7	40	60
Days to 1st service-(%herd < VWP)	16	11.6	11	1	38
Days to 1st service-(%VWP to 100 d)	19	55.5	21.5	23	92
Days to 1st service-(%herd > 100 d)	19	34.8	18.4	4	71
Days to 1st service-Total herd	19	102.1	23.2	71	160
Days to 1st service(%herd <100 d)-1st lactation	18	60.7	24.1	16	96
Days to 1st service(%herd <100 d)-2nd lactation	19	64.1	22.6	22	94
Days to 1st service(%herd <100 d)-3rd+ lactation	19	67.7	14.7	48	96
Conception rate for past 12 mo-1st service	21	45.3	24.1	0	95
Conception rate for past 12 mo-2nd service	21	46.5	23.8	0	100
Conception rate for past 12 mo-3rd+ service	21	49	27.3	0	100
Service per pregnancy-All lactation	19	2.8	1	1.3	4.8
Service per pregnancy-1st lactation	19	3	1.2	1.4	6.1
Service per pregnancy-2nd lactation	19	2.7	1.1	1.1	5
Service per pregnancy-3rd+ lactation	19	2.9	1.2	1.3	5.9
Heats observed for year, %	19	27.9	15.5	2	53
Heats observed-Last test, %	18	30.4	20.1	1	63
Abortions in past year, #	21	0.1	0.4	0	2
Calvings in past year, #	21	140.1	89.9	39	357
Dry less than 40 days, %	19	13.9	8.2	3	28
Dry more than 70 days, %	21	38.3	14.5	9	55
Genetics					
Percentile rank of young AI bulls	21	40.7	27.1	0	77
Percentile rank of young AI bulls	21	28.5	33.6	0	88
Herd bred to Proven AI bulls, %	17	57.5	30	0.6	100
Herd bred to Young AI bulls, %	21	9.7	13.2	0	36
Herd bred to Non-AI bulls, %	21	34.3	37.1	0	100
Net merit $ for 1st lactation cows	16	110	94	10	381
Net merit $ for all cows	18	57.6	50.7	-38	137
Net merit $ for heifers	18	74.8	72.2	-64	208
Heifers ID'd by sire, %	19	59.7	33.2	0	100
Cows ID'd by sire, %	21	57.7	40	0	100
Replacement/rate(#heifer/#cows)*100	21	81.3	46.1	0	167
Replacement/rate(#heifer 0-12 mo/#cows)*100	21	33.7	17.9	0	63
Replacement/rate(#heifer 13+ mo/#cows)*100	21	47.2	32.2	0	135

Table 2. DairyMetrics for all breeds in Arkansas, May, 2007.

Trait	Number of herds	Average	SD	Minimum	Maximum
General					
Number of cows-All lactation	30	157.8	132.5	40	681
Number of cows-1st lactation	30	61.4	65.2	2	293
Number of cows-2nd lactation	30	39.9	32.3	9	150
Number of cows-3rd lactation	30	56.5	44	7	238
Number of cows-Year change %	30	-2.2	16.5	-35	27
In milk on test day, %	30	89.2	6.3	74	100
Days in milk	30	195.1	25.8	146	257
Age of 1st lactation cows (mo)	30	27.9	2.6	23	34
Cows left herd-All lactation, %	29	40.2	21.4	17	96
Cows left herd-1st lactation, %	30	37.6	43.1	2	184
Cows left herd-2nd lactation, %	30	25.5	24.7	1	98
Cows left herd-3rd lactation, %	30	36.3	19.4	1	78
Cows died-All lactation, %	30	8.2	5.3	2	22
Cows died-1st lactation, %	30	5.3	4.9	0	14
Cows died-2nd lactation, %	30	6.6	5.5	0	21
Cows died-3rd lactation, %	30	12.8	10	0	37
Cows left herd for reproduction-All lactation, %	30	5.9	6	0	26
Cows left herd for reproduction-1st lactation, %	30	4.4	4.9	0	16
Cows left herd for reproduction-2nd lactation, %	30	5.3	5.9	0	17
Cows left herd for reproduction-3rd lactation, %	30	8.1	10.4	0	52
Daily value produced-Milk cows, $	30	11.2	2.3	7.2	16.6
Daily feed cost-Milk cows, $	24	4.6	1.2	2.5	7.3
Daily feed cost/Cwt milk, $	24	8.1	2.3	5.3	13.2
Daily income minus feed-Milk cows, $	24	6.6	2.1	2	11.5
Milk blend price, $	30	19.4	2.2	16.4	26

Table 2. DairyMetrics for all breeds in Arkansas, May, 2007 (Continued).

Trait	Number of herds	Average	SD	Minimum	Maximum
Production					
Rolling milk, lb	30	16,086	3,931	10,076	24,079
Rolling milk-Year change, lb	30	-225.3	2,921.8	-3,236.5	3,738
Rolling fat, lb	30	578.6	138.1	357	878
Rolling protein, lb	30	502.1	118.9	292	739
Daily milk 1-40 D-1st lactation, lb	23	51.4	9.2	31	70
Daily milk 1-40 D-2nd lactation, lb	24	71.8	18.3	39	104
Daily milk 1-40 D-3rd+ lactation, lb	20	72	17.2	45	103
Daily milk-Milk cows, lb	30	58	10.4	39.4	77.8
Daily milk-All lows, lb	30	51.9	11.1	33.8	77.8
Daily fat, %	30	3.5	0.5	3.1	5.5
Daily protein, %	30	3.1	0.1	2.9	3.4
Summit milk 1st lactation (lb)	30	56.5	11.2	34	80
Summit milk 2nd lactation (lb)	30	70.2	14.2	41	94
Summit milk 3rd+ lactation (lb)	30	75.9	15	52	106
Peak milk 1st lactation (lb)	29	60.4	12.6	33	86
Peak milk 2nd lactation (lb)	30	73.3	15.1	42	103
Peak milk 3rd+ lactation (lb)	30	78.7	15.9	51	108
Projected 305 day ME milk (lb)	30	1,8641.9	36,33.9	12,578	25,664
Standardized 150 day milk (lb)	30	61.6	11.1	38.2	80.6
Fat:protein 1-40 d-1st lactation	23	1.1	0.2	0.8	1.6
Fat:protein 1-40 d-2nd lactation	24	1.1	0.3	0.5	1.8
Fat:protein 1-40 d-3rd+ lactation	20	1.2	0.2	0.8	1.6
Fat:protein 41-100 d-1st lactation	27	1.1	0.2	0.7	1.7
Fat:protein 41-100 d-2nd lactation	27	1.1	0.2	0.8	1.7
Fat:protein 41-100 d-3rd+ lactation	29	1.2	0.2	0.9	1.7
Fat:protein 100-199 d-1st lactation	25	1.1	0.2	0.5	1.7
Fat:protein 100-199 d-2nd lactation	30	1.1	0.2	0.7	1.7
Fat:protein 100-199 d-3rd+ lactation	30	1.1	0.2	0.8	1.6
Fat:protein 200-305 d-1st lactation	28	1.1	0.1	0.9	1.6
Fat:protein200-305 d-2nd lactation	29	1.1	0.2	0.8	1.6
Fat:protein 200-305 d-3rd+ lactation	29	1.1	0.1	1	1.5
Fat % 1-40 d-1st lactation	23	3.4	0.6	2.6	5.5
Fat % 1-40 d-2nd lactation	23	3.6	0.9	2.4	6.6
Fat % 1-40 d-3rd+ lactation	20	3.7	0.8	2.6	5.4
Fat % 41-100 d-1st lactation	27	3.2	0.6	2	5.3
Fat % 41-100 d-2nd lactation	27	3.3	0.6	2.5	5.7
Fat % 41-100 d-3rd+ lactation	29	3.4	0.6	2.6	5.3
Fat % 100-199 d-1st lactation	24	3.5	0.6	2.4	6.1
Fat % 100-199 d-2nd lactation	30	3.5	0.6	2.3	5.7
Fat % 100-199 d-3rd+ lactation	30	3.4	0.6	2.3	5.5
Fat % 200-305 d-1st lactation	28	3.7	0.6	2.8	5.6
Fat % 200-305 d-2nd lactation	29	3.6	0.6	2.4	5.6
Fat % 200-305 d-3rd+ lactation	29	3.6	0.4	2.9	5.2
Udder Health					
Somatic cell count (X1000)[1], actual	29	435.2	301.7	145	1,806
Somatic cell score	29	3.5	0.8	2.2	6
Somatic cell score for 1st lactation cows	29	3.1	0.8	1.6	5.6
Somatic cell score for 2nd lactation cows	29	3.4	1.1	1.7	7.1
Somatic cell score for 3rd+ lactation cows	29	3.9	1	2.4	7.4
Somatic cell score for cows in milk 41-99 days	29	3	1.1	1.3	5.6
Somatic cell score for cows in milk 100-199 days	29	3.3	0.9	1.9	6.1
Somatic cell score for cows in milk 200-305 days	29	3.8	0.9	2	6.3
Somatic cell score for cows in milk 306+ days	29	4	0.8	2.7	6.3
Cows (Somatic cell score of 0-3), %	29	52.8	14	16	78
Cows (< 41 d with somatic cell score> 4), %	29	37.7	25.7	0	100
1st lactation (Somatic cell score of 0-3), %	29	63	16.2	20	100
2nd lactation (Somatic cell score of 0-3), %	29	53.9	20.8	0	92
3rd lactation (Somatic cell score of 0-3), %	29	45.2	17.6	0	74
Cows culled for mastitis, %	30	3.5	6.5	0	34
Value produced lost from somatic cell count, %	30	3.6	2.5	0	10

Table 2. DairyMetrics for all breeds in Arkansas, May, 2007 (Continued).

Trait	Number of herds	Average	SD	Minimum	Maximum
Reproduction					
Pregnancy rate-current, %	27	18.9	9.7	1	36
Days open-projected minimum-total herd	30	187.6	42.1	121	280
Projected calving interval	30	15.4	1.4	13.2	18.4
Actual calving interval	30	14.9	1.7	12.5	21.1
Cows calving-current test, %	30	7	4.7	0	20
Births 4+ calving difference-1st lactation, %	23	5.3	8.1	0	33
Days open-projected minimum-1st lactation	30	208.8	65.8	110	409
Days open-projected minimum-2nd lactation	30	188.2	57.9	85	329
Days open-projected minimum-3rd+ lactation	30	178.1	47.1	84	316
Voluntary waiting Period(VWP)	30	51.3	7.8	40	60
Days to 1st service-(%herd < VWP)	24	13.5	11.9	1	44
Days to 1st service-(%VWP to 100 d)	28	48.7	22	17	92
Days to 1st service-(%herd > 100 d)	28	39.8	19	4	71
Days to 1st service-total herd	28	109.8	26.5	71	160
Days to 1st service(%herd <100 d)-1st lactation	27	57.9	22.5	16	96
Days to 1st service(%herd <100 d)-2nd lactation	28	59.3	23.7	14	94
Days to 1st service(%herd <100 d)-3rd+ lactation	28	62	17.4	26	96
Conception rate for past 12 mo-1st service	30	45.7	22.4	0	95
Conception rate for past 12 mo-2nd service	30	46.9	22.2	0	100
Conception rate for past 12 mo-3rd+ service	30	47.6	25.1	0	100
Service per pregnancy-All lactation	28	3	1.1	1.3	5.5
Service per pregnancy-1st lactation	28	3.1	1.4	1.3	7.4
Service per pregnancy-2nd lactation	28	3.1	1.4	1.1	6.1
Service per pregnancy-3rd+ lactation	28	3	1.2	1	5.9
Heats observed for year, %	28	27.9	14.3	2	53
Heats observed-last test, %	24	31.8	20.1	1	69
Abortions in past year, #	30	0.1	0.4	0	2
Calvings in past year, #	30	154.7	134	36	671
Dry less than 40 days, %	28	14.1	9.4	2	38
Dry more than 70 days, %	30	41.4	16.5	9	82
Genetics					
Percentile rank of young AI bulls	30	41.2	25.5	0	77
Percentile rank of young AI bulls	30	32.8	32.2	0	88
Herd bred to proven AI bulls, %	25	52.8	29.8	0.6	100
Herd bred to young AI bulls, %	30	12.7	15.1	0	49.2
Herd bred to non-AI bulls, %	30	36.6	36.8	0	100
Net merit $ for 1st lactation cows	25	85.8	100.2	-170	381
Net merit $ for all cows	27	46.4	68.5	-142	137
Net merit $ for heifers	27	67.7	72.9	-69	208
Heifers ID'd by sire, %	28	62.3	31.5	0	100
Cows ID'd by sire, %	30	61.7	37.2	0	100
Replacement/rate(#heifer/#cows)*100	30	82.5	39.6	0	167
Replacement/rate(#heifer 0-12 mo/#cows)*100	30	35.4	16.2	0	63
Replacement/rate(#heifer 13+ mo/#cows)*100	30	46.7	27.9	0	135

Arkansas Milk Stabilization Board

Jodie A. Pennington[1]

Story in Brief

The Arkansas Milk Stabilization Board was established by Act 754, which was passed by the 2007 Arkansas Legislature. Governor Mike Beebe signed the bill on April 2, 2007. This act established the Arkansas Milk Stabilization Board to assure the viability of dairy farming in the state by encouraging increased milk production and to assure consumers of an adequate supply of milk. The board will be composed of two dairy farmers, one consumer, one processor and one retailer.

The goals of the board are (1) to ensure an adequate supply of fluid milk for the population of the state, especially in the case of natural disaster, an act of terrorism or other events that might restrict the flow of milk into the state, (2) to stabilize and/or grow the dairy industry so that it provides an adequate supply of local milk to supply the fluid milk needs of the state, and (3) to promote economic development in the state, especially in rural communities.

The first meeting of the newly formed Arkansas Milk Stabilization Board was September 12, 2007, at the Arkansas State Plant Board in Little Rock. After introductions, Woody Bryant, dairy farmer, was elected to serve as the first chairman of the Dairy Board. Steve Wheetley, Affiliated Foods, will serve as vice-chairman while Brownie Ledbetter, consumer representative, will serve as secretary-treasurer. The other two members of the board are Mike Fisher, dairy farmer, and Mike Flagg, from Coleman Dairy. Secretary of Agriculture Richard Bell coordinates the meetings as the secretary of the Arkansas Agriculture Department, and the director of the Livestock and Poultry Commission shall assist the Arkansas Milk Stabilization Board when necessary by providing resources and guidance.

Introduction

Dairy farms in Arkansas produce approximately 200 million pounds of milk per year while dairy plants process over 900 million pounds of milk per year. Furthermore, Arkansas residents consume over 500 million pounds of fluid milk products yearly and consume over 1,600 million pounds of dairy products each year, based on per capital consumption of dairy products.

Fluid milk is needed on an almost daily basis and is not easily stored for long periods of time compared to cheese, meat products, and other hard products such as cereal grains that are harvested yearly and can be stored for many weeks or longer. Milk is a unique and necessary food for infants and very young children and is considered a daily need for school children.

More and more states provide financial incentives to dairy producers to ensure an adequate supply of milk in the states for economic reasons related to dairy production or to ensure an adequate supply of milk in the event of a natural or man-induced disaster that might prevent milk from getting to the state. Since milk production in Arkansas continues to decline, financial incentives for dairy producers in the state are required to ensure that milk will be available to the population of Arkansas when needed.

The purpose of this report is to update the industry on the establishment of the Arkansas Milk Stabilization Board, which was established to stabilize and/or grow milk production in the state and could be a historic activity relative to the dairy industry.

Procedures

The Arkansas Milk Stabilization Board was established by Act 754, which was passed by the 2007 Arkansas legislature. Governor Mike Beebe signed the bill on April 2, 2007. This act established the Arkansas Milk Stabilization Board, which is to assure the viability of dairy farming in the state by encouraging increased milk production and to assure consumers of an adequate supply of milk. The board is to be composed of two dairy farmers, one consumer, one processor and one retailer. The board is to create a plan to assist Arkansas dairy farmers that would be equitable to all parties in the state dairy industry and withstand legal challenges. The Secretary of Arkansas Agriculture Department and the Director of the Livestock and Poultry Commission shall assist the Arkansas Milk Stabilization Board when necessary by providing resources and guidance.

Results and Discussion

The goals of the Arkansas Milk Stabilization Board are (1) to ensure an adequate supply of fluid milk for the population of the state, especially in the case of natural disaster, an act of terrorism or other events that might restrict the flow of milk into the state, (2) to stabilize and/or grow the dairy industry so that it provides an adequate supply of local milk to supply the fluid milk needs of the state, and (3) to promote economic development in the state, especially in rural communities. For the general population, the goals of the board mean that an adequate supply of fluid milk would be available in cases of short-term shutdown of milk from out of state. Hypothetical examples of a shutdown of the milk supply could be from an act of terrorism or a natural disaster that results in the interstate highway system being closed. Arkansas now produces less than 25 percent of the milk needed by processors in the state. For dairy producers, the goals of the board mean an economic incentive to produce milk and stay in business.

[1] Department of Animal Science, Little Rock

Nominations for the Arkansas Milk Stabilization Board were received in the governor's office in summer, 2007, and members were appointed by Governor Mike Beebe. The first meeting of the newly formed Board was September 12, 2007, at the Arkansas State Plant Board in Little Rock. After introductions, Woody Bryant, dairy farmer, was elected to serve as the first chairman of the Dairy Board. Steve Wheetley, Affiliated Foods, was elected as vice-chairman while Brownie Ledbetter, consumer representative, was elected as secretary-treasurer. The other two members of the Board are Mike Fisher, dairy farmer, and Mike Flagg, from Coleman Dairy and Prairie Farms. Secretary of Agriculture Richard Bell coordinates the meetings as the Secretary of Arkansas Agriculture Department and the Director of the Livestock and Poultry Commission shall assist the Arkansas Milk Stabilization Board when necessary by providing resources and guidance.

The Arkansas Milk Stabilization Board continues to meet monthly. The incentives for dairy producers and funding for the incentives are still being discussed. The proposed incentives include (1) a 10% investment tax credit on money spent to construct, improve or acquire buildings or equipment for dairy animal housing, feeding, milk production or waste management, (2) production and quality incentives based on increased milk production above the previous 2 years with quality incentives for milk below somatic cell count levels of 500,000, and (3) a monthly stabilization payment payable to registered Arkansas milk producers when the monthly average price for milk purchased from Arkansas producers by the Arkansas Dairy Cooperative Association and Dairy Farmers of America falls below 70 percent of the average cost of milk production as determined by the National Agricultural Statistics Service (USDA/NASS) in the surrounding states of Missouri and Tennessee. There will be proposed limits of $50,000 per dairy per year for the first 2 incentive programs and $85,000 per dairy per year for the monthly stabilization payments.

The board will recommend a stabilization assessment on fluid milk consumed and/or milk equivalents for other dairy products to be used to fund the Arkansas Milk Stabilization Program. These recommendations must be approved by the state legislature and be signed as law by the governor. A fund balance will be established to accumulate funds in periods when there are no milk stabilization payments. If approved, the Arkansas Department of Finance and Administration (DFA) will collect the assessment. Administration of distributions to milk producers will be by the Arkansas Agriculture Department.

Implications

The Arkansas Milk Stabilization Board has goals to increase milk production in the state so that milk will be available in emergency situations where outside milk cannot come into the state, hypothetically as a result of disaster that might prevent milk from outside the state being delivered to in-state processors. If the recommendations become law, the recommended incentives should make dairy producers in Arkansas more competitive in producing milk with producers in other states.

Arkansas Beef Quality Assurance Refrigerator Demonstration[1]

T.R. Troxel and B.L. Barham[2]

Story in Brief

WatchDog data loggers were used to record the temperature at 10-min intervals for 48 h in 142 refrigerators of producers (73.2%), retail stores (20.4%) and veterinarian clinics (6.3%). The most common refrigerator tested was a refrigerator with the freezer-on-top (42.4%), followed by mini-refrigerators (21.1%), side-by-side refrigerators (19.5%), other types of refrigerators (16.2%), and freezer-on-bottom refrigerators (0.7%). The refrigerator ages were listed as ≤ 5 yr (22.5%), 6 to 10 yr (36.6%), 11 to 15 yr (21.3%), and > 15 yr (19.5%). The other category (57.0%) was the most common category for refrigerator location, followed by kitchen (16.2%), barn (15.5%), tack room (5.6%), mud room (4.9%), and porch (0.7%). Of the 4,665 animal health products stored in refrigerators, 3.5% were expired, and 8.7% were opened. Over 38% of the refrigerators contained human food, whereas 59.7% of refrigerators contained drinks for human consumption. The majority (52.1%) of the refrigerators surveyed contained beef cattle animal health products, whereas 47.9% of the refrigerators contained beef cattle and other livestock animal health products. The only differences detected were due to refrigerator location ($P < 0.05$). Refrigerators located in a mud room had a higher ($P < 0.05$) average temperature, fewer ($P < 0.05$) points below 35°, more ($P < 0.05$) points above 45°, fewer ($P < 0.05$) percentage points below 35°, and more ($P < 0.05$) percentage points above 45°. As a result of this study, livestock producers should monitor the refrigerator temperature where animal health products are stored.

Introduction

The Arkansas Beef Quality Assurance Program (BQA) is an educational program that illustrates the importance of proper handling and administration of animal health products. One BQA recommendation is to store animal health products at the proper temperature (Arkansas BQA Handbook, 2006).

Refrigeration is required for most animal health products (antibiotics, pharmaceuticals, biologicals, vaccinations, etc.). Biological products should be kept under refrigeration between 35° to 45°F (2° to 7°C) unless the inherent nature of the product makes storage at a different temperature advisable (APHIS, 2007). Storing animal health products < 35°F can be more damaging than storing animal health products > 45°F because the antigen can separate from the adjuvant. Producers are very good about storing animal health products in a refrigerator. These refrigerators are often older models and are located outside, in a tack room, near the working chute, in barns, and/or out in the elements. Given these situations, maintaining proper temperature for animal health products becomes a genuine concern.

Therefore, the objectives of this study were to determine the temperature of refrigerators where animal health products are stored and to conduct an animal health product inventory to determine if any products were opened or expired.

Experimental Procedures

To record temperatures of refrigerators containing animal health products, 10 WatchDog data loggers (Model 100 8K) and Spec 8 Basic software (Spectrum Technologies, Inc., Plainfield, Ill.) were purchased. Data loggers were programmed to record the temperature at 10-min intervals for up to 56 d and are accurate to ± 1°F (± 0.6°C). WatchDog data loggers were loaned to county extension agents, and agents placed the data loggers in refrigerators of producers, retail stores, and veterinarian clinics. The WatchDog data loggers remained in the refrigerator for 48 h before being returned for summary and analysis. Once the data were summarized, the temperature results were sent to the county agent, who forwarded the information to the producer, store manager, or veterinarian.

In addition, county agents conducted a survey for each refrigerator tested, including refrigerator location (barn, tack room, porch, mud room, kitchen, and other), type of refrigerator (side-by-side, freezer-on-top, freezer-on-bottom, mini-refrigerator, and other), refrigerator age (≤ 5 yr, 6 to 10 yr, 11 to 15 yr, and > 15 yr), the date and time the WatchDog was placed and removed from the refrigerator, number of animal health products in the refrigerator, number of animal health product that were expired and/or open, and human food or drink items in the refrigerator. Also, the presence of any animal health products for other species other than bovine was noted.

Each refrigerator sampled contained 288 temperature data points (48 h measured every 10 min) and each data point was analyzed to determine if it was over or under the critical temperatures of 35° to 45°F. All 288 data points for each refrigerator were averaged to produce a mean temperature and percentage of observations that were below and above the critical temperatures. These summarized data were analyzed using ANOVA, JMP v7.0.1 (SAS Inst., Inc., Cary, N.C.) with dependent variables of mean temperature, percentage of time over critical temperature and percentage of time below critical temperature using individual refrigerators as the experimental unit. Independent variables analyzed included refrigerator owner (producer, retail store, or veterinarian), location of refrigerator (barn, tack room, porch, mud room, kitchen, and other), type of refrigerator (freezer-on-top, side-by-side, freezer-on-bottom, mini-refrigerator, and other), and age of refrigerator (≤ 5

[1] Funding was provided by the Arkansas Beef Council.

[2] Department of Animal Science, Little Rock

yr, 6 to 10 yr, 11 to 15 yr, and > 15 yr). When a significant F-test was observed, least squares means were separated utilizing t-tests.

Results and Discussion

The majority of the refrigerators tested were producer's refrigerators (73.2%), with 20.4 and 6.3% found in retail stores and veterinarian clinics, respectively. Producers were not identified as to what type of producer (i.e. cow-calf, stocker, dairy, equine, etc.). The most common refrigerator was a refrigerator with the freezer-on-top (42.4%), followed by mini-refrigerators (21.1%), side-by-side refrigerators (19.5%), other types of refrigerators (16.2%), and freezer-on-bottom refrigerators (0.7%). The front glass/display case refrigerator was the most common refrigerator in the other category. Refrigerator ages were listed as ≤ 5 yr (22.5%), 6 to 10 yr (36.6%), 11 to 15 yr (21.3%), and > 15 yr (19.5%).

Other (57.0%) was the most common category for refrigerator location. The other locations listed included within a store (33.8%), office (25.7%), workshop (18.9%), and garage (13.5%). Additional refrigerator location categories included kitchen (16.2%), barn (15.5%), tack room (5.6%), mud room (4.9%), and porch (0.7%).

The majority (52.1%) of the refrigerators surveyed contained beef cattle animal health products, whereas 47.9% of the refrigerators contained beef cattle and other livestock animal health products. Of the 4,665 animal health products stored in refrigerators, 3.5% were expired, and 8.7% were opened. Over 38% of the refrigerators contained human food including milk (11.7%), eggs (10.3%), cheese (8.3%), fruit (8.3%), and vegetables (7.6%). Furthermore, almost 60% of refrigerators (59.7%) contained drinks for human consumption, particular soft drinks (42.1%), water (28.3%), Gatorade® (9.2%), beer (8.6%), and fruit/juice drinks (7.2%).

Average temperature, number of data points below 35° and above 45°F, and the percentage of data points below 35° and above 45°F for owners (producers, retail stores, or veterinarian clinics), refrigerator location, refrigerator type, and refrigerator age are summarized in Table 1. The only differences detected were due to refrigerator location ($P < 0.05$). Refrigerators located in a mud room had a higher ($P < 0.05$) average temperature, fewer ($P < 0.05$) points below 35°, more ($P < 0.05$) points above 45°, fewer ($P < 0.05$) percentage points below 35°, and more ($P < 0.05$) percentage points above 45° than refrigerators located in a barn, tack room or other location, but not for refrigerators located in a kitchen. It appears refrigerators located in heated and cooled rooms (kitchen and mud room) maintained warmer temperatures. There was a trend ($P < 0.30$) for refrigerators ≤ 5 yr and 6 to 10 yr to be cooler than refrigerators 11 to 15 yr and > 15 yr old.

Although it's important to analyze the overall data, individual refrigerator information is critical in determining whether or not any given refrigerator is storing animal health products at the proper temperature. Figure 1 depicts an example of a refrigerator where temperature varied very little, maintaining the temperature between 35° and 45° over a 24-h period. Conversely, the refrigerator example in Figure 2 also kept the temperature between 35° and 45° but the variation was substantially greater when compared to the refrigerator in Figure 1.

After the Watchdog data logger was inserted into the refrigerator in Figure 3, it took approximately 7.5 h before the temperature dropped below 45°F. Figure 4 is an example of a refrigerator that kept the temperature too cold with all but 2 datum points blow 35°F across the 24-h observation period. Moreover, there was almost a 10°F variation in 50 min throughout the 24-h period (Figure 4). Storing animal health products at temperatures < 35°F can be more damaging than storing animal health products at temperatures of > 45°F, because the antigen can separate from the adjuvant.

Figure 5 illustrates a refrigerator set too warm with all of the data points 10 to 15° above 45°F. It is not advisable to store animal health products at this temperature, and it was recommended to the producer to dispose of all animal health products stored in this refrigerator.

The refrigerator in Figure 6 illustrates 2 points. First, temperature varied from approximately < 45° to < 30°F during the first 12 to 14 h after data logger insertion. It appeared the condenser was on an approximately 1-h defrost cycle causing the temperature variation. Secondly, refrigerator temperature got as low as < 30°F 5 times in 24 h.

All refrigerators require general maintenance, and it is important to keep the refrigerator coils clean. Refrigerator coils are located in the rear of the refrigerator and can be cleaned by vacuuming the vents and coils. Dusty coils have to work harder to cool down the interior and contents of the refrigerator.

The drip pan, located beneath the refrigerator, should also be cleaned. In automatic defrost models, the water from the defrost process flows out a drain in the floor of the refrigerator and into a pan where it sits until evaporating. Food particles can be carried along and clog the drain or be left behind to rot. You can clear out the tube that carries particles to the pan by removing the stopper at the opening. Stick a pipe cleaner or similar device into the opening to push any particles through to the pain. Flush with soapy water and then empty and clean the pan.

The gaskets are the seals that keep cold air in and the room air out of the refrigerator, and the gaskets should last the life of the refrigerator if properly cared for. Gaskets should be washed with soapy water, and the "paper test" can be used to test the condition of the gasket. You should not be able to slide a piece of paper between the rubber seal and the wall of the refrigerator. If the piece of paper slips between the seal and the wall, the seal is not tight enough and the gasket requires replacement.

Consider the location of your refrigerator and/or freezer. Do not position them in direct contact with hot appliances as this will make the compressor work harder. Regularly defrost manual-defrost freezers, never allowing frost to build up more than 0.25 in.

Implications

This demonstration assisted producers in determining if they are storing animal health products according to labeled instructions. When animal health products are stored incorrectly, the effectiveness of animal health products may become compromised. All animal health products that are past their expiration date or opened should be disposed of properly.

Literature Cited

APHIS. Title 9 – Animals and Animal Products. Chapter I, Part 114 – Production requirements for biological products. 2007. Code of Federal Regulations. Title 9, Volume 1.

Arkansas Beef Quality Assurance Handbook. 2006. Fourth Edition. Editors: T.R. Troxel and J. Powell. University of Arkansas Division of Agriculture Cooperative Extension Service. Little Rock, Ark.

Table 1. The least square means (± SE) for average temperature, number of data points below 35° and above 45° F, and the percentage of data points below 35° and above 45° F stratified across refrigerator owners, refrigerator location, refrigerator type and refrigerator age.

Item	Average temperature	Number of points below 35°	Number of points above 45°	Percentage of points below 35°	Percentage of points above 45°
Owner:					
Producer	39.3 ± 1.52	77.4 ± 27.39	39.3 ± 17.46	26.9 ± 9.51	13.6 ± 6.06
Retail store	40.8 ± 2.23	50.2 ± 40.16	43.6 ± 25.61	17.4 ± 13.95	15.1 ± 8.89
Veterinarian clinics	41.6 ± 2.74	52.5 ± 49.30	94.0 ± 31.44	18.2 ± 17.12	32.6 ± 10.92
Location:					
Mud room	45.1 ± 2.96^{a}	6.0 ± 53.36^{a,b}	128.4 ± 34.02^{a}	20.1 ± 18.53^{a,b}	44.6 ± 11.82^{a}
Kitchen	42.6 ± 2.07^{a,b}	8.8 ± 37.28^{b}	72.4 ± 23.7^{a,b}	3.0 ± 12.95^{b}	25.1 ± 8.26^{a,b}
Other	39.3 ± 1.62^{b}	83.9 ± 29.07^{a}	40.4 ± 18.54^{b}	29.2 ± 10.09^{a}	14.0 ± 6.43^{b}
Barn	38.6 ± 2.24^{b}	80.6 ± 40.34^{a,b}	34.6 ± 25.72^{b}	28.0 ± 14.00^{a,b}	12.0 ± 8.93^{b}
Tack room	37.3 ± 2.87^{b}	120.8 ± 51.67^{a}	18.9 ± 32.95^{b}	41.9 ± 17.94^{a}	6.6 ± 11.44^{b}
Refrigerator type:					
Side by side	38.4 ± 1.81	90.6 ± 32.59	43.4 ± 20.78	31.4 ± 11.32	15.1 ± 7.22
Freezer on top	39.0 ± 1.45	91.6 ± 26.18	46.5 ± 16.69	31.8 ± 9.09	16.2 ± 5.80
Freezer on bottom	43.0 ± 6.59	18.0 ± 118.67	37.1 ± 75.67	6.3 ± 41.21	12.9 ± 26.3
Mini refrigerator	41.1 ± 1.71	74.1 ± 30.82	90.0 ± 19.66	25.7 ± 10.70	31.2 ± 6.83
Other	41.4 ± 1.91	25.8 ± 34.31	77.7 ± 21.88	9.0 ± 11.92	27.0 ± 7.60
Refrigerator age:					
≤ 5 yr	39.8 ± 2.07	67.4 ± 37.32	48.1 ± 23.80	23.4 ± 12.96	16.7 ± 8.26
6 to 10 yr	39.2 ± 1.81	75.9 ± 32.56	43.0 ± 20.76	26.4 ± 11.31	14.9 ± 7.21
11 to 15 yr	41.4 ± 2.15	34.3 ± 38.56	63.5 ± 24.59	11.9 ± 13.39	22.1 ± 8.54
>15 yr	41.9 ± 2.13	62.5 ± 38.38	81.1 ± 24.47	21.7 ± 13.32	28.1 ± 8.50

^{a,b} Within a column and category, least squares means lacking a common superscript letter differ ($P < 0.05$).

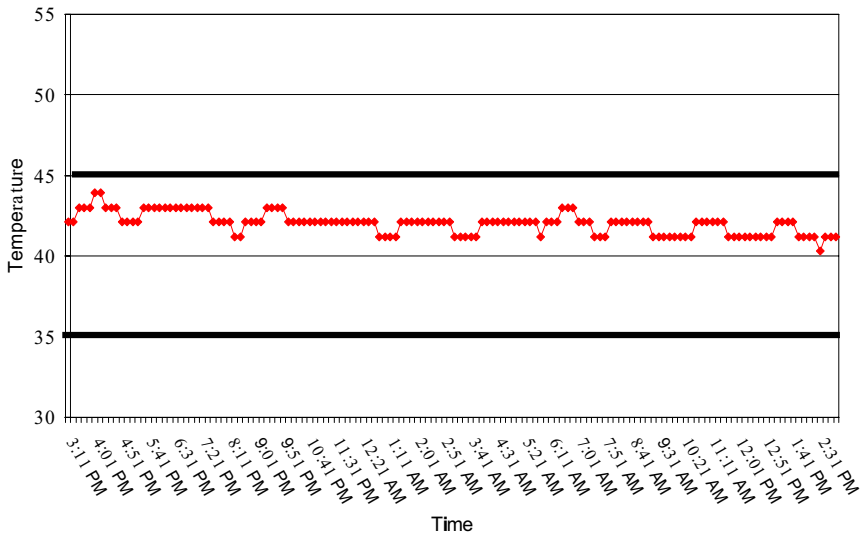

Fig. 1. An example of a refrigerator that kept a constant temperature between 35° and 45°F within a 24-h period.

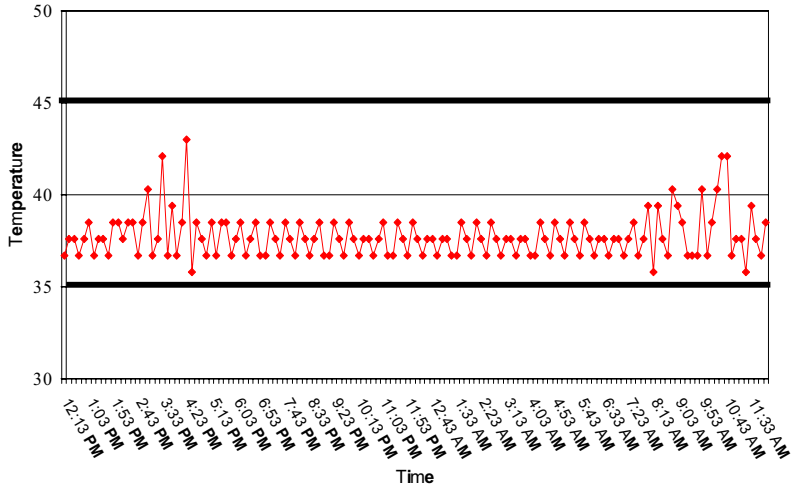

Fig. 2. An example of a refrigerator that kept the temperature between 35° and 45°F but showed some variation within a 24-h period.

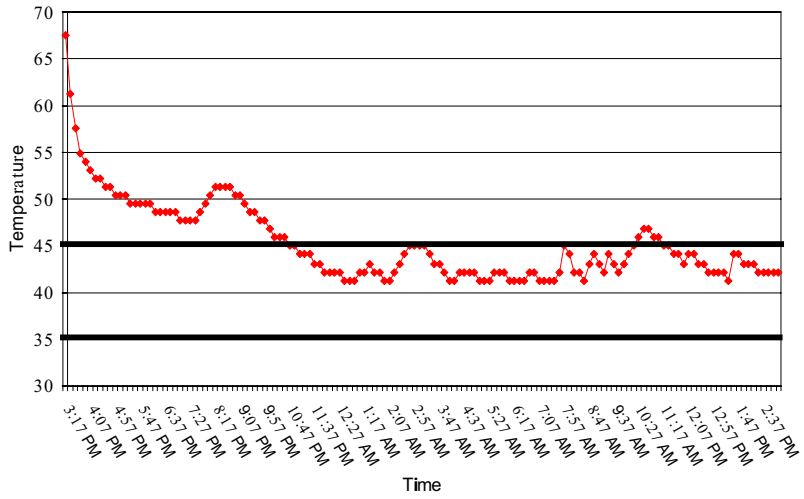

Fig. 3. An example of a refrigerator that took approximately 7.5 h before the temperature was below 45°F.

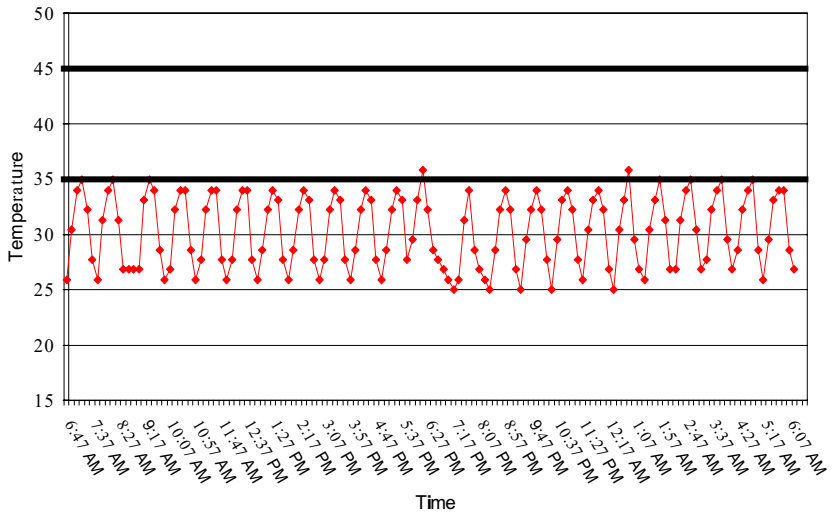

Fig. 4. An example of a refrigerator that kept the temperature below 35°F (except for two data points) and showed an approximately 10 degree variation every 50 min over a 24-h period.

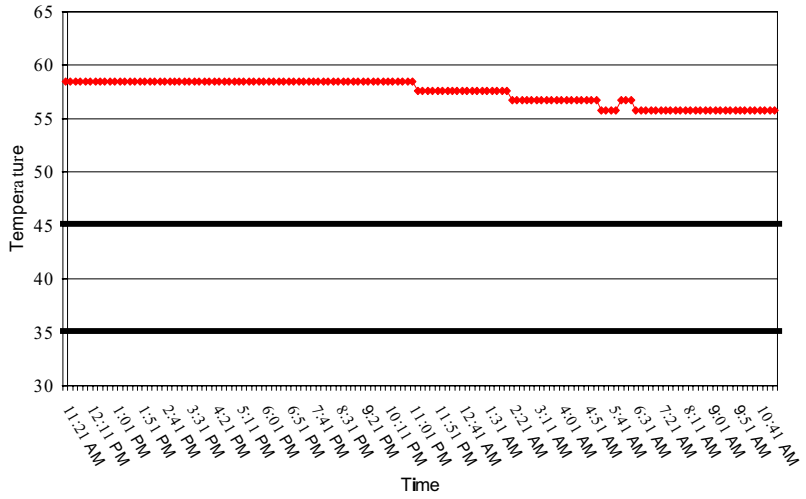

Fig. 5. An example of a refrigerator that kept the temperature above 45°F over a 24-h period.

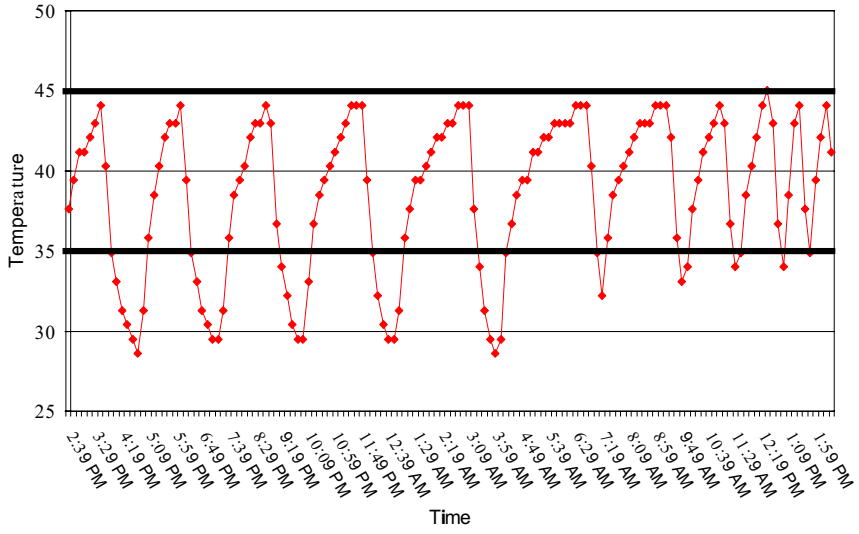

Fig. 6. An example of a refrigerator that demonstrated an approximately 15 degree variation every 2 h and dropped the temperature below 30°F 5 times over a 24-h period.