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D. Wayne Kellogg
Editors

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ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT 2006

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INTRODUCTION

The faculty and staff of the Department of Animal Science are pleased to present the ninth edition of the Arkansas Animal Science Department Report. We owe a great debt to Drs. Zelpha Johnson and Wayne Kellogg who have edited this publication since 1999 and to Dr. Stacey Gunter who designed the format and edited the first edition in 1998. This publication has been valuable to the Department and its stakeholders.

Research is wasted unless it is presented to those who supported it and should benefit from it. While peer-reviewed journals are the ultimate sites for research publication, the timelines for journal publication usually stretch over a couple of years. Stakeholders, researchers, extension faculty and industry professionals need to see results more quickly. Too often useful and well-designed research does not get published in peer-reviewed journals because the studies were not comprehensive enough to pass the exhaustive tests for journal acceptance. Hence, there is the need for a publication format that lets stakeholders read the breadth of research ongoing at the Department of Animal Science.

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 in Monticello, and the Livestock and Forestry Branch Station near Batesville. Additionally, valuable work was conducted on private dairies and beef cattle operations across the state.

Readers are invited to view all programs of the Department of Animal Science at the Departmental website at www.anschome.com, the Extension website at www.uaex.edu, and the Livestock and Forestry Branch Station website at www.batesvillestation.org.

Finally, we want to thank the many supporters of our teaching, research and extension programs. Whether providing grants for research and extension, funds for scholarships, supporting educational and extension programs, 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 reported herein to be timely, useful, and making a contribution to the field of Animal Science.

Sincerely,

Keith Lusby
Department Head

Tom Troxel
Professor and Associate 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 .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
°C	Degrees Celsius
°F	Degrees Fahrenheit
ft	Foot or feet
g	Grams(s)
gal	Gallon(s)
in	Inch(es)
IU	International unit(s)
kcal	Kilocalories(s)
kg	Kilograms(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	Days(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
Ca	Calcium
CP	Crude protein
CV	Coefficient of variation
cwt	100 pounds
DM	Dry matter
DMI	Dry matter intake
DNA	Deoxyribonucleic acid
EPD	Expected progeny difference
F/G	Feed:gain ratio
FSH	Follicle stimulating hormone
K	Potassium
LH	Lutenizing hormone
N	Nitrogen
NDF	Neutral detergent fiber
NEg	Net energy for gain
MEm	Net energy for maintenance
NS	Not significant
P	Phosphorus
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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Injection of Conjugated Lineolic Acid into Beef Strip Loins

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Story in Brief

Beef strip loins (IMPS 180; n=15) were sectioned in thirds, and sections (n = 45) were left untreated (CNT) or injected with either a commercial powder conjugated linoleic acid (CLA) source (Powder) or a commercial oil CLA source (Oil), whose major isomers were 18:2*cis*-9, *trans*-11 and 18:2*trans*-10, *cis*-12 CLA isomers. Fresh Oil steaks had 0.320 and 0.315, Powder steaks had 0.467 and 0.462, and CNT steaks had 0.019 and 0.002% of muscle tissue (wet basis) of the *cis*-9, *trans*-11 and *trans*-10, *cis*-12 CLA isomers, respectively. Lipid oxidation (TBARS) was similar for Oil-treated steaks and lower for Powder-treated steaks, compared to CNT steaks. Powder steaks had similar beef and off flavor characteristics as CNT. Artificial marbling was created with Oil steaks having USDA Small[79] and Powder steaks having USDA Modest[86] marbling scores, while CNT steaks had USDA Slight[94] marbling scores. Injection of CLA can be effective in significantly increasing CLA and potentially creating artificial marbling.

Introduction

Conjugated linoleic acids (CLA) have recently received considerable attention due to possible human health benefits in regard to anticarcinogenicity, cardiovascular health, immune modulation, and lean body mass/fat reduction benefits. Two CLA isomers that are the focus of attention are 18:2*cis*-9, *trans*-11 and 18:2*trans*-10, *cis*-12. These isomers are used in medical research and are typically the 2 major CLA isomers in meat animal lipid fractions, with the *cis*-9, *trans*-11 isomer predominating.

Because of human health interest and animal lipids naturally having higher concentrations of these 2 isomers of CLA, animal and meat scientists have focused on animal diet modulation to enhance CLA in the meat/milk lipids. Studies invoking diet modulation have experienced success in heightening CLA levels in lean tissue lipids of swine and ruminants. However, the increased CLA in the lean tissue lipid fraction of meat animals due to diet modulation, would require complete human dietary lifestyle changes to attain the levels of CLA necessary for possible health benefits. Greater concentrations of CLA in meat tissues are required than is currently available to provide levels necessary for possible health benefits in smaller portion sizes. Therefore, the objective of this study was to determine the effects of injection of 2 commercial sources of CLA into beef strip loins on fatty acid composition, meat quality, retail display, and sensory characteristics.

Experimental Procedures

Fresh beef strip loins (IMPS 180; n = 15) from USDA Select carcasses were obtained from a commercial packing plant, transported to the University of Arkansas red meat abattoir and stored at 34°F until 14 d postmortem. Muscles were subsequently removed from vacuum-sealed bags and all external fat and adjacent muscles were removed from the *longissimus* muscle. Each muscle was transversely sectioned in thirds, allowing for muscle section as the experimental unit (n = 45).

Three treatments were allocated to the sections within each muscle, such that each muscle comprised all 3 treatments (n = 15 per treatment; equally represented at anterior, medial, and posterior positions across muscles). The 3 treatments were an untreated control (CNT), and 2 commercial sources of CLA. One commercial source of CLA was a water-soluble milk powder base (Powder; Tonalin® 60 WDP, Cognis Corp., Cincinnati, Ohio) and the other commercial source was a triglyceride safflower oil base (Oil; Tonalin® TG80, Cognis Corp., Cincinnati, Ohio). Each of the CLA sources predominated in approximately equal concentrations of the *cis*-9,*trans*-11 and *trans*-10,*cis*-12 CLA isomers. Complete fatty acid profiles of the 2 CLA sources are presented in Table 1. Both CLA sources were mixed in 37°F tap water. The powder source was directly added to the water and mixed with a Rotosolver® high-shear mixer (Admix, Inc., Manchester, N.H.). For the oil source, lecithin (Thermolec WFC®, ADM, Decatur, Ill.) was utilized as an emulsifier and was added to the solution at 15% of the oil concentration. The solutions for both CLA treatments were injected into the strip loins at 110% of fresh product weight via a Fomaco 20/40 injector (Reiser Inc., Canton, Mass.) comprising 80 needles with 4 needles/1.97 in^2. Following injection, muscle sections from all 3 treatments were then reweighed, vacuum-packaged and stored at 34°F for approximately 48 h.

At 2 d post-enhancement, muscles were removed from their packages, pH was measured with a probe-type pH meter (Meat Probes, Inc., Topeka, Kan.). Muscle sections were then cut into 1 in steaks for the respective analyses. At this time 3 steaks from each muscle section were vacuum-packaged and stored at 34°F for subsequent fatty acid analysis, Warner-Bratzler shear force, and sensory evaluation. The remaining fabricated steaks were placed on foam trays with absorbent pads and overwrapped with polyvinyl chloride film with an oxygen transmission rate of 14,020 cc $O_2/m^2/24h/atm$-60 gauge (PrimeSource®, Koch Supplies, Inc., Kansas City, Mo.). Those steaks, designated for thiobarbituric acid reactive substances (TBARS), were stored under simulated retail conditions (37°F; deluxe warm white fluorescent lighting, 1600 lx, Philips, Inc., Somerset, N.J.) for 7 days. All analyses were performed on fresh muscle samples.

[1] Tyson Foods, Inc., Springdale, Ark.
[2] Department of Animal Science, Fayetteville
[3] Department of Food Science, Fayetteville

For Warner-Bratzler shear force (day 6 post-enhancement) steaks (1-in thick) were removed from their vacuum-sealed packages and cooked in a Blodgett forced-air convection oven (Blodgett Oven Co., Burlington, VT) until the internal temperature of each steak was 158°F. Internal temperature was monitored using Teflon-coated copper-constantan thermocouples (Omega Engineering, Inc., Stamford, Conn.) attached to a Doric multichannel data logger (VAS Engineering, Inc., San Diego, Calif.). After cooking, steaks were allowed to cool to room temperature for approximately 2 h. Upon cooling to room temperature, six 0.50-in diameter cores were taken parallel to the muscle fibers from each steak for Warner-Bratzler shear force (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 110-lb load cell and 9.84-in/min crosshead speed.

Cooking loss of the steaks was determined during the cooking process for WBS. After steaks were removed from the vacuum-sealed packages, each steak was weighed on a balance prior to cooking. Upon completion of cooking, a final weight was obtained and cooking loss was determined as the difference between the fresh and cooked weight divided by the fresh weight x 100.

On days 2, 3, and 4 post-enhancement, sensory evaluation was conducted across 5 sessions with 3 replicates of each treatment represented each session. Prior to each sensory session, the designated steaks were removed from their vacuum-sealed packages and cooked as previously described for Warner-Bratzler shear force. Immediately after cooking, steaks were cut into 0.39 in x 0.39 in x 1 in pieces and held in a food warmer (Alto-Shamm, Inc., Menomonee Falls, Wis.) at 145°F for approximately 10 min prior to sensory evaluation and during the evaluation process. Samples (9) were served in a random order to each panelist, each session. Sensory panelists (9) were selected and trained according to AMSA (1995) guidelines. Each panelist was allowed to evaluate each sample at his/her own pace. Panelists evaluated myofibrillar and overall tenderness, connective tissue amount, juiciness and beef flavor on an 8-point scale (1 = extremely tough, abundant, extremely dry, extremely non-beef like; 8 = extremely tender, none, extremely juicy, extremely beef like). Panelists also evaluated samples for off flavor intensity on a 5-point scale (1 = extreme off flavor, 5 = no off flavor). Tests were conducted under color neutralizing lights with partitioned booths to isolate panelists.

Marbling scores of all steaks were assessed by 3 experienced individuals on day 0 of display due to an artificial marbling effect from the CLA treatments. Marbling scores were assigned to each steaks using USDA marbling photographs (National Cattlemen's Beef Association, Centennial, Colo.).

On day 0, 3, and 6 of simulated retail display 15 steaks (n = 5 per treatment/day) were sampled for TBARS (ppm malonaldehyde) as previously described by Jimenez-Villarreal et al. (2003) to assess the degree of lipid oxidation.

On day 4 post-enhancement, steaks utilized for fatty acid analysis were removed from vacuum-sealed packages and sectioned transversely in half, such that one half was utilized for fresh, uncooked fatty acid analysis and the other was utilized for cooked fatty acid analysis. Cooked sections were cooked as previously described for Warner-Bratzler shear force. Fresh and cooked samples were cubed, and 0.53 oz from each sample were freeze-dried in duplicate for 96 h utilizing a vacuum pressure of < 10 microns Hg at < - 58°F on a freeze dryer (Labconco Corp., Kansas City, Mo.). After drying, moisture percentage was calculated as the difference between the wet and dry sample weights divided by the wet weight multiplied by 100. Duplicates from each sample were then commingled and ground using a home-style electric coffee grinder. Ambient air exposure was minimized to avoid moisture uptake by samples.

Direct transesterification of duplicate 0.01 oz of dried muscle tissue from each sample was performed based on the methodology of Murrieta et al. (2003) using 0.2 M KOH in anhydrous methanol as the catalyst and tridecanoic acid as the internal standard. Fatty acid methyl esters were separated using a Hewlett-Packard 5890 GLC (Hewlett-Packard, Avondale, Pa.) equipped with a flame ionization detector and a 109.36 yds x 0.01 (i.d.) fused silica capillary column (SP-2560, 7.874×10^{-6} in film thickness, Supelco, Bellefonte, Pa.). Oven temperature was maintained at 324°F for 32 min, then increased at 35°F/min to 383°F and held for 15 min, followed by an increase to 455°F at 36°F/min and held for 5 min. Injector and detector temperatures were 482°F. Helium was the carrier gas with a split ratio of 50:1 and a 7.87-in/sec column flow. Fatty acids were identified by comparing retention times with fatty acid methyl ester standards (Matreya, Inc., Pleasant Gap, Pa., Nu-Chek Prep, Inc., Elysian, Minn., Supelco, Bellefonte, Pa.) and are reported as % wet tissue.

Data were analyzed via PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.) with the fixed effect of treatment and the random effect of muscle as independent variables in the model. Day and the day x treatment interaction were included in the model for retail display variables. Panelist was included in the model for sensory color and taste data. Cooked and fresh fatty acid data were analyzed independently to directly assess treatment effects in the cooked or fresh state. For all variables, means were generated using LSMEANS and when significant ($P < 0.05$) F values were observed, were separated with the PDIFF option.

Results and Discussion

Untreated steaks (CNT) had the least ($P < 0.05$) whole muscle and retail purge, and Oil steaks had the greatest ($P < 0.05$) whole muscle purge, with steaks from the 2 CLA treatments having similar ($P > 0.05$) retail purge (Table 2). Steaks from both CLA treatments were similar ($P > 0.05$) in cooked losses, and both had higher ($P < 0.05$) cooked losses than CNT. There were no differences ($P > 0.05$) in muscle pH among the treatments. The increased purge from the solution-enhanced treatments was expected without the addition of phosphate, sodium chloride, or other binders to help retain the solution.

Artificial marbling was observed in steaks treated with the CLA sources. Marbling scores revealed that steaks from both CLA treatments increased ($P < 0.05$) marbling compared to CNT, and Powder steaks had higher ($P < 0.05$) marbling scores than Oil (Table 2). The CNT steaks had USDA Slight marbling scores, whereas Oil had USDA Small marbling scores and Powder had USDA Modest marbling scores, with Powder steaks having approximately 2 full marbling grade scores higher than CNT. This was a profound effect, particularly because all treatments were represented in each muscle, and also equally represented at the anterior, medial, and posterior positions of muscles.

Steaks from both CLA treatments required less ($P < 0.07$) shear force than CNT steaks (Table 2). The decreased shear force from the CLA treatments is probably an effect of the needles invoking mechanical tenderization on the muscles more so than the impact of lipid/solution incorporation. Likewise, steaks from both CLA treatments were rated more tender ($P < 0.05$) than CNT for myofibrillar, connective tissue, and overall tenderness (Table 3).

However, there was a trend ($P = 0.06$) for Powder steaks to be juicier than CNT or Oil steaks. The improved juiciness relative to CNT is probably due to the direct affect of solution addition, and improved juiciness for Powder relative to Oil is probably due to decreased whole-muscle purge with similar cooking losses.

Sensory appraisal of flavor indicated that Oil steaks had decreased ($P < 0.05$) beef flavor and increased ($P < 0.05$) off flavor compared to CNT or Powder, with CNT and Powder steaks being similar ($P > 0.05$) in flavor. The powder steaks having similar flavor as CNT and Oil having greater off flavors may be a result of the solution ingredients. The Powder treatment had a dried milk base that may have invoked milder flavor than the Oil treatment's oil and lecithin ingredients causing increased off flavor and diluted beef flavor. Flavor may also have been influenced by treatment impacts on lipid oxidation as is subsequently discussed for TBARS.

There was a significant ($P < 0.05$) day x treatment interaction for TBARS of steaks during display (Fig. 1). While there were no differences ($P > 0.05$) in TBARS at the beginning of display, Powder steaks had lower ($P < 0.05$) TBARS than CNT or Oil on days 3 and 6 of display, indicating decreased oxidation during display for steaks from this treatment. Likewise, the greater lipid oxidation for Oil steaks compared to Powder steaks may also be due to the addition of lecithin in the enhancement solution of the Oil treatment and the oxidation of polyunsaturated fatty acids from the phospholipid fraction of the lecithin.

Fatty acid profiles were obtained on fresh (Table 4) and cooked (Table 5) samples to assess the concentrations of the 2 CLA isomers post-injection for retention, and to assess the concentrations post-cooking that would be consumed. Fresh steaks from both CLA treatments had greater ($P < 0.05$) concentrations of the *cis*-9,*trans*-11 and *trans*-10,*cis*-12 isomers than untreated steaks, and Powder steaks had greater ($P < 0.05$) concentrations of these 2 isomers than Oil steaks. The increase in CLA was of large magnitude with Powder steaks and Oil steaks having approximately 1,600% and 2,500% increases in the *cis*-9,*trans*-11 isomer compared to CNT steaks, respectively. The increase in the *trans*-10,*cis*-12 isomer, compared to CNT steaks, was approximately 16,000% and 23,000% for Oil and Powder steaks, respectively.

Cooked samples from CNT and Oil treatments had numerically higher concentrations of both CLA isomers than their respective fresh samples, indicating retention of CLA combined with water losses for greater concentration expressions per unit of wet sample weight. However, cooked Powder steaks had numerically similar concentrations of both CLA isomers as fresh Powder steaks. This may have resulted from the Powder CLA source being water dispersible and being lost with the water fraction during cooking. While cooked steaks from both CLA treatments had greater ($P < 0.05$) concentrations of both CLA isomers than cooked CNT steaks, the loss of CLA with moisture during cooking for Powder steaks caused cooked Oil steaks to have greater ($P < 0.05$) concentrations of both CLA isomers than cooked Powder steaks. Even so, both CLA treatments substantially increased concentrations of the *cis*-9, *trans*-11 and *trans*-10, *cis*-12 isomers.

Implications

Injection of either a powderized CLA source or an oil CLA source dramatically increased the proportions of the *cis*-9, *trans*-11 and *trans*-10, *cis*-12 isomers of CLA. This effect would allow for the levels of CLA utilized for potential health benefits in medical studies to be consumed by individuals in relatively small portions, as opposed to complete dietary adjustments. Additionally, injection of the powderized CLA source created artificial marbling in steaks that increased visual appraisal of marbling by 2 full USDA marbling scores. Injection of CLA could have potential as a value-addition/fortification tool for beef products in terms of health implications and/or artificial marbling, and warrants further research.

Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. The support of Tyson Foods, Inc., Springdale, Ark., and Astaris, LLC, St. Louis, Mo., during these trials is also appreciated. Additionally, the authors would like to express their gratitude to S.A. Quilo, C.W. Rowe, and J. Stephenson for their assistance during these trials.

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Table 1. Fatty acid profile of Oil and Powder commercial sources of conjugated linoleic acid (CLA).

Fatty acid, % sample	Commercial CLA Oil product	Commercial CLA Powder product
16:0	0.122	0.487
18:0	2.601	2.023
18:1*cis*-9	14.84	11.64
18:1*cis*-11	0.852	0.677
18:2*cis*-9,*trans*-12	0.407	0.326
18:2*cis*-9,*trans*-11	40.55	30.53
18:2*trans*-10,*cis*-12	40.69	30.699
18:2*trans*-9,*trans*-11	0.696	0.517
18:2*cis*-9,*cis*-11	1.159	0.802
20:0	0.00	0.019
21:0	0.994	0.725

Table 2. Treatment effects for *longissimus* pH, purge, marbling, Warner-Bratzler shear force, cooking loss and retail purge traits.

	Post pH[a]	Purge[b]	Marbling[c]	Warner-Bratzler shear force (N)	Cooking loss[d]	Retail purge[e]
Untreated	5.71	0.68^{y}	394.7^{y}	29.56	24.54^{x}	5.75^{x}
CLA Oil	5.70	2.61^{w}	478.9^{x}	22.61	28.64^{w}	6.90^{w}
CLA Powder	5.72	1.76^{x}	586.2^{w}	24.52	28.51^{w}	6.64^{w}
SEM	0.01	0.14	14.0	2.24	0.66	0.30

[a]Muscle pH post-equilibration.
[b]Whole muscle equilibration purge: (pre-equilibration wt-post-equilibration wt)/pre-equilibration wt x 100.
[c] 300-399 = Slight; 400-499 = Small; 500-599 = Modest.
[d]Cooking loss = (pre-cooked wt - cooked wt)/pre-cooked wt x 100.
[e]Retail purge = (day 0 steak wt - day 6 steak wt)/day 0 steak wt x 100.
[wxy]Trait means with different superscripts differ ($P < 0.05$).

Table 3. Treatment effects for sensory taste panel characteristics.

	Myofibrillar Tenderness[a]	Connective tissue amount[a]	Overall Tenderness[a]	Juiciness[a]	Beef flavor[b]	Off flavor[c]
Untreated	6.55^{x}	6.70^{x}	6.65^{x}	6.55	7.25^{w}	4.69^{w}
CLA Oil	7.12^{w}	6.98^{w}	7.07^{w}	6.61	6.96^{x}	4.25^{x}
CLA Powder	7.17^{w}	6.98^{w}	7.08^{w}	6.85	7.13^{wx}	4.55^{w}
SEM	0.13	0.11	0.12	0.15	0.09	0.07

[a] 1-8: 1 = extremely tough, abundant, extremely dry; 8 = extremely tender, none, extremely juicy.
[b] 1-8: 1 = extremely non-beef like; 8 = extremely beef like.
[c] 1-5: 1 = extreme off-flavor; 5 = no off-flavor.
[wxy]Trait means with different superscripts differ ($P < 0.05$).

Table 4. Treatment effects for fresh, uncooked *longissimus* fatty acid profiles.

Fatty acid , % wet tissue	Untreated	CLA Oil	CLA Powder	SEM
10:0	0.003	0.002	0.002	0.0003
12:0	0.004	0.003	0.003	0.0006
14:0	0.161	0.142	0.143	0.021
14:*cis*-9	0.038	0.033	0.033	0.006
15:0	0.021	0.018	0.018	0.003
16:0	1.276	1.187	1.151	0.117
16:1*trans*-9	0.012	0.01	0.01	0.001
16:1*cis*-9	0.196	0.183	0.176	0.022
17:0	0.053	0.046	0.046	0.006
17:1*trans*-10	0.000	0.001	0.001	0.0002
18:0	0.626	0.618	0.611	0.051
18:1*trans*[a]	0.169	0.140	0.140	0.029
18:1*cis*-9	1.803	1.82	1.836	0.159
18:1*cis*-11	0.09	0.09	0.092	0.008
18:2*cis*-9,*trans*-12	0.207^{x}	0.25^{w}	0.206^{x}	0.015
18:2*cis*-9,*trans*-11	0.019^{y}	0.32^{x}	0.467^{w}	0.031
18:2*trans*-10,*cis*-12	0.002^{y}	0.315^{x}	0.462^{w}	0.032
18:2*trans*-9,*trans*-11	0.000^{y}	0.008^{x}	0.017^{w}	0.002
18:2*cis*-9,*cis*-11	0.000^{y}	0.013^{x}	0.019^{w}	0.001
18:3*cis*-9,12,15	0.014	0.012	0.015	0.001
20:0	0.001	0.001	0.001	0.0003
20:1*cis*-11	0.004^{x}	0.01^{w}	0.003^{x}	0.001
20:3*cis*-8,11,14	0.010	0.011	0.010	0.001
20:4*cis*-5,8,11,14	0.037	0.038	0.037	0.002
20:5*cis*-5,8,11,14,17	0.002	0.001	0.002	0.0007
22:5*cis*-7,10,13,16,19	0.008	0.007	0.008	0.0008
n-6/n-3[b]	1.169^{x}	1.513^{w}	1.143^{x}	0.126
Saturates[c]	2.143	2.017	1.974	0.195
Monounsaturates[d]	2.312	2.285	2.292	0.215
Polyunsaturates[e]	0.300^{y}	0.978^{x}	1.24^{w}	0.071
Total *trans*[f]	0.182	0.160	0.169	0.030

[a]Comprises all 18:1*trans* isomers.
[b]n-6/n-3: (18:2*cis*-9,*trans*-12+20:3*cis*-8,11,14+20:4*cis*-5,8,11,14) / (18:3*cis*-9,12,15+20:5*cis*-5,8,11,14,17+ 22:5*cis*-7,10,13,16,19).
[c]Saturates= Fatty acids with no double bonds.
[d]Monosaturates= Fatty acids with one double bond.
[e]Polyunsaturates= Fatty acids with 2 or more double bonds.
[f]Total *trans*= 16:1*trans*-9+17:1*trans*-10+18:1*trans*+18:2*trans*-9,*trans*-11.
[wxy]Within a row, means with different superscripts differ ($P < 0.05$).

Table 5. Treatment effects for cooked *longissimus* fatty acid profiles.

Fatty acid, % wet tissue	Untreated	CLA Oil	CLA Powder	SEM
10:0	0.004	0.004	0.004	0.001
12:0	0.005	0.005	0.005	0.0007
14:0	0.252	0.225	0.238	0.029
14:*cis*-9	0.057	0.051	0.055	0.007
15:0	0.033	0.029	0.031	0.004
16:0	2.037	1.922	1.969	0.181
16:1*trans*-9	0.021	0.019	0.019	0.002
16:1*cis*-9	0.310	0.284	0.297	0.030
17:0	0.086	0.079	0.081	0.009
17:1*trans*-10	0.003	0.002	0.001	0.0008
18:0	1.067	1.045	1.049	0.097
18:1*trans*[a]	0.273	0.243	0.248	0.042
18:1*cis*-9	2.999	3.037	3.004	0.281
18:1*cis*-11	0.143	0.152	0.145	0.013
18:2*cis*-9,*trans*-12	0.331^{x}	0.417^{w}	0.340^{x}	0.020
18:2*cis*-9,*trans*-11	0.033^{y}	0.646^{w}	0.466^{x}	0.039
18:2*trans*-10,*cis*-12	0.001^{y}	0.635^{w}	0.452^{x}	0.039
18:2*trans*-9,*trans*-11	0.000^{y}	0.021^{w}	0.012^{x}	0.003
18:2*cis*-9,*cis*-11	0.000^{y}	0.023^{w}	0.015^{x}	0.001
18:3*cis*-9,12,15	0.024	0.020	0.024	0.003
20:0	0.003	0.003	0.002	0.0008
20:1*cis*-11	0.008^{x}	0.020^{w}	0.007^{x}	0.001
20:3*cis*-8,11,14	0.017	0.017	0.018	0.001
20:4*cis*-5,8,11,14	0.056	0.056	0.060	0.003
20:5*cis*-5,8,11,14,17	0.003	0.003	0.004	0.0012
22:5*cis*-7,10,13,16,19	0.013	0.012	0.014	0.001
n-6/n-3[b]	1.161^{x}	1.529^{w}	1.142^{x}	0.13
Saturates[c]	3.486	3.312	3.380	0.30
Monounsaturates[d]	3.814	3.810	3.776	0.363
Polyunsaturates[e]	0.477^{y}	1.853^{w}	1.403^{x}	0.088
Total *trans*[f]	0.296	0.285	0.280	0.044

[a]Comprises all 18:1*trans* isomers.
[b]n-6/n-3: (18:2*cis*-9,*trans*-12+20:3*cis*-8,11,14+20:4*cis*-5,8,11,14) / (18:3*cis*-9,12,15+20:5*cis*-5,8,11,14,17+ 22:5*cis*-7,10,13,16,19).
[c]Saturates= Fatty acids with no double bonds.
[d]Monosaturates= Fatty acids with one double bond.
[e]Polyunsaturates= Fatty acids with 2 or more double bonds.
[f]Total *trans*= 16:1*trans*-9+17:1*trans*-10+18:1*trans*+18:2*trans*-9,*trans*-11.
[wxy]Within a row, means with different superscripts differ ($P < 0.05$).

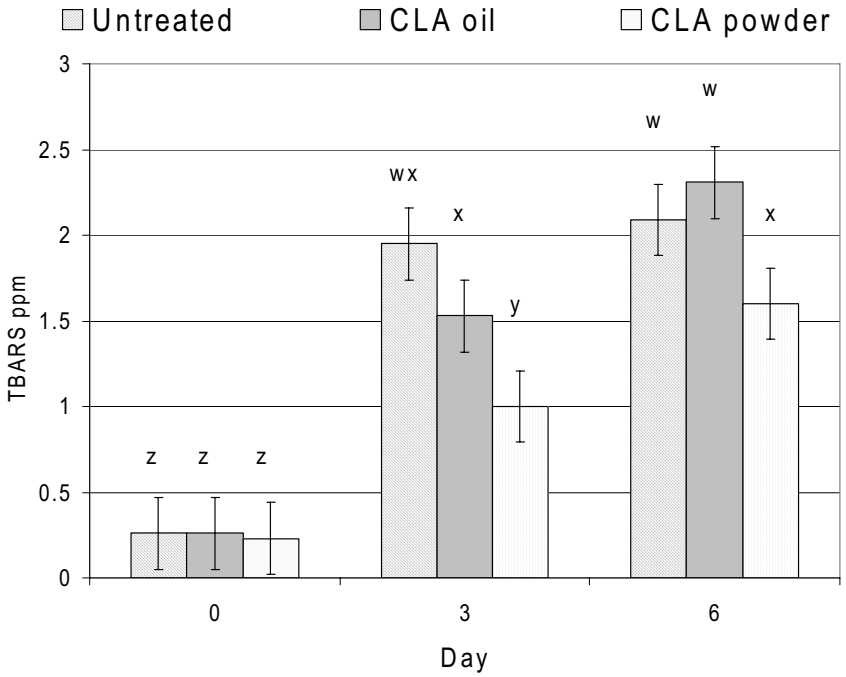

Fig. 1. Treatment x day interaction for TBARS (lipid oxidation; thiobarbituric acid reactive substances) of *longissimus* steaks during simulated retail display. Columns with different superscripts differ (P < 0.05).

Effect of Potassium Lactate, Sodium Metasilicate, Peroxyacetic Acid or Acidified Sodium Chlorite as Single Antimicrobial Interventions on Un-inoculated Beef Trimmings Prior to Grinding on Ground Beef Instrumental Color and Lipid Characteristics

F.W. Pohlman, P.N. Dias-Morse, and S.A. Quilo[1]

Story in Brief

Antimicrobial treatments on beef trimmings prior to grinding on ground beef instrumental color and lipid characteristics through display were evaluated and compared to an untreated control (CON). Beef trimmings were treated with 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 0.1% acidified sodium chlorite (ASC), or 0.02% peroxyacetic acid (PAA) prior to grinding. Ground beef was packaged and sampled at 0, 1, 2, 3, and 7 d of simulated retail display. Instrumental color results indicated that PAA produced lighter ($P < 0.05$) color ground beef compared with all the other treatments. The NMS-treated samples had higher ($P < 0.05$) oxymyoglobin content compared with other treatments. Ground beef made from KL, NMS and ASC treated trimmings maintained a similar ($P > 0.05$) redness to CON on day 0; however, ground beef from CON exhibited less ($P < 0.05$) redness and vividness compared to other treatments from 1 to 3 d of display. Additionally, all antimicrobial-treated ground beef had lower ($P < 0.05$) thiobarbituric acid reactive substances (TBARS) values compared with CON throughout display. These findings indicated that the use of tested antimicrobial agents on beef trimmings does not adversely affect instrumental color characteristics of ground beef, and may improve the oxidative stability of ground beef during retail display.

Introduction

Many studies have shown that decontamination of beef trimmings prior to grinding with antimicrobial agents could improve the microbiological quality of ground beef. Researchers found that treating beef trimmings with 1% ozonated water for 15 min or with 10% chlorine dioxide (Stivarius et al., 2002a), 5% acetic acid or 5% gluconic acid (Stivarius et al., 2002b), or 0.5% cetylpyridinium chloride and/or 10% trisodium phosphate (Pohlman et al., 2002) could reduce microbial pathogens in ground beef.

Meat color is an important factor that primarily determines the purchasing decision of the consumer. Previous studies shave discovered that application of antimicrobials on beef trimmings prior to grinding could adversely affect the ground beef color (Stivarius et al., 2002a, 2002b, 2002c). Red color stability and reduced rancidity values after the treatment of beef trimmings with antimicrobials are considered to be beneficial (Jimenez-Villarreal et al., 2003). In addition, the application of 5% lactic acid and 200 ppm chlorine dioxide produced similar color and lipid oxidation measures to untreated ground beef. Therefore, the objective of this study was to evaluate and compare the effects of antimicrobial agents such as potassium lactate, sodium metasilicate, acidified sodium chlorite, or peroxyacetic acid on un-inoculated beef trimmings prior to grinding on instrumental color and lipid characteristics of ground beef.

Experimental Procedures

Antimicrobial Treatment and Processing. The antimicrobial treatments included 3% (v/v) potassium lactate (KL; Purasal®, Purac America Inc., Lincolnshire, Ill.), 4% (w/v) sodium metasilicate (NMS; Avgard®, Rhodia Inc., Cranbury, N.J.), 0.1% (v/v) acidified sodium chlorite, (ASC; sodium chlorite supplemented with food grade citric acid in 1:1 ratio to obtain a solution of pH = 2.5; SANOVA®, Alcide Cooperation, Redmond, Va.), 0.2% (v/v) peroxyacetic acid (PAA; Inspexx-200®, Ecolab, St Paul, Minn.), and an untreated control (CON).

Antimicrobial application was carried out on 12 lb batches of beef trimming that were placed into a meat tumbler (Model 4Q; Lyco Inc. Janesville, Wis.). The selected volume of antimicrobial agents were added and tumbled at 60 rpm for 3 min. The volume of antimicrobial solution used in tumbling was 500 ml, except for PAA (1,500 ml). As per manufacturer's instructions, ASC treatment was tumbled for only 30 sec. Following the completion of antimicrobial application, beef trimmings were ground twice using a Hobart grinder (Model 310; Hobart Inc. Troy, Ohio) with a 3.2-mm plate. Then, 1 lb ground beef samples were placed on styrofoam trays with absorbent pads and over wrapped with polyvinyl chloride film with an oxygen transmission rate of 14,000 cc/mm^2/24 h/1 atm (Koch Supplies, Inc., Kansas City, Mo.) and stored under simulated retail conditions (39°F; deluxe warm white fluorescent lighting, 1630 lux, Phillips Inc., Somerset, N.J.). The pH of treated ground beef was determined by homogenizing ground beef with distilled water in 1:10 ratio. An ultra basic portable pH-mv meter (UP-10; Denver Inc. Denver, Colo.) was used to measure the pH of the homogenate.

Instrumental Color. For instrument color evaluations, ground beef was sampled on days 0, 1, 2, 3, and 7 of simulated display using a Hunter-Lab MiniScan XE Spectrocolorimeter, (Model 4500L; Hunter Associates Laboratory, Reston, W.Va.). Samples were evaluated for Commission Internationale de l'Eclairage (CIE L^*, a^*, and b^*) color values, hue angle ($\tan^{-1}(b^*/a^*)$, which describes the hue or color of ground beef, and saturation index $(a^{*2}+ b^{*2})^{0.5}$, which describes the brightness or vividness of the color (Hunt et al.,

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1991). In addition, reflectance measurements were taken in the visible spectrum from 580 to 630 nm, and the reflectance ratio (630/580 nm) was used to estimate the oxymyoglobin proportion of the myoglobin pigment (Hunt et al., 1991). All the values were determined from the mean of 5 measurements on each ground beef sample using Illuminant A and a 10° observer. The spectrocolorimeter was standardized using white tile, black tile, and working standards before used in measurements.

TBARS characteristics. Thiobarbituric acid reactive substances (TBARS) analysis was performed following a modified method of Tarladgris et al. (1960) and Rhee (1978). On days 0, 3, and 7 of simulated retail display, ground beef was sampled for TBARS analysis. Two grams of ground beef from each treated-ground beef and untreated-control was homogenized for 20 s using a SciMetric homogenizer (Model PRO250; Pro Scientific Inc., Monroe, Conn.) with 8 ml cold (39°F) phosphate buffer mix, containing 0.1% EDTA and 0.1% n-propyl gallate (Sigma Chemical Co., St Louis, Mo.) and standardized to pH 7. Then 2 ml of trichloroacetic acid was added to the mixture, centrifuged for 5 min, and filtered through a Whatman No. 4 filter paper (Whatman, England). Next, 2 ml of 0.02 M 2-thiobarbituric acid reagent (Sigma Chemical Co., St Louis, Mo.) was added to 2 ml aliquots of clear supernatant in 10-ml screw cap tubes, and boiled for 20 min. Immediately after boiling, tubes were placed into an ice bath for 5 min, and absorbance of the samples was read using a spectrophotometer (Model UV 12015; Shimadzu Scientific instruments, Inc., Japan) at 533 nm. Lipid oxidation (TBARS) values (mg malonaldehyde per kg of meat) were calculated by multiplying the absorbency by a factor of 12.21

Analysis of Data. The data were analyzed as a completely randomized 5 x 5 factorial design. The experiment was replicated 3 times. Main effects of antimicrobial treatment, day of display, and treatment by day interactions were examined using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Means were generated using LSMEANS and separated with the PDIFF option of GLM.

Results and Discussion

Lightness (CIE L).* The effect of antimicrobial treatments on CIE L^* and estimated oxymyoglobin proportions is summarized in Table 1. The KL and NMS treatments had similar ($P > 0.05$) CIE L^* values compared to CON. The highest ($P < 0.05$) L^* values were found in PAA-treated ground beef. The ASC treatment maintained a CIE L^* value similar ($P > 0.05$) to the NMS and KL treatments, but had a lower ($P < 0.05$) L^* than the CON. Additionally, L^* values from day 1 through day 7 of display were higher ($P < 0.05$) than day 0 of display (Table 2).

630 nm/580 nm Reflectance Ratio. The NMS treatment had the highest ($P < 0.05$) estimated oxymyoglobin proportions and was different ($P < 0.05$) from all the other treatments (Table 1). The KL-, PAA-, and ASC-treated ground beef had similar ($P > 0.05$) estimated oxymyoglobin proportions, but higher ($P < 0.05$) values than CON. Estimated oxymyoglobin proportions in ground beef decreased ($P < 0.05$) from day 0 to 7 of display (Table 2). Jimenez-Villarreal et al. (2003) experienced an increase in estimated oxymyoglobin content in cetylpyridinium chloride, trisodium phosphate, chlorine dioxide, or lactic acid treated ground beef by day 7 of display similar to the level of day 1. The reason for this, as they explained, was the accumulation of high levels of water soluble myoglobin (purge) on the surface of ground beef package.

Redness (CIE a).* The day of display by treatment interaction effect on ground beef redness (a^*), yellowness (b^*), hue angle, and saturation index are shown in Table 3. Ground beef from KL, NMS, and ASC maintained a similar ($P > 0.05$) redness (a^*) compared to CON on day 0 of display (Table 3). The PAA treatment was similar ($P > 0.05$) in red color to the ASC, NMS, and KL treatments but had more red color ($P < 0.05$) compared with CON on day 0 of display. The CON was the least ($P < 0.05$) red from day 1 through 7 of display. The red color in KL-, PAA-, and ASC- treated ground beef did not ($P > 0.05$) differ on day 1 of display, but NMS and PAA treatments maintained equal or greater ($P < 0.05$) a^* values compared with the CON from day 1 to 7 of display. Furthermore, the ASC and KL treatments had similar ($P > 0.05$) redness values throughout retail display. Ground beef became less red across the 7–day retail display, regardless of antimicrobial treatment.

Yellowness (CIE b).* The PAA-treated ground beef was more ($P < 0.05$) yellow compared with CON on day 0 of display; however, other treatments received similar ($P > 0.05$) b^* values to CON. Ground beef from CON was the least yellow on days 1 to 3 of display, and was differed ($P < 0.05$) from other treatments, except from ASC ($P > 0.05$), on day 2 of display. Conversely, antimicrobial treatments produced ground beef of similar ($P > 0.05$) yellowness to CON on day 7 of display.

Hue Angle. On day 0 of display, ground beef from the KL, PAA, and the ASC treatments had similar ($P > 0.05$) hue angles to CON. On day 1, the lowest ($P < 0.05$) and highest ($P < 0.05$) hue angles were observed in NMS and CON, respectively, and were different ($P < 0.05$) from other treatments. After day 3 of display, CON had higher ($P < 0.05$) hue angles than the other treatments; however, no differences ($P > 0.05$) in hue angles were found between the KL, PAA, ASC, and CON on day 7 of display.

Vividness. For saturation index, KL, NMS, and ASC were similar ($P > 0.05$) in vividness of color to CON on day 0 of display; however, the vividness of CON was lower ($P > 0.05$) than other treatments on day 1 through 7 of display, except for ASC on day 7 of display.

TBARS and pH. The effect of antimicrobial treatment on pH and lipid oxidation is shown in Table 4. The CON had the highest ($P < 0.05$) lipid oxidation compared to all other treatments on all days of display. Furthermore, the NMS and PAA treatments had similar ($P > 0.05$) lipid oxidation on day 7.

The results indicate that the use of NMS on beef trimmings prior to grinding raised the ground beef pH (Table 4). According to Jimenez-Villarreal et al. (2003), higher pH resulted in redder ground beef with less lipid oxidation. Our findings were consistent with this hypothesis and NMS-treated ground beef had the most estimated oxymyoglobin proportions, was redder-colored, and incurred in less lipid oxidation compared to the ground beef with lower pH values.

Implications

Results of this study indicate that sodium metasillicate and potassium lactate added to ground beef maintained a similar lightness to untreated controls, and outperformed peroxyacetic acid and acidified sodium chlorite treatments. All the antimicrobial-treated ground beef was similar in redness to the untreated control at the beginning of display. However, the sodium metasilicate and peroxyaetic acid treated ground beef remained red even on day 3 of display. Thus, treating beef trimmings with 3% potassium lactate, 4%

sodium metasilicate, 0.1% acidified sodium chlorite, or 0.02% peroxyacetic acid improved instrumental color and lipid characteristics of ground beef.

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Table 1. Effect of antimicrobial treatments applied to beef trimmings on the least-squares means for CIE *L values, oxymyoglobin, beef odor and off odor intensities of bulk ground beef through simulated retail display.**

	Treatment[a]					
Attribute	CON	KL	NMS	PAA	ASC	SE
CIE *L**[b]	50.03y	49.81yz	49.07yz	52.53x	48.90z	0.39
Oxymyoglobin[c]	2.12z	2.63y	3.07x	2.79y	2.64y	0.06

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] *L** (Lightness; 0 = black and 100 = white). CIE = Commission Internationale de l'Eclairage.
[c] Calculated as the ratio 630 nm/580 nm reflectance.
[x,y,z] Least-squares means within a row bearing different letters are different (P < 0.05).

Table 2. Effect of duration of display on the least-squares means for CIE *L values and oxymyoglobin content of ground beef.**

	Days of display					
Attribute	0	1	2	3	7	SE
CIE *L**[a]	48.41w	50.64v	50.37v	50.15v	50.77v	0.39
Oxymyoglobin[b]	4.27v	3.09w	2.47x	2.23y	1.21z	0.06

[a] *L** (lightness, 0 = black and 100 = white). CIE = Commission Internationale de l'Eclairage.
[b] Calculated as the ratio 630 nm/580 nm reflectance.
[v,w,x,y,z] Least-squares means within a row bearing different letters are different (P < 0.05).

Table 3. Days of display by antimicrobial treatment[a] interaction effect on the least squares-means of CIE a*[b], CIE b*[c], hue angle[d] and saturation index[e] of ground beef.

Attribute	Days of display				
	0	1	2	3	7
*CIE a**					
CON	25.14x	19.89y	16.90y	13.74z	9.05y
KL	27.49wx	23.34x	19.67x	17.64y	10.97wx
NMS	26.16wx	25.64w	22.94w	22.20w	13.64w
PAA	28.03w	24.21wx	22.07w	20.02x	12.37wx
ASC	26.79wx	23.18x	19.34x	19.22xy	9.62xy
SE	0.77	0.46	0.52	0.63	1.01
*CIE b**					
CON	20.99xy	18.16y	17.20y	16.61y	16.61wx
KL	22.82wx	20.31x	18.94x	17.68x	17.55w
NMS	20.65y	21.41w	19.63wx	19.43w	16.03x
PAA	23.18w	20.82wx	19.84w	19.01w	16.95wx
ASC	22.01wxy	19.95x	17.96y	17.72x	16.27x
SE	0.61	0.32	0.27	0.26	0.31
Hue Angle					
CON	39.87w	42.43w	45.57w	50.42w	61.39w
KL	39.73wx	41.10x	44.12wx	45.14x	58.16w
NMS	38.26x	39.88y	40.56y	41.26y	49.87x
PAA	39.60wx	40.73x	41.97xy	43.59xy	54.19wx
ASC	39.40wx	40.75x	42.89wxy	42.67xy	59.04w
SE	0.49	0.26	0.86	0.84	2.40
Saturation Index					
CON	32.75x	26.94y	24.15y	21.57z	18.91x
KL	35.73wx	30.95x	27.36x	24.99y	20.80w
NMS	33.34x	33.41w	30.20w	29.52w	21.09w
PAA	36.38w	31.94wx	29.69w	27.62x	21.07w
ASC	34.67wx	30.59x	26.39x	26.15xy	18.90x
SE	0.95	0.55	0.43	0.57	0.57

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC =1000ppm acidified sodium chlorite.
[b] *a** (redness; -60 = green and +60 = red). CIE = Commission Interantionale de l'Eclairage.
[c] *b** (yellowness; -60 = blue and +60 = yellow).
[d] Calculated as $\tan^{-1}(b^*/a^*)$.
[e] Calculated as $(a^{*2}+b^{*2})^{0.5}$.
[w, x,y,,z] Least–squares means within a column for an attribute bearing different letters are different (P< 0.05).

Table 4. Days of display by antimicrobial treatment interaction effect on the least-squares means of pH and TBARS values of ground beef.

Attribute	Treatment[a]	Days of display				
		0	1	2	3	7
pH						
	CON	5.60w	5.59w	5.58w	5.65w	5.61vw
	KL	5.55w	5.58w	5.54wx	5.62w	5.39w
	NMS	6.49v	6.36v	6.32v	6.19v	5.75v
	PAA	5.47w	5.48y	5.48x	5.52w	5.50wx
	ASC	5.52w	5.54x	5.52wx	5.57w	5.56wx
	SE	0.05	0.01	0.02	0.11	0.05
TBARS[b]						
	CON	2.56v	-	-	4.33v	5.16v
	KL	1.31w	-	-	2.90w	3.42w
	NMS	0.82w	-	-	0.82z	1.90x
	PAA	0.88w	-	-	1.38y	2.22x
	ASC	1.19w	-	-	2.35x	3.73w
	SE	0.25			0.13	0.36

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite
[b] Thiobarbituric acid reactive substances
[v,w,x,y,z] Least–squares means within a column for an attribute bearing different letters are different ($P < 0.05$).

Effect of Potassium Lactate, Sodium Metasilicate, Peroxyacetic Acid or Acidified Sodium Chlorite as Single Antimicrobial Interventions on Un-inoculated Beef Trimmings Prior to Grinding on Ground Beef Sensory Characteristics

F.W. Pohlman, P.N. Dias-Morse, and S.A. Quilo[1]

Story in Brief

The effects of antimicrobial treatments on beef trimmings prior to grinding on ground beef sensory color characteristics through simulated retail display were evaluated and compared to an untreated control (CON). Beef trimmings (90/10) were treated with 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 0.1% acidified sodium chlorite (ASC) or 0.02% peroxyacetic acid (PAA) prior to grinding. The ground beef was packaged and sampled at 0, 1, 2, 3, and 7 d of simulated retail display. Sensory panelists found ground beef from all treatments to be similar ($P > 0.05$) to the CON in beef odor and similar ($P > 0.05$) or improved ($P < 0.05$) off odor characteristics throughout retail display. All treatments were brighter ($P < 0.05$) in red color on days 1 to 3 for worst point color and overall color attributes. Similarly, on those days the percentage discoloration was less ($P < 0.05$) for all treatments when compared with the CON. However, on day 7 of display, only the NMS treatment was different ($P < 0.05$) from the CON for the percentage discoloration. These findings indicated that use of antimicrobial agents does not adversely affect the sensory odor and color characteristics and can potentially improve color during retail display.

Introduction

Previous studies have shown that decontamination of beef trimmings prior to grinding by utilizing different antimicrobial agents would reduce microbial counts in ground beef (Pohlman et al., 2002; Stivarius et al., 2002a; 2002b). Results from Ellebracht et al. (2005) suggested that dipping beef trimmings into 200 ppm peroxyacetic acid solutions reduced *E. coli* O157:H7 and *Salmonella typhimurium* by 1.01 log CFU/cm^2. King et al. (2005) reported that spraying carcass surfaces with 1000 ppm peroxyacetic acid for 15 s reduced counts of *E. coli* and *Salmonella typhimurium* by 1.7 and 1.3 logs CFU/cm^2, respectively. A product known as SANOVA® (a combination of sodium chlorite and citric acid in aqueous solution) was also found to be effective in reducing bacteria on beef carcasses and on beef cuts and trimmings. For the potential use of sodium metasilicate as an antimicrobial agent in beef decontamination, sufficient information is not available for its effect on meat quality traits. Potassium and sodium lactates, commercially available as neutral pH aqueous solution (60%), are recommended for extending shelf life in cured and uncured meat and poultry products. However, little work on their antimicrobial effects and resulting product quality has been published. Therefore the objective of this study was to evaluate and compare the effects of using potassium lactate, sodium metasilicate, acidified sodium chlorite or peroxyacetic acid on un-inoculated beef trimmings prior to grinding on sensory color and odor characteristics of ground beef.

Experimental Procedures

Antimicrobial Treatment and Processing. The antimicrobial treatments included 3% (v/v) potassium lactate (KL; Purasal®, Purac America Inc., Lincolnshire, Ill.), 4% (w/v) sodium metasilicate (NMS; Avgard®, Rhodia Inc., Cranbury, N.J.), 0.1% (v/v) acidified sodium chlorite, (ASC; sodium chlorite supplemented with food grade citric acid in 1:1 ratio to obtain a solution of pH = 2.5; SANOVA®, Alcide Cooperation, Redmond, Va), 0.02% peroxyacetic acid (PAA; Inspexx-200®, Ecolab, St Paul, Minn.), and an untreated control (CON).

To perform each antimicrobial agent application, 12 lb batches of meat were placed into a meat tumbler. The selected volume of antimicrobial agents was added and tumbled at 60 rpm for 3 min. The volume of antimicrobial solution used for tumbling was 500 ml except for PAA (1,500 ml). As per manufacturer's instructions, ASC treatment was tumbled only for 30 sec. Following the complete antimicrobial application, beef trimmings were ground twice using a Hobart grinder with a 3.2 mm plate. Between each treatment the grinder was washed, sanitized, and rinsed to avoid cross contamination. Then, ground beef samples of 1 lb were placed on styrofoam trays with absorbent pads and over wrapped with polyvinyl chloride film and stored under simulated retail conditions (39°F; deluxe warm white fluorescent lighting). The pH of the treated ground beef was determined by homogenizing ground beef with distilled water in a 1:10 ratio. An ultra basic portable pH-mv meter was used to measure the pH.

Processing Properties. The processing abilities refer to the behavior of ground beef in the presence or absence of the antimicrobial compounds. Sensory analysis was conducted using a 4-member sensory panel to evaluate those processing abilities. Sensory panelists evaluated smearing during the grinding process on a 6-point scale (6 = extreme smearing; 1 = extreme cut – grind) for each treatment.

Sensory Evaluation. Eight trained panelists (Hunt et al., 1991) were selected for the sensory panel. Sensory evaluation of ground beef treated with antimicrobial agents prior to grinding was carried out on 0, 1, 2, 3, and 7 d of simulated retail display. The panelists evaluated overall color and worst point color using a modified scale of Hunt et al. (1991) 5 = bright purplish red; 1 = brown. Percentage surface discoloration was evaluated on a 1 to 7 scale (7 = no discoloration (0%), 6 = slight discoloration (1 to 20%), 5 = small discoloration (20 to 39%), 4 = modest discoloration (40 to59%), 3 =

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moderate discoloration (60 to 79%), 2 = extensive discoloration (80 to 95%), 1 = total discoloration (96 to100%).

The odor characteristics of ground beef were evaluated as beef odor (8 = extremely beef like; 1 = extremely non - beef like) and off odor (5 = no off odor; 1 = extreme off odor) as described by Hunt et al. (1991).

Analysis of Data. The data were analyzed in a complete 5 x 5 factorial design and replicated three times. Treatments were analyzed for the main effects of antimicrobial treatment, day of display, 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 GLM.

Results and Discussion

Processing Abilities. During this study KL, PAA, and ASC patties had much less ($P < 0.05$) particle definition than the CON, whereas NMS bulk ground beef was similar ($P > 0.05$) to CON for grinding ability (Table 1).

Treatment Main Effect on Ground Beef Odor and Off Odor. The effect of antimicrobial treatments on the least-squares means for ground beef odor characteristics is summarized in Table 1. Sensory panelists did not find a difference ($P > 0.05$) in beef odor between CON and the other treatments. The NMS and KL treatments had similar ($P > 0.05$) off odor to the control (CON). Although off odor intensities of PAA and ASC were different ($P < 0.05$) with the CON they were similar ($P > 0.05$) to KL and NMS. The overall numerical values for the off odor, regardless of their statistical difference ($P < 0.05$) indicate that there were no abnormal odors other than the beef like odor (Table 1).

Days of Display Main Effect on Ground Beef Odor and Off Odor Characteristics. No differences ($P > 0.05$) were found in beef odor on day 0 to day 2 of display (Table 2). The beef odor decreased ($P < 0.05$) at day 3 and day 7 of display. The off odor intensities also decreased ($P < 0.05$) slightly towards the end of the display days. The panelists did not detect any off odors on day 1 of display, whereas the off odor intensity on day 0 was similar ($P > 0.05$) to d 2 and d 3 of display. However, samples had more ($P < 0.05$) off odor intensities and less ($P < 0.05$) beef odor intensities on d 7 compared to d 1, 2, and 3.

Worst Point Color. The display days of antimicrobial treated beef on sensory worst point color characteristics are summarized in Table 3. The KL, NMS and ASC treatments had a similar ($P > 0.05$) worst point color on day 0 of display, whereas PAA treated ground beef had a brighter red color than the CON and the rest of the treatments. Nevertheless, worst point color values were higher ($P < 0.05$) for all the treatments when compared with the CON on days 1 to 3. No differences ($P > 0.05$) were detected for worst point color between any treatment and the CON at day 7 of display.

Overall Color. The days of display by antimicrobial treatment interaction effect on sensory overall color characteristics are summarized in Table 3. Sensory panelists were unable to detect differences ($P > 0.05$) in overall color between the CON and the rest of the treatments on day 0 of display. All treatments were redder ($P < 0.05$) in overall color attributes when compared with the CON on days 1 to 3 of display. However, on day 7 of display the ASC treated ground beef was similar ($P > 0.05$) to the CON. All other treatments were slightly brighter in red overall color, however their numerical values were low as is it would normally be expected at the last day of display.

Percent Discoloration. The days of display by antimicrobial treatment interaction effect on sensory percent discoloration characteristics are summarized in Table 3. All treatments were slightly less ($P < 0.05$) discolored than the CON on day 0 of display. However, on days 1 to 3 of display all treatments contained small ($P < 0.05$) or modest ($P < 0.05$) discoloration compared with the CON. In addition, at day 7 of display, the KL, NMS, and PAA had an extensive discoloration as expected, however, only NMS differed ($P < 0.05$) with the CON. The CON and ASC were also similar ($P > 0.05$) revealing a total discoloration of their surface.

Implications

These results indicate that all treated ground beef samples were performing similar or better compared to the control ground beef sample for sensory color attributes especially from day 0 to day 3 of display. The NMS treatment demonstrated a better performance against discoloration of the meat surface and brighter red color at its worst point and overall color at late stages of display. Also, all treatments demonstrated non residual off odors.

Acknowledgments

Sincere appreciation is expressed to J. Stephenson, S. McCord and J.L. Aparicio for their assistance in conducting this study. The authors would also like to thank Purac America Inc., Lincolnshire, Ill.; Rhodia Inc., Cranbury, N.J.; and Ecolab, St Paul, Minn., for their material and technical support.

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Table 1. Effect of antimicrobial treatments applied to beef trimmings on the least-squares means for beef odor and off odor intensities of bulk ground beef through simulated retail display.

Attribute	Treatment[a]					
	CON	KL	NMS	PAA	ASC	SE
Processing Abilities						
Grinding ability[b]	1.00yz	3.33x	1.50y	4.16w	3.58wx	0.22
Sensory Properties						
Beef odor[c]	7.29wx	7.19x	7.27wx	7.42w	7.19x	0.07
Off odor[d]	4.48x	4.60wx	4.62wx	4.73w	4.67w	0.05

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] Grinding ability score: 6 = extreme smearing; 1 = extreme cut – grind.
[c] Beef odor score: 1 = extremely non – beef like and 8 = extremely beef like.
[d] Off odor score: 1 = extreme off odor and 5 = no off odor.
[wxyz] Least-squares means within a row bearing different letters are different (P < 0.05).

Table 2. Effect of duration of display on the least-squares means for beef odor and off odor characteristics of ground beef.

Attribute	Days of display					
	0	1	2	3	7	SE
Beef odor[a]	7.60x	7.43xy	7.49xy	7.38y	6.45z	0.07
Off odor[b]	4.64y	5.00x	4.74y	4.62y	4.11z	0.05

[a] Beef odor score: 1 = extremely non –beef like and 8 = extremely beef like.
[b] Off odor score: 1 = extreme off odor and 5 = no off odor.
[xyz] Least-squares means within a row bearing different letters are different (P < 0.05).

Table 3. Effects of days of display by antimicrobial treatment interaction effect on the least-squares means for worst point color, overall color and percent discoloration of ground beef through simulated retail display.

Attribute	Treatment[a]	Days of display				
		0	1	2	3	7
Worst Point Color[b]						
	CON	3.88y	2.86z	1.76y	1.37z	1.07w
	KL	4.03xy	3.26y	2.70x	2.00y	1.18w
	NMS	4.33x	4.46w	3.73w	4.14w	1.22w
	PAA	4.81w	3.86x	3.90w	3.51x	1.22w
	ASC	4.33x	4.03x	3.63w	3.59x	1.11w
	SE	0.13	0.12	0.14	0.15	0.07
Overall Color[b]						
	CON	4.74w	3.66y	3.16y	2.51z	1.14y
	KL	4.74w	4.23x	3.66x	3.37y	1.85x
	NMS	4.81w	4.76w	4.63w	4.70w	2.33w
	PAA	4.88w	4.36x	4.56w	4.25x	2.03wx
	ASC	4.74w	4.46wx	4.40w	4.29x	1.40y
	SE	0.07	0.10	0.10	0.10	0.13
% Discoloration[c]						
	CON	6.22y	5.46y	4.43y	3.59y	1.85xy
	KL	6.62x	6.06x	5.40x	5.07x	2.33wx
	NMS	6.70wx	6.76w	6.43w	6.44w	2.70w
	PAA	7.00w	6.63w	6.40w	6.33w	2.33wx
	ASC	6.59x	6.50w	6.16w	6.48w	1.44y
	SE	0.10	0.11	0.16	0.17	0.25

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] Color score: 1 = brown and 5 = bright purple red.
[c] Percentage discoloration: 1= total discoloration (96 to100%) and 7 = no discoloration (0 to4%).
[wxyz] Least–squares means within a column and attribute bearing different letters are different (P < 0.05).

Within-Muscle Variation in Color and pH of Beef *Semimembranosus*

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

Story in Brief

A research trial was conducted to measure the within muscle variation in color and pH of the *semimembranosus* (SM), a muscle highly affected by chilling rate. *Semimembranosus* muscles from Prime (Pr), Choice (Ch), and Select (Se) grade carcasses (3 muscles/quality grade) were cut into 0.75-in-thick steaks and numbered 1 through 10, beginning at the dorsal end. Steaks were subsequently divided into 4 quadrants according to their location within the steak (CaD = caudal-distal; CaP = caudal-proximal; CrD = cranial-distal; and CrP = cranial-proximal). When comparing instrumental color differences, the steaks from the ventral portion were generally lighter, redder, and more yellow than those from the dorsal portion. Furthermore, steaks from quadrant CrD had the greatest ($P < 0.05$) L^*, a^*, and b^* values, whereas steaks from the most exterior quadrant CaP had the lowest ($P < 0.05$) L^*, a^*, and b^* values, with steaks from quadrants CrP and CaD having intermediate color values. Within steaks, pH was higher ($P < 0.05$) in the ventral-most steaks (steaks 7 through 9) than in dorsal-most steaks (steaks 1 through 5). Furthermore, pH was higher ($P < 0.05$) in steaks from quadrant CrD, followed by CrP, with the lowest pH values ($P < 0.05$) occurring within quadrant CaP. Traditionally, light meat color has been associated with low pH; however, unexpectedly, these results indicated the quadrant with the lightest color meat had the highest pH.

Introduction

The beef *semimembranosus* (SM) is a thick, large muscle that extends from the inner surface of a carcass to the femur. Variations in the initial color, color uniformity, and color stability within the muscle can be related to early postmortem conditions. Because of its location, the deep SM, the portion of the muscle closest to the femur, has a slower rate of chilling than the superficial portion, resulting in accelerated glycolysis and rapid pH decline postmortem (Sammel et al., 2002). Follett et al. (1974) indicated that use of an accelerated chilling system could reduce the rate of postmortem pH decline, resulting in improved muscle color and protein functionality of the deeper/thicker portions of the SM. Differences in postmortem temperature and pH decline in the deep and superficial SM may also alter oxidation and reduction of myoglobin, which is thought to be the ultimate factor affecting the color stability within the SM (Sammel et al., 2002). However, most research involving the SM does not differentiate between the two muscle portions; therefore, this study was undertaken to define the intramuscular pH and instrumental color differences within the SM of the beef round.

Experimental Procedures

Nine beef inside rounds (IMPS #168) from USDA Prime, Choice, and Select carcasses (3 inside rounds/quality grade) were obtained from a commercial slaughter facility, transported to the University of Arkansas Red Meat Abattoir, and aged at 35.6°F for 14 d from the box date. The SM was fabricated from each inside round and trimmed to 0.25 in or less of subcutaneous fat. Each muscle was faced and cut into ten 0.75-in-thick steaks perpendicular to the fiber direction, and steaks were numbered 1 though 10 starting with the first steak from the dorsal end. Steaks were subsequently divided into 4 quadrants based on measurements of steak width and depth (Fig. 1; CaD = caudal-distal; CaP = caudal-proximal; CrD = cranial-distal; and CrP = cranial-proximal).

Instrumental color readings of steaks were measured using a Hunter MiniScan XE (Model 45/0-L, Hunter Associates Laboratory Inc., Reston, Va.) after a 30-min bloom period. Instrumental color (L^*, a^*, b^* values) data were collected from taking the mean of 3 readings within each quadrant (CaD, CaP, CrD, and CrP) on the surface of each steak using Illuminant A and a 10° observer. Furthermore, the saturation index (C*), or chroma, was calculated as $[a^{*2}+b^{*2}]^{[1/2]}$ (AMSA, 1991).

After taking instrumental color readings on each steak, the pH was measured in each quadrant (2 readings/quadrant) and averaged for analysis, using a portable stainless steel pH probe and meter (Model MPI pH-100; Meat Probes, Inc). The pH probe was calibrated after each muscle using a 2-point method of buffers at a pH of 4 and 7, if the automatic buffer recognition sample (pH of 7) was off more than ± 0.2.

Statistical analysis. Data were analyzed using PROC MIXED of SAS (SAS Inst. Inc., Cary, N.C.) arranged in a split-plot design, with steak as the whole plot and quadrant as the sub-plot. The whole plot was blocked by muscle. The 3 quality grades were selected to increase the variation in the study, and quality grade was initially included in the model; however, with the exception of a 3-way interaction for pH, quality grade did not ($P \geq 0.05$) affect SM color and was subsequently removed from the model. Least squares means were computed and statistically separated by pair-wise t-tests (PDIFF option) when the F-test was significant ($P< 0.05$).

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Results and Discussion

Quality Grade. Main effects of quality grade on *L*, a*, b**, saturation index, and pH are reported in Table 1. There were no ($P \geq 0.05$) detectable differences among quality grades for any instrumental color measurements; yet, the SM from USDA Prime carcasses had a lower ($P < 0.05$) pH value than the SM from either USDA Choice or Select carcasses.

pH. There was no steak x quadrant interaction ($P \geq 0.05$) for SM pH. However, pH values appeared to increase from the dorsal-most to the ventral-most steaks, with steaks 7 through 10 having higher ($P < 0.05$) pH values than steaks 1 through 4 (Fig. 2A). Also, steak 1 had a lower ($P < 0.05$) pH value than steaks from the ventral half (steaks 5 through 10) of the SM. Furthermore, pH values were highest ($P < 0.05$) in the CrD quadrant; whereas pH values for quadrant CaP were lower ($P < 0.05$) than quadrant CrP (Fig. 2B).

Instrumental Color Measurement. Regardless of steak location, those in the the CrD quadrant were the lightest (highest *L** values; $P < 0.05$) compared to other within-steak quadrants (steak location x quadrant, $P < 0.05$; Fig. 3). Within steaks 6 and 10, quadrant CaP was darker (lower *L** values; $P < 0.05$) than quadrant CaD, whereas *L** values were lower ($P < 0.05$) in quadrant CaP than either quadrants CrP or CaD in steaks 7 through 9. Additionally dorsally located steaks (steaks 1 and 2), quadrant CrP was darker ($P < 0.05$) than quadrant CaD.

Redness (*a**) values appeared to increase in steaks 1 through 6, with quadrant CrD of steaks 2 through 5 being redder (higher *a** value; $P < 0.05$) than quadrants CrP, CaP, and CaD (steak location x quadrant, $P \geq 0.05$; Fig. 4). The CrD quadrant was only redder ($P < 0.05$) than quadrant CaP in steaks 6 and 7, whereas both distal quadrants of steak 8 were redder ($P < 0.05$) than the proximal quadrants. In steak 9, quadrant CrD had the highest ($P < 0.05$), and quadrant CaP the lowest ($P < 0.05$), *a** values, whereas the quadrants CrP and CrD were redder ($P < 0.05$) than quadrants CaP and CaD of steak 10.

Similar to the *L** and *a** results, yellowness (*b**) values (Fig. 5) and saturation index (C*) values (Fig. 6) appeared to increase throughout the dorsal section (steaks 1 through 4), peak in the medial section (steaks 5 through 7), and appear to level off in the ventral portion (steaks 8 through 10) of the SM. Even though *b** (steak location x quadrant, $P < 0.05$) and C* values (steak location x quadrant, $P < 0.05$) were similar ($P > 0.05$) within steak 1, the CrD quadrant of steaks 2, 3, 4, and 6, were more ($P < 0.05$) yellow (higher *b** values) than the other three quadrants. In steaks 5 and 7; however, the CrD quadrant was only more ($P < 0.05$) yellow (higher *b** values) and more vivid (higher C* values) than quadrants CrP and CaP. Although the cranial half of steak 8 had greater ($P < 0.05$) *b** and C* values than the caudal half, quadrant CrD had the highest ($P < 0.05$), and quadrant CaP the lowest ($P < 0.05$), *b** and C* values within steak 9, whereas both quadrant CaP and CaD had lower ($P < 0.05$) *b** and C* values than quadrants CrP and CrD within steak 10.

There has been very little work done to define the color differences within the SM, with most prior research focusing almost exclusively on beef tenderness within the muscle. More research on the color uniformity within the SM could provide more information to improve the marketability of the SM, as well as the whole inside round.

The instrumental color results of this study are in agreement with those of Sammel et al. (2002), who reported that the deep portion of the SM was noticeably different in color than the superficial portion. They speculated that the color differences were caused by low pH and high temperature prior to chilling of the deep portion of the SM, which would lead to protein denaturation and the reduced color intensity and stability typically associated with it. Both glycolytic proteins, which prematurely halt glycolysis, and pigment proteins are denatured, creating a very light colored muscle. Results of this study indicate that the color in the deep portion of the SM was quite similar to PSE pork, having a more open structure and greater light scattering (Sammel et al., 2002). Further research is warranted to determine ways to create a more uniform colored SM, which will, in turn, lead to improved marketability and value.

Implications

These results have provided a detailed look into the color variation within the SM. From the information gathered, it can be concluded that there is a substantial amount of color variation within such a large muscle. The observed variation in beef color can be attributed to: 1) the lack of a uniform chilling rate due to the location and size of the SM; and 2) the rate of postmortem glycolysis that the SM undergoes during the conversion of muscle to meat. Further research will be necessary for a more in depth investigation of the relationship of color and pH in this inconsistent muscle.

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Table 1. Influence of USDA quality grade on the pH and instrumentally measured color of beef *semimembranosus* steaks

	Quality grade			
Quality trait	Prime	Choice	Select	SE
Muscle pH	5.38[b]	5.57[a]	5.63[a]	0.049
Lightness (L*)[1]	44.37	45.47	45.19	1.431
Redness (a*)[1]	34.40	33.76	33.12	0.551
Yellowness (b*)[1]	28.63	28.25	27.08	0.585
Saturation index (C*)[2]	44.76	77.03	42.78	0.790

[1]L* = a measure of darkness to lightness (greater L* value indicates a lighter color); a* = a measure of redness (greater a* value indicates a redder color); and b* = a measure of yellowness (greater b* value indicates a more yellow color).
[2]Saturation index is a measure of the total color/vividness of color (higher C* value indicates a more vivid color/more total color).
[ab]Means, within a row, with different superscript letters differ ($P < 0.05$).

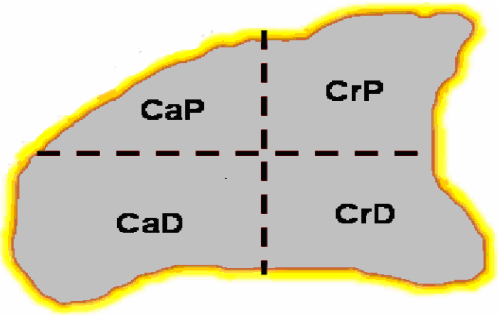

Fig. 1. Within-steak location of quadrants in the *semimembranosus*.: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

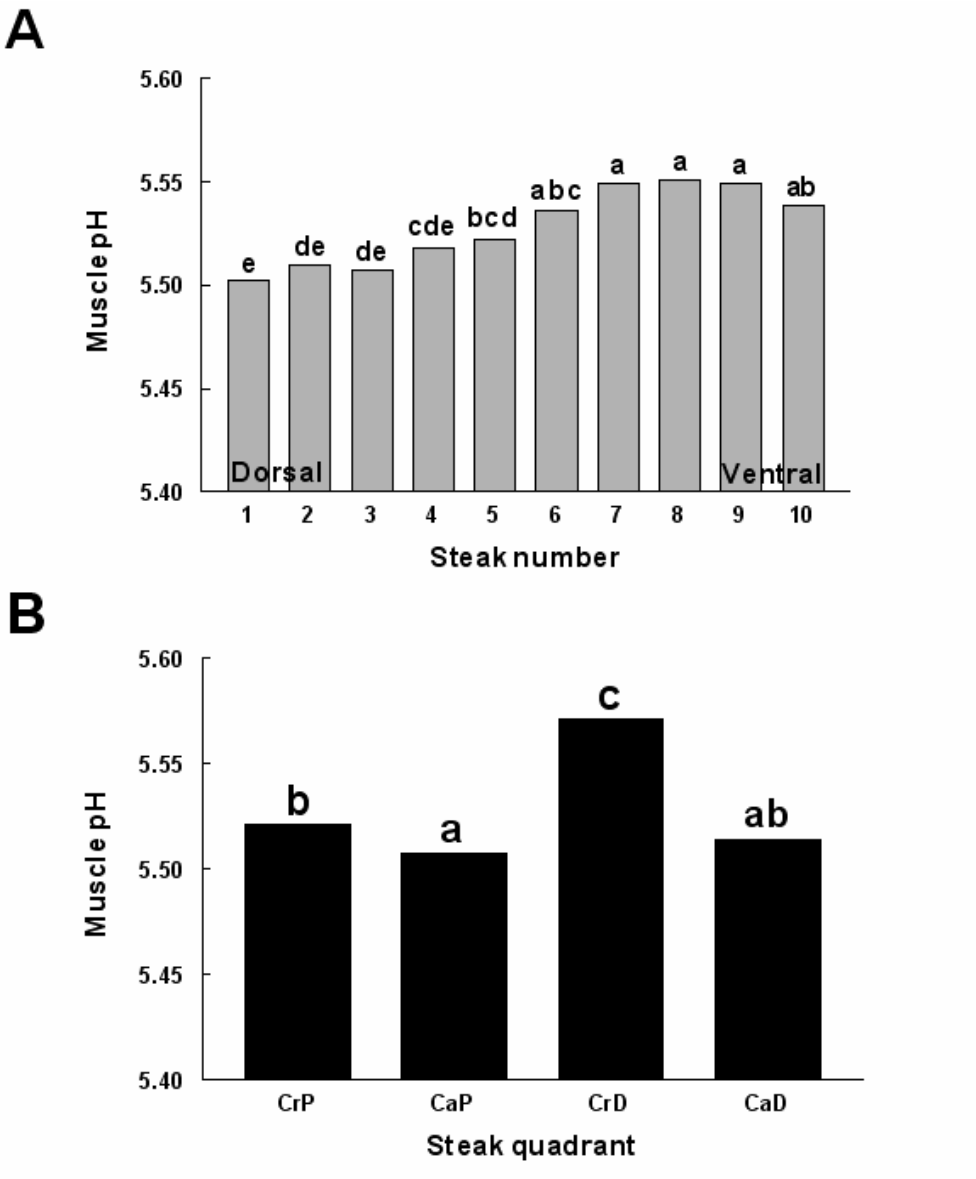

Fig. 2. Variation of pH between steaks (A) and within steaks (B) of the *semimembranosus*.
[a-e] means, within a graph, with no letters in common differ (P < 0.05).
***Steaks were divided into four quadrants: CrP = Cranial Proximal;**
CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

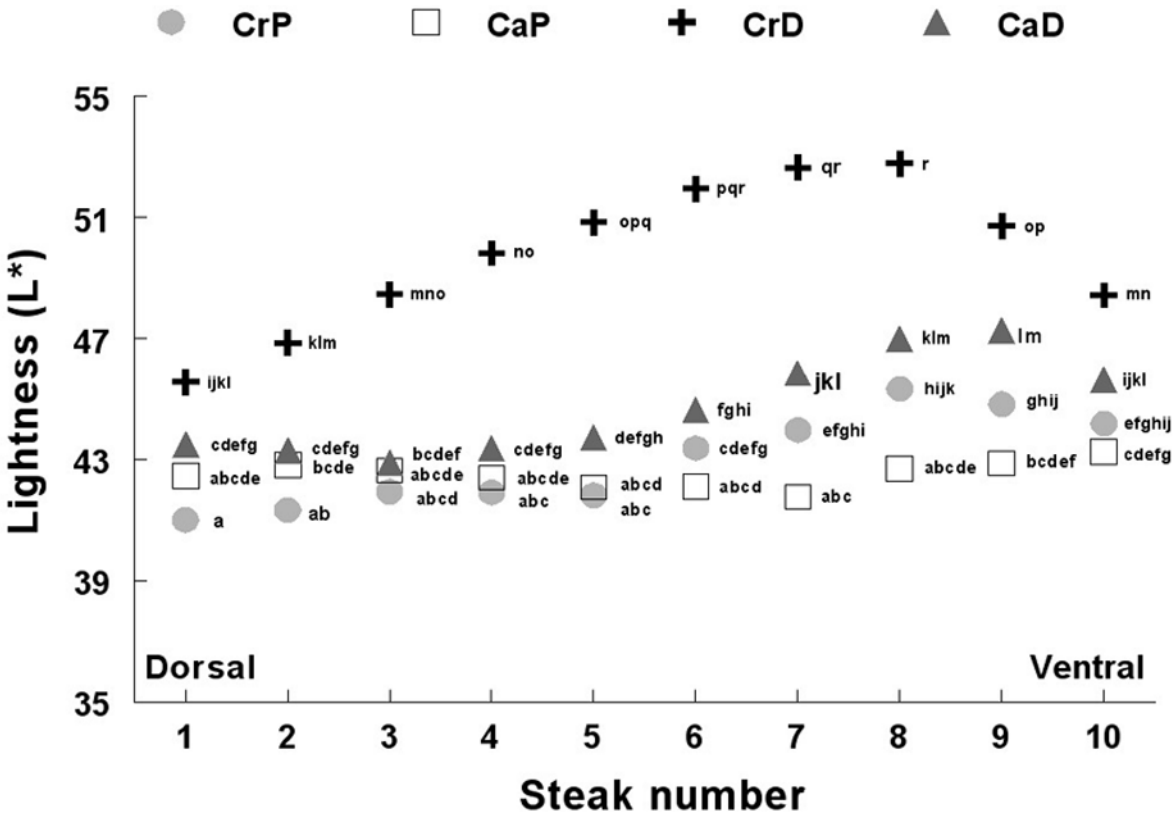

Fig. 3. Within-muscle variation of lightness (*L) of the *semimembranosus*.**
[a-r] means, within a graph, with no letters in common differ (P < 0.05). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

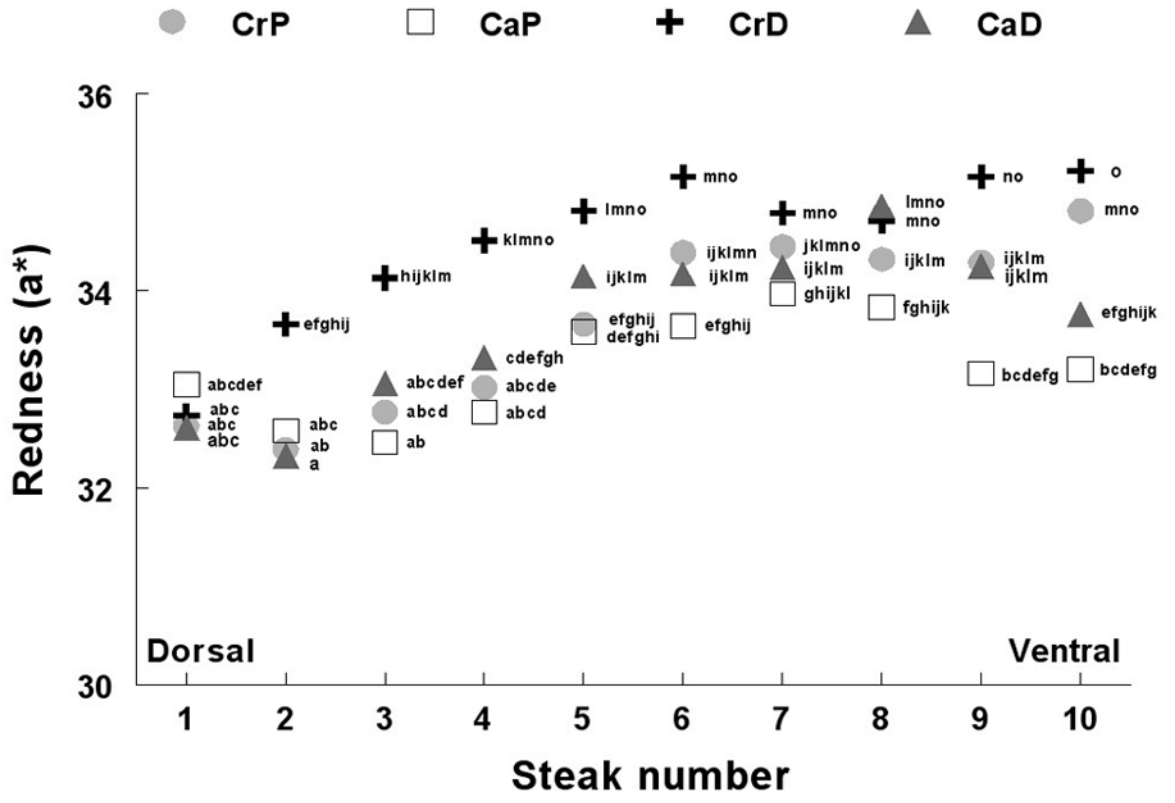

Fig. 4. Within-muscle variation of redness (*a) of the *semimembranosus*.**
[a-r] means, within a graph, with no letters in common differ (P < 0.05). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

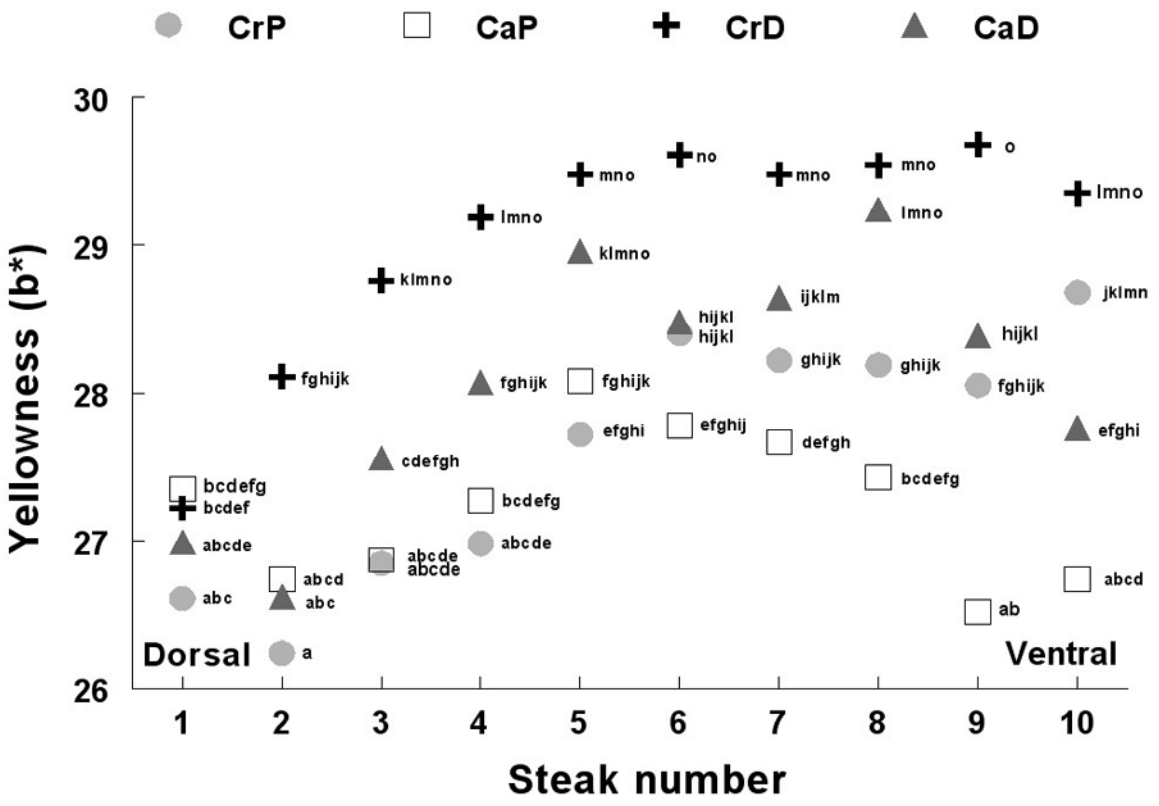

Fig. 5. Within-muscle variation of yellowness (*b) of the *semimembranosus*.**
[a-o] means, within a graph, with no letters in common differ (P < 0.05). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

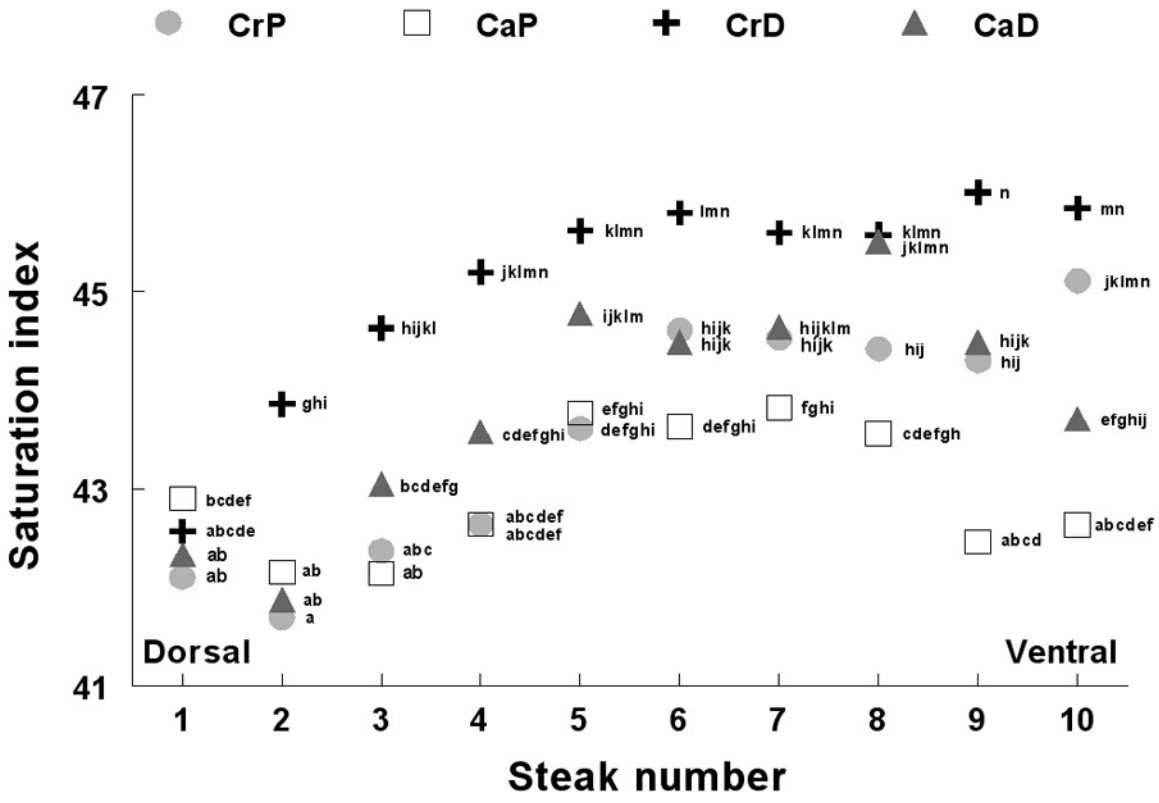

Fig. 6. Within-muscle variation of saturation index (B) of the *semimembranosus*.
[a-o] means, within a graph, with no letters in common differ (P < 0.05). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

Instrumental Color Characteristics of Ground Beef Treated with Potassium Lactate, Sodium Metasilicate, Peroxyacetic Acid, or Acidified Sodium Chlorite

S.A. Quilo, F.W. Pohlman, and P.N. Dias-Morse [1]

Story in Brief

The effects of selected antimicrobial compounds on ground beef were evaluated to determine if instrumental color characteristics were impacted. Beef trimmings, inoculated with *Escherichia coli* (EC) and *Salmonella typhimurium* (ST), were treated with 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 1,000 ppm acidified sodium chlorite (ASC), 200 ppm peroxyacetic acid (PAA), or left untreated (CON) prior to grinding. Trimmings were ground, weighed, packaged, displayed under simulated retail conditions, and sampled on days 0, 1, 2, 3, and 7 for instrumental color. Instrumental color results indicated that KL, NMS, and PAA treated samples were similar ($P > 0.05$) in redness (a^*) to the CON. Additionally, the KL treated samples were also similar ($P > 0.05$) to the CON in lightness (L^*), yellowness (b^*), oxymyoglobin proportions (630nm/580nm), hue angle [tan-1(b^*/a^*)], and saturation index ($a^{*2} + b^{*2}$)0.5 measurements. The a^* values and saturation index remained similar ($P > 0.05$) in contrast with the oxymyoglobin proportions and hue angle which increased ($P < 0.05$) from day 3 to day 7. These findings indicated that use of tested antimicrobial agents on inoculated beef trimmings before grinding will maintain the instrumental color attributes of the ground beef through display.

Introduction

The color of meat is the most important indicator of freshness, especially in beef products. For this reason, when testing antimicrobial agents applied to ground beef as a safety intervention technology, the potential impact on meat color is of special consideration for consumer acceptance. Studies from Pohlman et al. (2002a; 2002b; 2005a; 2005b) and Stivarius et al. (2002) not only focused on the reduction of bacterial counts but included the effect of the tested antimicrobial agents on instrumental and sensory shelf life stability. In addition, the instrumental color characteristics of ground beef have been evaluated.

Consumer demand depends on the degree of quality that sensory attributes such as color exhibit. To obtain standardized color measurements of the samples, as an alternative to human perception by itself, instrumental analysis should be performed. The instrumental analysis is the best approach to determine specific color attributes that directly impact the overall color of the meat. These attributes, besides the redness (a^*), also include lightness (L^*), yellowness (b^*), trueness of red through the hue angle, vividness of the color through the saturation index, and oxymyoglobin proportions through the reflectance ratio.

Safety issues through antimicrobial intervention in ground beef is one area of study and research; however, the impact on the quality attributes is also of concern. Therefore, the objective of this study was to evaluate and compare the effects of using potassium lactate, sodium metasilicate, acidified sodium chlorite or peroxyacetic acid on beef trimmings prior to grinding on instrumental color characteristics of ground beef.

Experimental Procedures

Bacterial Preparation and Inoculation. From frozen (-112°F) stock cultures of *Escherichia coli* (ATCC # 11775) and nalidixic acid resistant *Salmonella typhimurium* (ATTC # 1769 NR) inoculums were prepared and used to inoculate a 60 lb batch of beef trimmings composed of 90% lean meat and 10% fat (90/10), as described by Pohlman et al. (2002a, 2002b) for inoculating the meat.

Antimicrobial Treatment. Treatments for this study were (1) 3% (v/v) potassium lactate (KL; Purasal®, Purac America Inc., Licncolnshire, Ill.), (2) 4% (w/v) sodium metasilicate (NMS; Avgard®, Rhodia Inc., Cranbury, N.J.), (3) 0.1% (v/v) acidified sodium chlorite (ASC; sodium chlorite supplemented with food grade citric acid in 1:1 ratio to obtain a solution of pH = 2.5; SANOVA®, Alcide Cooperation, Redmond, Va) prepared minutes before the application, (4) 0.2% (v/v) peroxyacetic acid (PAA) which is an equilibrium mixture of peroxyacetic acid, octanoic acid, acetic acid, hydrogen peroxide, and 1-hydroxyehylidine-1.1-diphosponic acid (Inspexx 200®; Ecolab, St Paul, Minn.) prepared minutes before the application, and (5) an untreated control (CON). The treatments, prepared minutes before the application on the meat, had the purpose of being in an active decontaminating state as per manufacturer's indications.

Meat was divided into 12 lb batches and placed into tumblers (Model 4Q; Lyco Inc., Janesville, Wis.) with 500 ml of the chosen chemical compound solution and tumbled with the meat for 3 min at 60 rpm, then removed and allowed to drip dry for 1 min. As an exception, the PAA antimicrobial solution consisted of 1,500 ml. The ASC treatment was also an exception as it was only tumbled for

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30 sec due to manufacturer's instructions. Upon completion of the antimicrobial application, the beef trimmings were ground twice using a Hobart grinder with a 3.2-mm plate. After grinding of each treatment, the grinder was washed with commercial sanitizer and bleach, and rinsed. Then, 1 lb ground beef samples were placed onto foam trays with absorbent pads and over wrapped with polyvinyl chloride film, and stored under simulated retail conditions (39°F; deluxe warm white fluorescent lighting) for 7 days of simulated retail display. To determine the pH of the ground beef, 1.8 g of ground beef was homogenized in 18 ml of distilled water (1:10 ratio) and measured with a pH meter.

Instrumental Color. Instrumental readings of ground beef samples under simulated display conditions were measured on day 0, 1, 2, 3, and 7 using a Hunter Lab MiniScan XE. The L^*, a^*, and b^* values from the Commission Internationale de l'Eclairage (CIE) as well as spectral data were determined from the mean of 8 random readings on the displayed surface of each ground beef bulk package using Iluminant A/10° standard observer. In addition, the hue angle $[\tan^{-1}(b^*/a^*)]$, the saturation index $(a^{*2} + b^{*2})^{0.5}$, and estimated oxymyoglobin proportions of the myoglobin pigment (630 nm/580 nm) according to AMSA (1991) were also measured.

Statistical Analysis. The data were analyzed as a 5 x 5 factorial design with 3 replications. Data were analyzed for the main effects of antimicrobial treatment, day of display, and treatment by day interactions using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). Means were generated using LSMEANS and separated with the PDIFF option of GLM.

Results and Discussion

Antimicrobial Treatment Effect. There was not a treatment x day interaction for instrumental color values ($P > 0.10$). Table 1 is a summary of the effect of antimicrobial treatments on ground beef instrumental color. When comparing the KL to CON, no difference was observed ($P > 0.05$) in the values of lightness (L^*), redness (a^*), yellowness (b^*), oxymyoglobin proportions (630nm/580nm), trueness of red (hue angle) or vividness (saturation index) of color. The NMS treated samples had lower ($P < 0.05$) lightness, yellowness and hue angle (redder color) compared with the untreated control. The NMS was similar ($P > 0.05$) to CON in redness, and higher ($P < 0.05$) in estimations of oxymyoglobin proportions than CON. These observations were in agreement with the sensory panel results (Pohlman et al., 2005b) which indicated more ($P < 0.05$) redness in overall color in the KL and NMS treatments compared with the ASC or PAA treatments on days 0 to 2. The higher ($P < 0.05$) oxymyoglobin proportions or estimations in those samples when compared to the PAA or ASC treated samples, is an explanation for the bright red color intensity (Table 1). Therefore, KL and NMS treatments appear to be more effective in maintaining similar color conditions as the CON by not having redness discoloration of the ground beef in comparison with the other tested antimicrobial agents which also reduced bacterial counts (Pohlman et al, 2005a). The lightness was higher ($P < 0.05$) in the PAA treated ground beef (Table 1). However, no difference ($P > 0.05$) was present for PAA treated samples in redness, yellowness, oxymyoglobin, hue angle, or saturation index when compared to CON. The ASC treated samples were less ($P < 0.05$) red, less yellow ($P < 0.05$), and contained lower ($P < 0.05$) oxymyoglobin proportions than the CON. Conversely, there was no difference ($P > 0.05$) in lightness or hue angle. Our findings were in agreement with Jimenez-Villarreal et al. (2003a; 2003b) who hypothesized that instrumental color values were related to final pH of the treated ground beef. Similarly, during this study pH numerical values (data not statistically analyzed and not shown in tables) were as follows: NMS (pH = 6.8) and KL (pH = 5.8) treated ground beef compared with PAA (pH = 5.2) and ASC (pH = 5.1) treated samples. In the case of ASC, pH may have caused lower redness and oxymyoglobin proportion values when compared to the CON.

Days of Display. The effect of duration of display on instrumental color properties is presented in Table 2. Lightness (L^*) remained relatively constant ($P > 0.05$) from day 0 to 3 and then reduced ($P < 0.05$) on day 7 of display. Conversely, redness values (a^*) gradually declined ($P < 0.05$) to day 3 of display then remained stable ($P > 0.05$) to day 7 of display. Similarly, the yellow color (b^*) of the ground beef decreased ($P < 0.05$) across days, except from day 2 to day 3 when no difference ($P > 0.05$) was found in the yellowness intensity of ground beef. Oxymyoglobin proportions decreased ($P < 0.05$) from day 0 to day 3. Nevertheless, there was no difference ($P > 0.05$) in values of oxymyoglobin between day 2 and day 7. Oxymyoglobin estimation declined ($P < 0.05$) from day 0 to day 3 of display then increased slightly to day 7 of display. These results are in accordance with Jimenez-Villarreal et al. (2003a; 2003b) who reported similar increase in redness and oxymyoglobin estimation on day 7 of display suggesting a purge accumulation on the surface of the ground beef package which contained high levels of water soluble oxymyoglobin. A stable ($P > 0.05$) hue angle was measured from day 0 to day 2. However, the hue angle on day 3 only remained similar ($P > 0.05$) to day 2 but was greater ($P < 0.05$) at day 7 of display. This specific attribute can be related to the yellow intensity which was also similar ($P > 0.05$) on days 2 and 3. The hue angle value on day 7 was similar ($P > 0.05$) to day 0, but it was different ($P < 0.05$) from the values on days 1 to 3 of display. The vividness (saturation index) of the ground beef decreased ($P < 0.05$) from day 0 until day 3; however, it was similar ($P > 0.05$) on day 3 and 7 of display. The decrease in the vividness of the ground beef as the display days increased is in accordance with our hypothesis and expectations of the reduction in overall instrumental color values of ground beef.

Implications

The 4% sodium metasilicate, 3% potassium lactate, and 200 ppm peroxyacetic acid treatments exhibited similar or better color performance throughout display than the untreated samples. The 1,000 ppm acidified sodium chlorite treatment performance was lower for redness, yellowness, oxymyoglobin proportions and saturation index; however, the lightness and the hue angle were similar to the untreated control. Therefore, results of this study indicate that these treatments applied to beef trimmings generally produced ground beef of similar or improved color as an untreated control throughout display.

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Table 1. Effect of antimicrobial treatments on instrumental color.

	Treatment[1]					
Attribute	CON	KL	NMS	PAA	ASC	SE
CIE L^*[2]	42.68b	43.10b	39.07c	46.96a	42.27b	0.45
CIE a^*[3]	21.12ab	22.38a	22.17a	20.48b	17.87c	0.56
CIE b^*[4]	18.57a	18.56a	17.27b	18.84a	16.54b	0.35
630nm/580nm[5]	2.98bc	3.23ab	3.60a	2.65cd	2.55d	0.13
Hue Angle[6]	41.82ab	39.60bc	37.78c	42.86a	42.84a	0.90
Saturation Index[7]	28.27a	29.15a	28.14a	27.91a	24.40b	0.55

[1] CON = Control; KL = 3% potassium lactate; NMS = 4% sodium metasilicate; PAA = 200 ppm peroxyacetic acid; ASC = 1000 ppm acidified sodium chlorite.
[2] L^* is a measure of lightness (0 = black and 100 = white).
[3] a^* is a measure of redness (-60 = green and + 60 = red.).
[4] b^* is a measure of yellowness (-60 = blue and + 60 = yellow).
[5] Calculated as 630 nm reflectance/580 nm reflectance.
[6] Calculated as $\tan^{-1}(b^*/a^*)$.
[7] Calculated as $(a^{*2} + b^{*2})^{0.5}$.
[a,b,c,d] Least-squares means within a row bearing different letters are different ($P < 0.05$).

Table 2. Effect of duration of display on CIE L^*, a^* and b^* values, 630nm/580nm, hue angle, saturation index.

Attribute	Days of display					
	0	1	2	3	7	SE
CIE L^*[1]	43.23a	43.81a	43.73a	43.14a	40.17b	0.45
CIE a^*[2]	23.95a	22.28b	20.66c	18.38d	18.76d	0.56
CIE b^*[3]	20.36a	19.26b	18.22c	17.37c	14.58d	0.35
630nm/580nm[4]	3.78a	3.18b	2.82b	2.37c	2.87b	0.13
Hue Angle[5]	40.48bc	40.91b	41.49ab	43.72a	38.30c	0.90
Saturation Index[6]	31.45a	29.47b	27.58c	25.36d	24.03d	0.55

[1] L^* is a measure of lightness (0 = black and 100 = white).
[2] a^* is a measure of redness (-60 = green and + 60 = red).
[3] b^* is a measure of yellowness (-60 = blue and + 60 = yellow).
[4] Calculated as 630 nm reflectance/580 nm reflectance.
[5] Calculated as $\tan^{-1}(b^*/a^*)$.
[6] Calculated as $(a^{*2} + b^{*2})^{0.5}$.
[a,b,c,d] Least-squares means within a row bearing different letters are different ($P < 0.05$).

The Effects of Single Antimicrobial Interventions on Instrumental Color Characteristics When Used in a Ground Beef Patty Production System

S.A. Quilo, F.W. Pohlman, and P.N. Dias-Morse [1]

Story in Brief

Prior to grinding, beef trimmings (90/10) were left untreated (CON), or were treated with either 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 200 ppm of peroxyacetic acid (PAA) or 1,000 ppm acidified sodium chlorite (ASC) and utilized to evaluate antimicrobial chemical compound impact on instrumental color characteristics of ground beef patties. After antimicrobial application, the trimmings were ground, made into patties, packaged, and evaluated during simulated retail display for 7 days. Patties from the PAA treatment were lighter (L^*; $P < 0.05$) than patties from CON whereas KL, NMS, and ASC patties were similar ($P > 0.05$) to CON patties. At day 0 of display, the KL, NMS and PAA patties were redder (a^*, $P < 0.05$) than those left untreated (CON). Estimated oxymyoglobin proportions (630/580 nm) were higher ($P < 0.05$) for all antimicrobial treatments when compared to the CON on day 0 of retail display. Furthermore, on day 1 of display patties from all other treatments were more yellow (b^*, $P < 0.05$) than the CON patties. Patties from all other treatments were more ($P < 0.05$) vivid in color (saturation index) than the CON patties on day 1 of display. Application of NMS, KL, PAA or ASC antimicrobials to beef trimmings prior to grinding suggests a minimum deleterious impact on color characteristics by allowing similar or improved quality over the untreated patties.

Introduction

As the ground beef patty producers satisfy the great demand from worldwide fast food chains, restaurants, hospitals, and further processing plants in the fabrication of beef patties, various approaches to increase safety have been utilized. Beef carcass hot water washing, alkaline compounds spraying, steam pasteurization, and organic acid rinses, among other decontaminating methods, have been employed. Antimicrobial intervention on beef trimmings prior to grinding has been reported to potentially improve safety characteristics by reducing pathogenic bacteria log counts (Pohlman et al., 2002a; 2002b). There are several techniques to reduce bacterial counts and various types of antimicrobials that can be utilized to protect the product from these pathogenic strains and increase its safety. Some of these antimicrobials have been tested on beef carcasses or in pork and chicken further processed products such as sausages or comminuted chicken patties. However, the impact on quality characteristics of ground beef patties has received limited attention. Furthermore, regarding instrumental color attributes, investigations of the effects of antimicrobial agent intervention on beef trimmings prior to grinding with the purpose of fabricating patties is also limited to studies such as the ones from Jimenez –Villareal et al. (2002a; 2002b). Therefore, the objective of this study was to investigate the instrumental color characteristics of ground beef patties after the application of four antimicrobial compounds onto beef trimmings destined for the grinding and processing of patties, relative to untreated sample patties.

Experimental Procedures

Antimicrobial treatment and processing technique of the patties. The treatments included 3% (v/v) potassium lactate (KL; Purasal®, Purac America Inc., Lincolnshire, Ill.) 4% (w/v) sodium metasilicate (NMS; Avgard®, Rhodia Inc., Cranbury, N.J.), 0.1% (v/v) acidified sodium chlorite, (ASC; sodium chlorite supplemented with food grade citric acid in 1:1 ratio to obtain a solution of pH = 2.5; SANOVA®, Alcide Cooperation, Redmond, Va.), 0.2% (v/v) peroxyacetic acid (PAA; Inspexx-200®, Ecolab, St Paul, Minn.), and an untreated control (CON). As per the manufacturers' instructions, 0.1% ASC and 0.2% PAA were prepared just before the experimental run in order to use the solutions in an active decontaminating state. For antimicrobial application, 12-lb batches of meat were placed into a meat tumbler. The selected volume of antimicrobial agent was added and tumbled at 60 rpm for 3 min. The volume of antimicrobial solution used in tumbling was 500 ml except for PAA (1,500 ml). As per manufacturer's instructions, ASC treatment was tumbled only for 30 sec. Following antimicrobial application, beef trimmings were ground using a Hobart grinder with a 3.2 mm plate. Between the applications of each treatment, the grinder was washed with commercial sanitizer and bleach and was well rinsed. Patties of 220 g were fabricated using a Hollymatic® patty machine and placed on foam trays with absorbent diapers. Polyvinyl chloride film was used to over wrap, and the patties were stored under simulated retail conditions (39°F; deluxe warm white fluorescent lighting) for 7 days.

Instrumental color. Instrumental color readings of patties were measured on days 0, 1, 2, 3 and 7 of simulated retail display using a Hunter-Lab Miniscan XE Spectrocolorimeter. The samples were evaluated using illuminant A/10° observer for the Commission Internationale de l'Eclairage (CIE) lightness (L^*), redness (a^*) and yellowness (b^*) color values. Reflectance values at 580 and 630 nm were also taken to determine a ratio of 630/580 nm to estimate the proportion of oxymyoglobin of the myoglobin pigment (Hunt et al., 1991). The spectrocolorimeter was standardized using a white tile and a black tile and a working standard. The shift from red to yellow of the ground beef patties, known as the hue angle, was calculated [tan-1 (b^*/a^*)]. Also the saturation index [$(a^{*2} + b^{*2})^{0.5}$]

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which describes the brightness or vividness of color was determined (Hunt et al., 1991). Five measurements were taken of each sample and averaged for statistical analysis.

Statistical analysis. The experiment was arranged in a randomized 5 x 5 factorial design. The experiment was analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). The treatments were analyzed for the main effects of antimicrobial treatment, day of display, and treatment by day interactions. For variables involved in an interaction, means were generated and then separated within day using the PDIFF option of GLM in SAS. Least-squares means for variables not confounded by interaction were generated and separated using PDIFF.

Results and Discussion

*L**. There was not a significant treatment x day interaction for *L**(lightness) values. Therefore, main effects of treatment and day are reported in Tables 1 and 2. In comparison to the CON, only the PAA ground beef patties were lighter ($P < 0.05$), but the KL, NMS, and ASC treatments and the CON did not differ ($P > 0.05$) in CIE *L** values. Ground beef patties became lighter ($P > 0.05$) in color across 7 days of display (Table 2).

*a**. The day of display by antimicrobial treatment interaction effect on CIE *a** value is summarized in Figure 1A. On day 0 of display, the KL, NMS and the ASC treatments were similar ($P > 0.05$) in redness, but only KL, NMS and PAA were redder ($P < 0.05$) than ground beef patties left untreated (CON). However, on day 1 of display all treatments were redder ($P < 0.05$) than the CON. On day 2 of display, NMS patties were redder ($P < 0.05$) than the rest of the treatments; KL, PAA, and ASC treatments were similar ($P > 0.05$) to the CON. Likewise, on day 3 of display NMS patties were redder ($P < 0.05$) than patties form the other treatments. However, PAA patties were redder ($P < 0.05$) than the CON patties which were similar ($P > 0.05$) to KL and ASC treated patties. No differences ($P > 0.05$) in redness intensity were found between any of the treatments on day 7 of display. Results from the addition of KL, NMS, PAA, and ASC treatments on non-inoculated beef trimmings before grinding and pattying agree with the previous results obtained by Jimenez-Villarreal et al. (2003a) who found an extension in patty redness through display after antimicrobial treatment in comparison with ground beef patties formed from untreated trimmings.

*b**. The CIE *b** value day of display by antimicrobial treatment interaction effect is shown in Figure 1B. On day 0 of display, PAA patties had the same ($P > 0.05$) intense yellow color as the KL and ASC treatments, whereas the NMS and ASC treated patties were similar ($P > 0.05$) to CON. However, on day 1 of display patties from all treatments were more ($P < 0.05$) yellow than CON patties. There was no difference ($P > 0.05$) between any of the treatments and CON for CIE *b** values on day 2 of display. On day 3 of display, the NMS treated patties were more ($P < 0.05$) yellow than the rest of the treatments. However, on day 7 of display patties from the NMS treatment were less yellow ($P < 0.05$) than those from KL and PAA treatments which were similar ($P > 0.05$) to patties from the CON and ASC treatments.

Hue Angle. The hue angle refers to the trueness of red. A lower value (excluding negative values) defines a redder intensity of the sample. Figure 2A, shows the day of display by treatment interaction effect on hue angle of ground beef through simulated retail display. On days 0, 2, and 3 of display, the NMS treatment was lower ($P < 0.05$) than the rest of the treatments. Likewise, on day 1 of simulated retail display, NMS, PAA and ASC had a lower ($P< 0.05$) hue angle than the CON treated patties. Additionally, the NMS treatment had a lower ($P < 0.05$) hue angle than the CON on day 7 of display. An explanation of the slightly lower values in hue angle for the NMS treatment in comparison to the rest of the treatments are the higher *a** values on days 2 and 3 and lower *b** values on day 0 and 7 of display, which indicated an overall brighter color for this particular treatment. These findings agree with those of Jimenez-Villarreal et al. (2003a; 2003b) for hue angle values in antimicrobial treated patties.

Saturation Index. The vividness of the ground beef patties is determined by the intensity of its corresponding *a** values and *b** values and is expressed as the saturation index. High values of this trait demonstrate how vivid the overall color of the sample is. In Figure 2B, the saturation index day by treatment interaction effect is shown. On day 0 of display, the KL and PAA treatment had a more ($P < 0.05$) vivid color compared with the CON treated patties that were similar ($P > 0.05$) to the NMS and ASC treatment. All treatments were more ($P < 0.05$) vivid in color than the CON on day 1 of display. On day 2 of display, the NMS treatment and PAA were similar ($P > 0.05$), but only NMS was more ($P < 0.05$) vivid in color in comparison with the CON patties. Patties from NMS and PAA treatments presented more ($P < 0.05$) vividness than the other treatments on day 3 of display. No difference ($P > 0.05$) was observed between any treatment and the CON on day 7 of display.

630/580 nm Ratio. The oxymyoglobin to metmyoglobin ratio is an indicator of overall color in the samples. Higher values indicate brighter red color of the samples. Estimated oxymyoglobin proportions (630/580 nm), summarized in Figure 3, were higher ($P < 0.05$) for all the treatments when compared with the CON on day 0 of retail display. On day 1 of display, the NMS, PAA and ASC treated patties had higher ($P < 0.05$) oxymyoglobin values when compared with the CON. On day 2 of display the NMS treated patties had considerably higher ($P < 0.05$) oxymyoglobin proportions than the rest of the treatments. Similarly, on day 3 of display, both NMS and PAA treatments were higher ($P < 0.05$) for this ratio than the CON treatment. Almost similar to day 2, on day 7 of display the NMS treatment had higher ($P < 0.05$) oxymyoglobin proportions than the rest of the treatments with the exception of KL which was similar ($P < 0.05$) to NMS.

Implications

Relative to traditionally processed ground beef patties, patties treated with potassium lactate, sodium metasilicate, peroxyacetic acid or acidified sodium chlorite application exhibited similar or improved instrumental color characteristics over 7 days of display. However, sodium metasilicate demonstrated a better performance compared to the other treatments up to day 3 of display. Additionally, the oxymyoglobin proportions of NMS were higher at day 7.

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Table 1. Effect of antimicrobial treatments applied to beef trimmings on the least-squares mean for lightness (CIE *L) values of raw ground beef patties.**

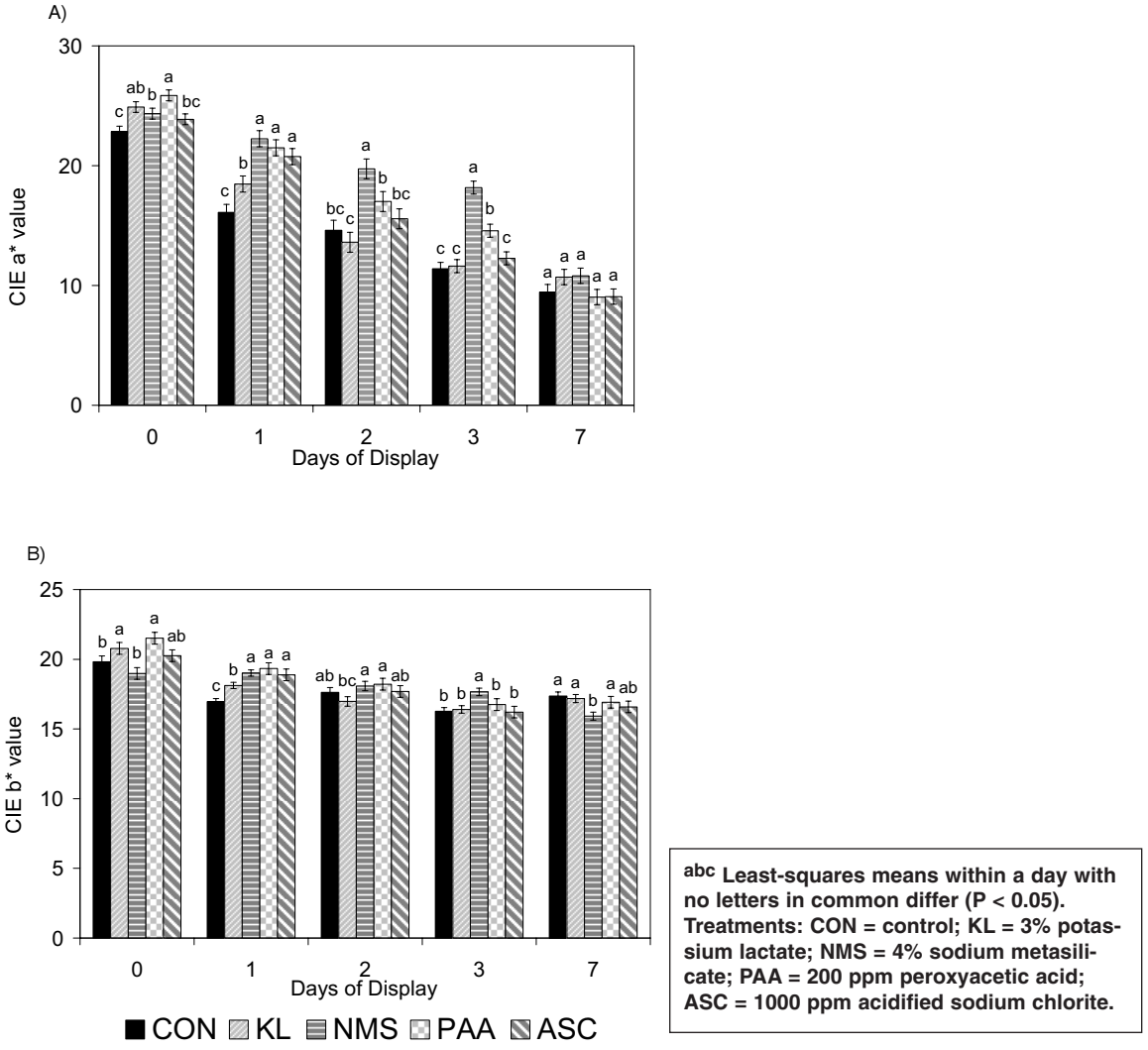
	Treatment[a]					
Instrumental color	CON	KL	NMS	PAA	ASC	SE
*L**[b]	48.03^{z}	47.73^{z}	47.75^{z}	50.49^{y}	47.68^{z}	0.48

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] *L** is a measure of lightness (0 = black and 100 = white).
[yz] Least-squares means within a row with no superscript in common differ (P < 0.05).

Table 2. Effect of duration of display on the least-squares mean for lightness (CIE *L) of raw ground beef patties.**

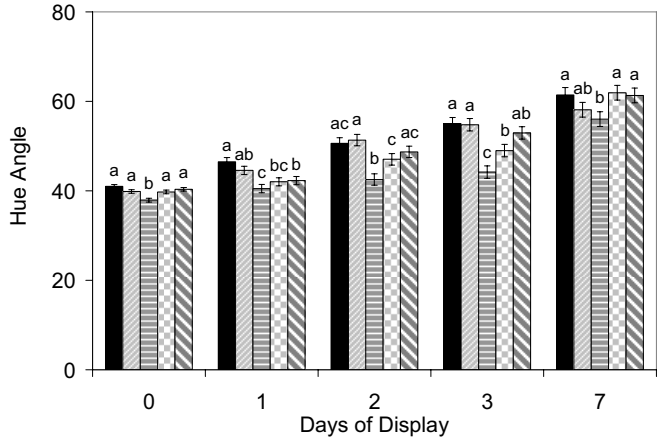
	Days of display					
Instrumental color	0	1	2	3	7	SE
*L**[a]	46.82^{z}	48.31^{xy}	47.00^{yz}	49.57^{wx}	49.99^{w}	0.48

[a] *L** is a measure of lightness *(* 0 = black and 100 = white).
[wxyz] Least-squares means within a row bearing different superscripts are different (P < 0.05).



[abc] Least-squares means within a day with no letters in common differ (P < 0.05). Treatments: CON = control; KL = 3% potassium lactate; NMS = 4% sodium metasilicate; PAA = 200 ppm peroxyacetic acid; ASC = 1000 ppm acidified sodium chlorite.

Fig. 1. Day of display by antimicrobial treatment interaction effect on the least squares means (±SE) (A) Commission Internationale de l'Eclairage (CIE) redness (*a; -60 = green and +60 = red) value and (B) CIE yellowness (*b**; -60 = blue and +60 = yellow) value of ground beef patties through simulated retail display.**



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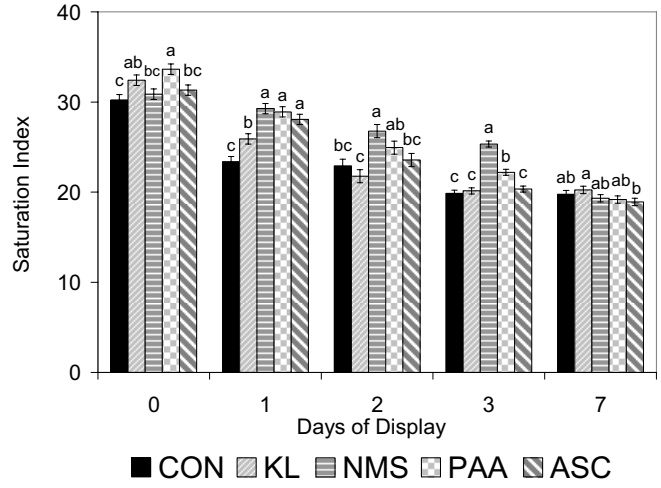
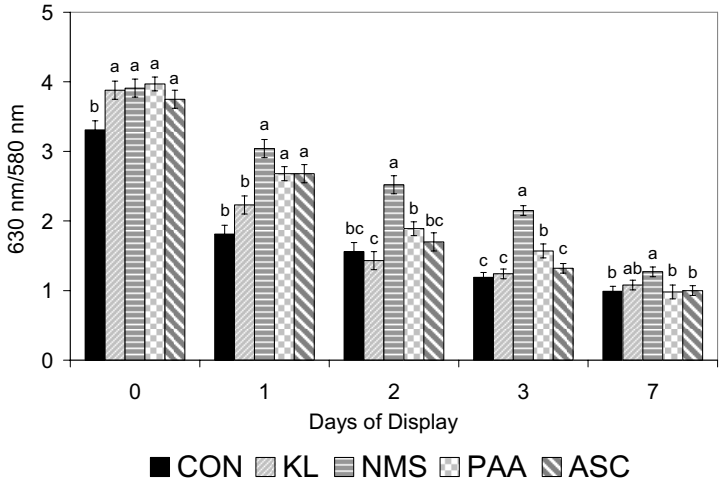


[abc]Least-squares means within a day with no letters in common differ (P < 0.05). Treatments: CON = control; KL = 3% potassium lactate; NMS = 4% sodium metasilicate; PAA = 200 ppm peroxyacetic acid; ASC = 1000 ppm acidified sodium chlorite.

Fig. 2. Day of display by antimicrobial treatment interaction effect on the least squares means (±SE) (A) hue angle (lower values indicate a redder color) and (B) saturation index (higher values indicate greater saturation of red) of ground beef patties through simulated retail display.



[abc]Least-squares means within a day with no letters in common differ (P < 0.05). Treatments: CON = control; KL = 3% potassium lactate; NMS = 4% sodium metasilicate; PAA = 200 ppm peroxyacetic acid; ASC = 1000 ppm acidified sodium chlorite.

Fig. 3. Day of display by antimicrobial treatment interaction effect on the least squares means (±SE) of the 630nm reflectance/580nm reflectance ratio (higher values indicate greater oxymyoglobin proportions) of ground beef patties through simulated retail display.

Quality and Sensory Characteristics of Ground Beef Patties Processed from Beef Trimmings Treated with Potassium Lactate, Sodium Metasilicate, Peroxyacetic Acid, or Acidified Sodium Chlorite

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Story in Brief

Beef trimmings were treated with 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 200 ppm peroxyacetic acid (PAA), 1,000 ppm acidified sodium chlorite (ASC), or left untreated (CON). Trimmings were ground and pattied. Grinding and patty forming abilities were evaluated during processing. Under simulated retail display, sensory characteristics, lipid oxidation, pH, and Lee-Kramer shear force were measured to evaluate the impact of the treatments. Panelists found patties from all treatments to have a brighter ($P < 0.05$) red overall color than the CON on day 0 of display. Panelists also found KL, NMS, PAA, and ASC patties to have less ($P < 0.05$) or similar ($P > 0.05$) off odor to CON on days 0 to 3. The NMS and PAA treated patties had lower ($P < 0.05$) lipid oxidation values than the CON at days 0, 3, and 7 of display. Patties from the NMS treatment had the highest ($P < 0.05$) pH of the treatments. Panelists did not find any difference ($P < 0.05$) in beef flavor or off flavor between the CON and the rest of the treatments. Therefore, KL, NMS, PAA and ASC treatments on ground beef trimmings before grinding improves or maintains the quality attributes in a patty production system.

Introduction

Ground beef patty safety became an issue of serious concern after the *E. coli* O157:H7 "Jack in the Box" outbreak in 1993. This case triggered federal safety agencies and meat scientists to develop research that would positively impact the safety of meat products. Most of this research also needed to include educational programs for the consumer regarding hamburger cooking methods; however, scientists needed to reduce pathogenic incidence at the beginning of processing before contamination could exponentially become greater, rather than at later stages. Factors such as cross contamination from the cutting and handling of the meat pieces create a constant potential for inoculation of bacteria onto newly exposed meat surfaces. For this reason, the use of chemical compounds (Pohlman et al., 2005) at later stages of the process have been tested on beef trimmings with the purpose of evaluating single antimicrobial intervention before grinding and the impact that this intervention has on the processing and quality attributes of the formed patties (Jimenez-Villareal et al., 2003a; 2003b).

Therefore, the objective of this study was to evaluate the impact of applying potassium lactate, sodium metasilicate, peroxyacetic acid or acidified sodium chlorite and their effects on processing characteristics, sensory attributes, TBARS value (which determines the thiobarbituric acid reactive substances produced during lipid oxidation), and sensory taste and odor characteristics when used in a ground beef patty production system.

Experimental Procedures

Antimicrobial Treatment Application and Ground Beef Patty Processing Technique. The antimicrobial treatments for this study were 3%(v/v) potassium lactate (KL; Purasal®, Purac America Inc., Lincolnshire, Ill.), 4% (w/v) sodium metasilicate (NMS; Avgard®, Rhodia Inc., Cranbury, N.J.), 0.1% (v/v) acidified sodium chlorite (ASC; sodium chlorite supplemented with food grade citric acid in 1:1 ratio to obtain a solution of pH = 2.5; SANOVA®, Alcide Cooperation, Redmond, Va), 0.2% (v/v) peroxyacetic acid (PAA; an equilibrium mixture of peroxyacetic acid, octanoic acid, acetic acid, hydrogen peroxide, and 1-hydroxyehylidine-1.1-diphosponic acid; Inspexx 200®, Ecolab, St Paul, Minn.), and an untreated control (CON). The 0.1% ASC and 0.2% PAA treatments were prepared minutes before the application on the meat with the purpose of having the solutions in an active decontaminating state. For the antimicrobial treatments, 12 lb of beef trimmings (90% lean and 10% fat) were placed into a meat tumbler (Model 4Q; Lyco Inc. Janesville, Wis.) with 500 ml of the chosen chemical compound solution and tumbled with the meat for 3 min at 60 rpm, then removed and allowed to drip dry for 1 min. In the case of PAA, 1,500 ml were utilized to apply onto the meat batch. The ASC treatment was an exception, and it was tumbled only for 30 sec according to the manufacturer's instructions.

Beef trimmings were ground twice using a Hobart grinder with a 3.2-mm plate. Between the applications of each treatment, the grinder was washed with commercial sanitizer and bleach and was well rinsed. Patties of 220 g were fabricated using a Hollymatic® patty machine, and placed on foam trays with absorbent diapers. Trays were over wrapped with polyvinyl chloride film and stored under simulated retail conditions (39°F; deluxe warm white fluorescent lighting) for 7 days of simulated retail display. Ground beef was sampled on days 0, 3 and 7 of display for thiobarbituric acid reactive substances (TBARS) evaluation which measures lipid oxidation. The pH from patties of each treatment was determined on days 0, 1, 2, 3, and 7 of display by homogenizing 1.8 g of ground beef in 18 ml of distilled water and measured with an Ultra Basic Portable pH/mv meter. Sensory panel, cook loss percentage and Lee-Kramer shear force characteristics were analyzed using patties at day 2 of display.

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Processing Properties. The processing abilities refer to the behavior of ground beef and ground beef patties in the presence or in the absence of the antimicrobial compounds. Sensory analysis was conducted using a 4-member sensory panel to evaluate those processing abilities. Sensory panelists evaluated smearing during the grinding process (6 = extreme smearing; 1 = extreme cut – grind) and patty forming ability (6 = extremely fragile; 1 = extremely cohesive) for each treatment.

Sensory Color and Odor. To evaluate sensory color and odor characteristics of ground beef patties through simulated retail display, a 10-member trained sensory panel was selected and trained according to AMSA (1991). Ground beef patty packages were evaluated for worst point color, overall color and percentage of discoloration (5 = bright purplish red, bright purplish red, 7 = no discoloration (0 to 4%); 1 = brown/gray, brown/gray, total discoloration (96 to100%)) on days 0, 1, 2, 3 and 7 of display. Ground beef patty packages were then taken to a static pressure room, opened, and evaluated for beef odor and off odor attributes. Panelists evaluated beef odor and off odor (8 = extremely beef like, 5 = no off odor; 1 = extremely non–beef like, extreme off odor) at the same display days.

TBARS Characteristics. A TBARS analysis was performed as described by Tarladgis et al. (1960) to evaluate the lipid oxidation of the treated and untreated patties.

Sensory Taste Evaluation. Sensory evaluation was carried out on day 2 of simulated retail display. An 11-member panel was selected and trained according to AMSA (1995). Patties were removed from their foam trays prior to the sensory session and cooked for evaluation using a Blodgett forced air convection oven to an internal temperature of 162°F (AMSA, 1995). Internal patty temperature was continuously monitored during cooking. Immediately after cooking, patties were sectioned into pieces and held in a food warmer at 158°F prior to sensory evaluation and during the evaluation process. Samples were randomly presented to the panelists using a complete design, where all panelists received all treatments during the evaluation session. Panelists evaluated bind, juiciness, and beef flavor (1 = extremely fragile, dry, no beef flavor; 8 = extreme bind, extremely juicy, intense beef flavor), and off flavor intensity on a 5 point scale (1 = extreme off flavor; 5 = no off flavor). Tests were conducted with individual booths and under low pressure sodium color neutralizing light to avoid bias.

Lee – Kramer Shear Force and Cooking Yield. Ground beef patties were cooked as described in the sensory taste evaluation section and then were cooled to room temperature (25°C) and sectioned (6 x 6 cm) for Lee – Kramer analysis. Shear force with a Lee – Kramer shear device attachment using an Instron Universal Testing Machine was analyzed.

Additionally, cooking loss % was calculated by weight differences for patties before and after cooking. The following formula was used for the calculation of the cooking loss:

$$\text{Cooking loss (\%)} = \frac{\text{(Fresh Patty wt. - Cooked Patty wt.)}}{\text{Fresh Patty wt.}} \times 100$$

Statistical Analysis. The experiment was arranged in a complete randomized 5 x 5 factorial design. The experiment was analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). The model included main effects of antimicrobial treatment, day of display, and treatment by day interactions. For sensory panel data, a panelist term was added to the model to account for sensory panelist variation. For variables involved in an interaction, interaction means were generated and then separated using the PDIFF option of GLM. Least-squares means for all other variables not confounded by interaction were generated and separated using PDIFF.

Results and Discussion

Processing Properties. Some of the limited research on the processing abilities of ground beef after being treated with antimicrobial agents includes studies of Jimenez-Villareal et al. (2003a; 2003b). Similarly, during this study KL, PAA, and ASC patties had much less ($P < 0.05$) particle definition than the CON, whereas NMS patties were similar ($P > 0.05$) to CON for grinding ability. Moreover, panelists found all treatments to be more ($P< 0.05$) fragile than the CON for patty forming ability (Table 1).

pH. The slightly acidic nature of KL, PAA, and ASC treated patties (pH = 5.8, pH = 5.2, and 5.1, respectively) was similar ($P > 0.05$) to CON across 7 days of display (Fig. 1A) although it may have contributed to the color differences. However, the NMS treatment had higher ($P < 0.05$) pH values than the CON and the rest of the treatments on days 0, 1, 2, and 3. This may be an explanation for the high redness (a^*) values of this treatment since high pH of the antimicrobial could potentially increase the pH of the meat proteins. A high pH further from the isoelectric point of meat results in more oxymyoglobin retention and brightness of its red color.

TBARS Values. Lipid oxidation among treatments is shown in Figure 1B. On day 0 of display the NMS, PAA, and ASC treated patties had lower ($P < 0.05$) TBARS values than the CON treatment, whereas KL was similar ($P > 0.05$) to CON. However, on day 3 of display the NMS-treated patties had less ($P < 0.05$) lipid oxidation than patties on the other treatments and CON which had the highest ($P < 0.05$) lipid oxidation compared with all the treatments. By day 7 of display, both the KL and the ASC were similar ($P > 0.05$) to CON but had higher ($P < 0.05$) TBARS values than NMS. Likewise, PAA had lower ($P< 0.05$) lipid oxidation than CON by day 7 of display, but it was similar ($P > 0.05$) to the rest of the treatments.

Sensory Color and Odor Evaluation. The day of display by antimicrobial treatment interaction effects for overall color, worst point color, percentage discoloration, and off odor are shown in Figures 2A, 2B, 3A, and 3B respectively. Panelists found all treatments to have a higher ($P < 0.05$) red color than the CON treated patties on day 0 of display for the overall color attribute (Fig. 2A). On day 1, 2 and 3 of display NMS had a brighter red color ($P < 0.05$) than the rest of the treatments. The high brightness in overall red color for KL and NMS was detected by the panelists in day 7 of display and they were considered redder ($P< 0.05$) than the CON. Sensory panelists detected that all treatments had a brighter ($P < 0.05$) red worst point color than the CON patties on day 0 and 1 of simulated retail display (Fig. 2B). The NMS treatment was clearly the highest ($P< 0.05$) at d 0, 1, 2, and 3 whereas PAA values were not as high as NMS but higher ($P < 0.05$) than CON until d 3 of display. Panelists were unable to find any difference in worst point color ($P > 0.05$) between the CON, KL, NMS, PAA, and ASC treatments on day 7 of retail display.

All treatments had slightly less ($P < 0.05$) discoloration than the CON patties on day 0 and 1 of display (Fig. 3A). On day 7 of display, the KL and NMS treated patties had slightly less ($P < 0.05$) discoloration than the CON, PAA, and ASC treated patties. These results can explain the brighter red in overall and worst point color of KL, NMS, and PAA and also the reduced percentage of discoloration of KL and NMS treatment when compared to the CON,

whereas ASC treated patties maintained relatively similar sensory color characteristics to the CON.

Figure 3B shows the day by treatment interaction effect of off odor. The NMS treated patties had slightly less ($P < 0.05$) off odor than the CON and the PAA patties but were similar ($P > 0.05$) to KL and ASC at d 0. However, on day 1 and 3 of display, the KL, NMS, PAA, and ASC treated patties had less ($P < 0.05$) off odor than the CON. On day 7 of display the NMS, PAA, and ASC had similar ($P > 0.05$) off odor when compared to the untreated patties (CON).

Sensory Taste, Shear Force and Cook Loss Percentage. Sensory panelists were unable to detect any difference in beef flavor among treatments (Table 2). Likewise, KL, NMS, PAA, and ASC patties were similar ($P > 0.05$) in off flavor to the CON. The NMS treatment was scored juicier ($P < 0.05$) than the CON. The KL and NMS treatments were found to have similar ($P > 0.05$) bind compared to the CON.

Ground beef patties from the NMS and PAA treatment produced the lowest ($P < 0.05$) peak force to shear (kg) compared with the rest of the treatments (Table 2). Cook loss (%) was also affected by treatment where the CON, KL, and ASC patties were similar ($P > 0.05$), but the NMS had the least ($P < 0.05$) loss during cooking. High pH treatments such as the NMS treatment have greater juiciness and require less peak force to shear (Table 2). The latter can be explained as high water holding capacity of the meat proteins, which is typical at high pH values.

Implications

The use of potassium lactate, sodium metasilicate, peroxyacetic acid and acidified sodium chlorite on beef trimmings before grinding could improve or maintain the same sensory color, odor and taste, lipid oxidation, shear characteristics, and cooking characteristics as traditionally processed ground beef patties. Therefore, the application of these antimicrobial treatments can be used effectively to potentially improve ground beef safety without adversely affecting ground beef quality.

Acknowledgments

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Table 1. Effect of antimicrobial treatments applied to beef trimmings on the least-squares means for processing abilities and beef odor of raw ground beef patties.

Attributes	Treatment[a]					
	CON	KL	NMS	PAA	ASC	SE
Processing abilities						
Grinding ability[b]	1.00z	3.33y	1.50z	4.16x	3.58yx	0.22
Patty forming[c]	1.91z	3.75x	2.91y	5.00w	4.58w	0.16

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] Grinding ability score: 6 = extreme smearing; 1 = extreme cut – grind.
[c] Patty forming ability score: 6 = extremely fragile; 1 = extremely cohesive.
[wxyz] Least-squares means within a row with no letter in common differ ($P < 0.05$).

Table 2. Effect of antimicrobial treatments applied to beef trimming on the least squares means for beef flavor, off flavor, juiciness, bind, odor characteristics, shear force and cook loss % of raw ground beef patties.

Attribute	Treatment[a]					
	CON	KL	NMS	PAA	ASC	SE
Sensory properties						
Beef flavor[b]	7.4z	7.2z	7.2z	6.9z	7.4z	1.20
Off flavor[c]	4.6z	4.7z	4.7z	4.6z	4.8z	0.53
Juiciness[d]	5.8y	4.7z	6.5x	6.1xy	6.3xy	1.12
Bind[e]	6.0x	6.0x	6.0x	4.2z	4.8y	1.22
Beef odor[f]	7.56y	6.86z	7.23yz	7.23yz	7.32yz	0.23
Physical properties						
Shear force (kg)	3.50x	3.17xy	2.60z	3.00yz	3.25xy	0.15
Cook loss %[g]	23.22xy	22.48y	17.82z	25.80x	22.68xy	1.01

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] Beef flavor score: 8 = extremely intense beef flavor; 1 = no beef flavor.
[c] Off flavor score: 5 = no off flavor; 1 = extreme off flavor.
[d] Juiciness score: 8 = extremely juicy; 1 = extremely dry.
[e] Bind score: 8 = extreme bind; 1 = extremely fragile.
[f] Beef odor score: 1 = extremely non – beef like; 8 = extremely beef like.
[g] Calculated as [(fresh patty weight - cooked patty weight)/fresh patty weight × 100].
[xyz] Least-squares means within a row with no letter in common differ (P < 0.05).

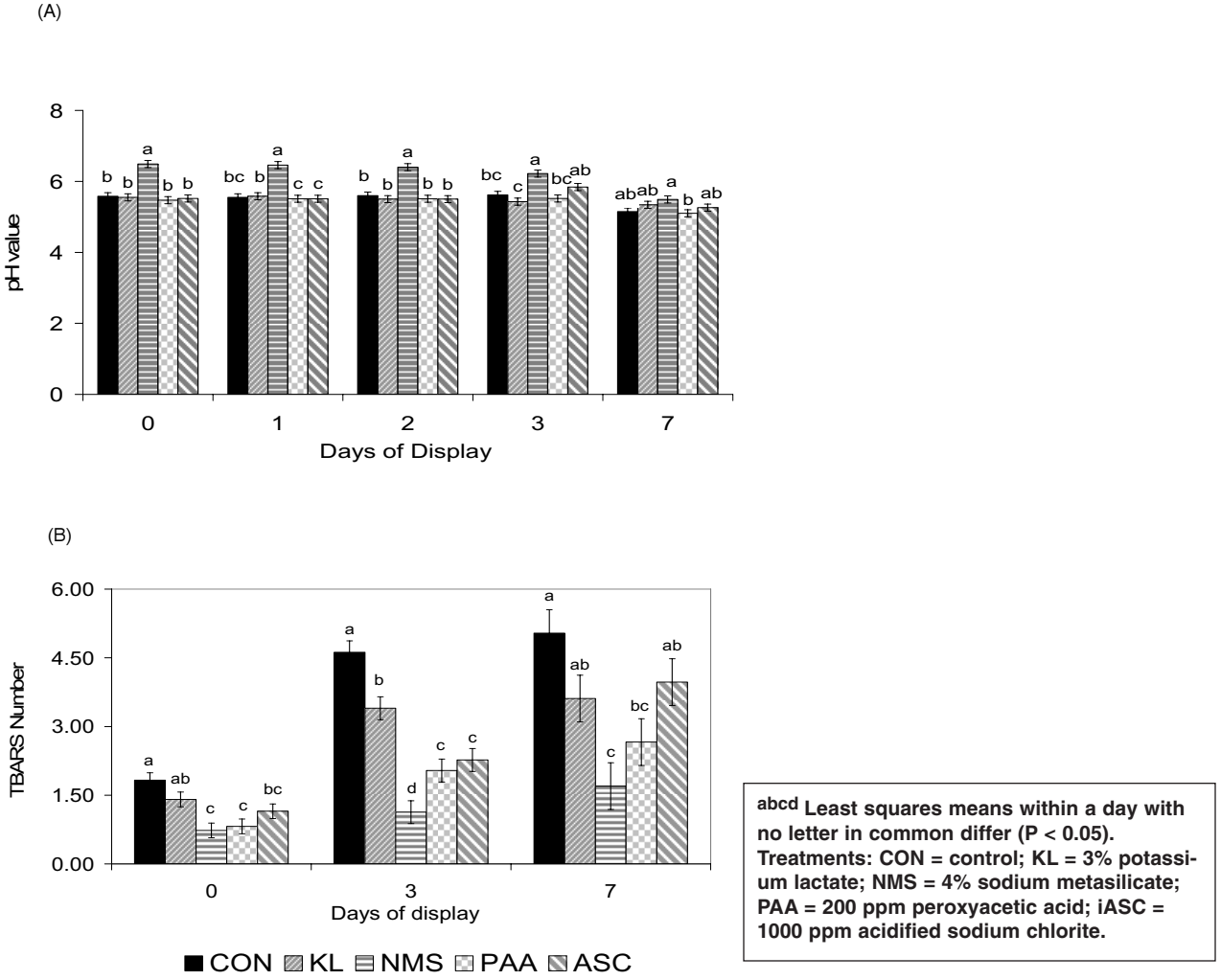
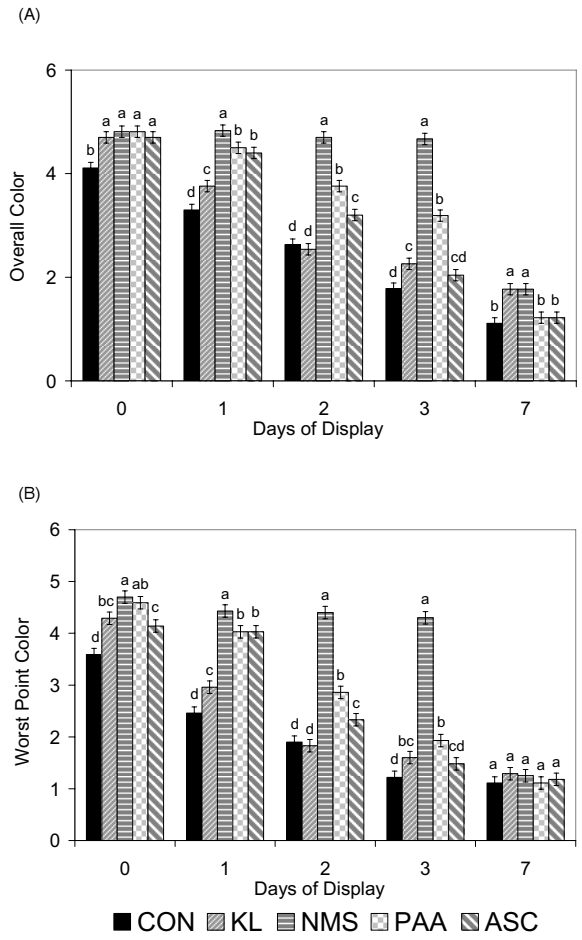
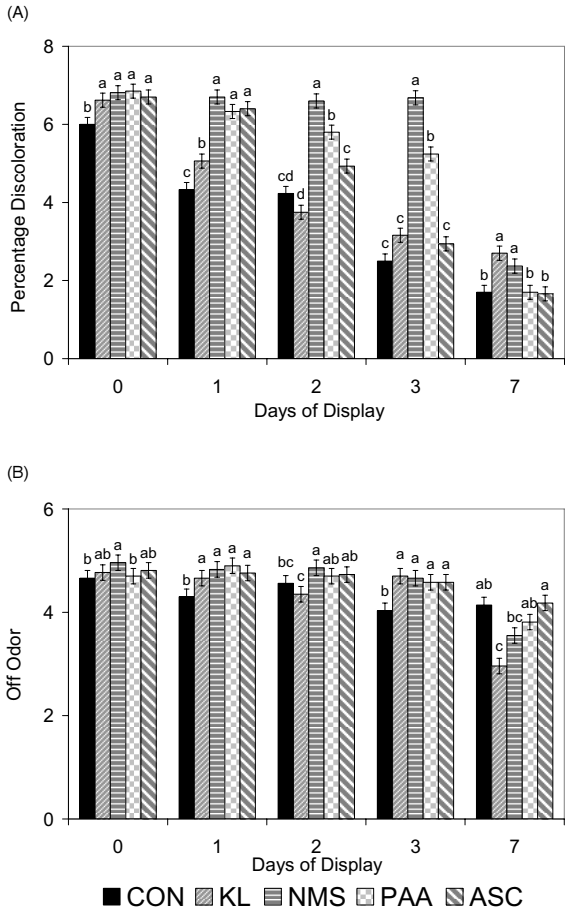


Fig. 1. Day of display by antimicrobial treatment interaction effect on the least squares means (±SE) of pH values and (B) TBARS (thiobarbituric acid reactive substances) values of ground beef patties through simulated retail display.



abcd Least squares means within a day with no letter in common differ (P < 0.05).
Treatments: CON = control; KL = 3% potassium lactate; NMS = 4% sodium metasilicate; PAA = 200 ppm peroxyacetic acid; ASC = 1000 ppm acidified sodium chlorite.

Fig. 2. Day of display by antimicrobial treatment interaction effect on the least squares means (±SE) for sensory evaluated (A) overall color score (1 = brown; 5 = bright purple red) and (B) worst point color of ground beef patties through simulated retail display.



abcd Least squares means within a day with no letter in common differ (P < 0.05).
Treatments: CON = control; KL = 3% potassium lactate; NMS = 4% sodium metasilicate; PAA = 200 ppm peroxyacetic acid; ASC = 1000 ppm acidified sodium chlorite.

Fig. 3. Day of display by antimicrobial treatment interaction effect on the least squares means (±SE) for sensory evaluated (A) percentage discoloration (1 = total discoloration (96 to 100%); 7 = no discoloration (0 to 4 %) and (B) off odor score (1 = extreme off odor; 5 = no off odor) of ground beef patties through simulated retail display.

Lateral and Longitudinal Characterization of Instrumental Tenderness and Sensory Characteristics in the Beef *Semimembranosus*

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Story in Brief

The objectives of this study were to characterize the longitudinal and lateral intramuscular variation of 2 instrumental tenderness measurements and trained sensory profile within the beef *semimembranosus*. Beef inside rounds were selected from 2 USDA (Top Choice and Select) quality grade categories (n = 9/quality grade). Steaks (0.75-in thick) were cut from each muscle at 3 locations (dorsal = D, medial = M, and ventral = V), vacuum-packaged, and then frozen at -4°F until analyzed for shear force and sensory taste characteristics. After cooking, instrumental and trained sensory tenderness were measured on steaks from each muscle location, and within each steak subsequently divided into 4 regions (caudal-distal = CaD, cranial-distal = CrD, caudal-proximal = CaP, and cranial-proximal = CrP). Instrumental tenderness measurements for Meullenet-Owens razor and Warner-Bratzler shear force values were generally lower for the CaD region of the D section, whereas regions within the V section were tougher and required greater shear force. Sensory panelists perceived lower amounts of connective tissue in the CaD of the D section, which tended to be more tender, whereas higher levels of connective tissue and greater toughness occurred in the CaP and CrP regions of the M and V sections.

Introduction

The meat industry continues to strive for the production of beef that meets consumers' palatability demands at the lowest cost level. Meat quality variation is the result of numerous factors, including a combination of breed, age, and environment. Palatability is an assessment of tenderness, juiciness, and flavor, with "consumers" continually ranking tenderness as the most desired attribute when eating a steak (Huffman et al., 1996).

While the round comprises 22% of the carcass weight and contains a portion of the largest and least tender muscles in the beef carcass, muscle quality variation is often difficult to measure. In general, muscles from the round tend to be reduced to ground products in an effort to improve their marketability, and Brooks et al. (2000) indicated that improvements in tenderness of retail cuts from the round were still needed to increase the value of this subprimal cut. Therefore, the objectives of this study were to evaluate longitudinal and lateral variation of instrumental tenderness and sensory characteristics in the *semimembranosus* from 3 different muscle locations and within 4 distinct regions.

Experimental Procedures

Beef inside rounds (IMPS #168), obtained from a large commercial slaughter facility, were selected from Top Choice and Select quality grade categories (n = 9/quality grade). Upon arrival at the University of Arkansas Red Meat Abattoir, inside rounds were aged at 35.6°F for 14 d from the box date. Muscles were then removed from vacuum-sealed bags, trimmed of external fat, and fabricated to obtain the *semimembranosus* (SM). Subsequently, each SM was divided into the dorsal (D), medial (M), and ventral (V) muscle location sections, and 0.75-in thick steaks were cut perpendicular to the muscle fiber orientation (n = 2/section; n = 108 total). A fishhook was placed into each fabricated steak marking muscle orientation, and steaks from each muscle section (D, M, and V) were further divided into 4 distinct regions (caudal-distal = CaD, cranial distal = CrD, caudal-proximal = CaP, and cranial-proximal = CrP; Fig. 1). Then individually identified steaks were vacuum-packaged, and stored at -4°F until analyzed for sensory taste and shear force determinations.

The Meullenet-Owens razor shear (MORS) was developed to measure tenderness in the *pectoralis major* muscle of broilers (Cavitt et al., 2005). Steaks (0.75-in thick) were cooked in a forced-air convection oven (Blodgett Oven Co., Burlington, Vt.) preheated to 375°F until the internal temperature of each steak reached 160°F. Internal steak temperature was monitored using Teflon-coated copper-constantan thermocouples (Omega Engineering Inc., Stamford, Conn.) attached to a multi-channel data logger (VAS Engineering Inc., San Diego, Calif.). After cooking, steaks were allowed to cool to room temperature (72°F) for approximately 2 h. The force required to shear perpendicular to the transversely cut surface of each steak was determined using a Texture Analyzer (Model TA-XT2i; Texture Technologies, Scarsdale, N.Y.), with an 11.01-lb load cell and a blunt blade shear attachment (height = 0.94 in and width = 0.31 in). The crosshead speed was 0.39 in/s, 0.022 lb of contact force initiated the test, and blade penetration depth was set at 0.78 in. Shear force was determined as the maximum force during the shearing process, and MORS measurements were repeated 3 times for each region (CaD, CrD, CaP, and CrP) within each steak.

Warner-Bratzler shear force (WBSF) analysis was performed on the same steaks used for razor shear analysis. Three, 0.50-in diameter cores were taken parallel to muscle fiber orientation from proximal locations utilized for MORS within each region of each steak. Each core was sheared once with a Warner-Bratzler compression-type shear attachment on an Instron Universal Testing Machine (Instron Corp., Canton, Mass.), equipped with a 110.15-lb load cell and a crosshead speed of 9.84 in/min.

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Sensory evaluation was conducted with 2 sensory sessions a day over a 3-day period. Steaks were cooked as described for MORS and WBSF shear force analyses. Three replicates were commingled and randomly assigned to sensory sessions so that 9 steaks were cooked in each of 6 sessions. Cooked steaks were cut into 0.39 in x 0.39 in x 1.0 in pieces, and held in a food warmer (Alto-Shamm Inc., Menomonee Falls, Wis.) at 145.5°F for approximately 10 min prior to, and during, each sensory evaluation. Sensory panelists (8) were selected and trained according to AMSA (1995) guidelines. During each session, samples (12) were served in random order to each panelist, and each panelist evaluated each region (CaD, CrD, CaP, and CrP) within a steak at his/her own pace. Panelists evaluated samples for myofibrillar and overall tenderness, connective tissue amount, juiciness, and beef flavor on an eight-point scale (1 = extremely tough, abundant, extremely dry, extremely non-beef like to 8 = extremely tender, none, extremely juicy, extremely beef like). Tests were conducted under color neutralizing lights with partitioned booths to isolate panelists.

Data were analyzed as a split-split plot design with quality grade as the whole plot, steak location within muscle as the sub-plot, and quadrant (region) within location of the muscle as the sub-sub-plot using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). Two and three-way interactions among main effects were also included in the model. The muscle x grade, muscle x grade x location, and muscle x grade x location x quadrant interactions were included as random effects to generate separate error terms for main effects. Panelist was included in the model as a fixed effect for all sensory variables to account for panelist variation. For all variables, least squares means were generated and, when significant ($P < 0.05$) F values were observed, least squares means were separated with pair-wise t-test (PDIFF option).

Results and Discussion

Quality grade of the SM had no ($P > 0.05$) effect on blunt-blade (MORS) force values (Table 1). The lowest ($P < 0.05$) MORS shear force values were obtained from the CaD region of the D section (Table 2). Intermediate shear values were located in the CrP region of the D section, the distal regions of the M and V sections, and the CrP region of the V muscle sections, whereas the proximal regions of the M section required the most ($P < 0.05$) force to shear than all other sections and regions within the SM.

As there was no effect of quality grade on WBSF values, there tended to be some similarities between WBSF and MORS force tenderness assessment within the SM. The CaD, CrD, and CaP regions of the D section had the lowest ($P < 0.05$) WBSF values, whereas intermediate WBSF values were noted in the CrP region of the D section, as well as the CaD, CrD, and CaP regions of the M section (Table 2). The distal and proximal regions of the V section and the CrP region of the M location had the ($P < 0.05$) greatest WBSF values.

There were no ($P > 0.05$) differences between Top Choice and Select grade SM for myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor, or off flavor (Table 1). Additionally, panelists failed to detect differences ($P > 0.05$) in beef flavor and off-flavor intensities among steak locations or within steak quadrants; however, the CrD region was perceived to be juicier ($P < 0.05$) than the other 3 steak regions.

There was a muscle location x steak region interaction ($P < 0.05$) for sensory connective tissue amount, myofibrillar tenderness, and overall tenderness (Table 2). Greater amounts of connective tissue were detected ($P < 0.05$) in the proximal regions of the M section and the CaP region of the V section. Myofibrillar tenderness scores were highest in the D section, with regions within the M section rated intermediate in tenderness. The CrP region of the V section was rated least tender ($P < 0.05$) for myofibrillar tenderness. These same trends were observed for sensory overall tenderness, with the D section rated the most tender, and the CrP region of the V section the least tender (Table 2).

Additionally, there was a quality grade x muscle section interaction ($P < 0.05$) for juiciness (Fig. 2). Juiciness ratings were lowest ($P < 0.05$) for the V section of the SM within Top Choice, whereas Select steaks from the M section received lower ($P < 0.05$) juiciness ratings than the D section.

The shear force gradients within the SM from the current study are in agreement with the results of by Paul and Bratzler (1955). Generally, shear force values were lower toward the superficial (medial side) and higher towards the posterior end (ventral). The trends noted within this study and the aforementioned studies lend support to previous theories for improving fabrication and marketing of more tender regions in the SM. Possible explanations for these differences in tenderness within the SM can be attributed to the rate of muscle temperature influencing rigor development (Hannula and Puolanne, 2004), muscle fiber type (Ashmore, 1974). More importantly, Hunt and Hendrick (1977) reported that differences in the fiber type, pH, and temperature decline have been noted among the deep and superficial portions of the SM, further supporting the biochemical effects that impact muscle tenderness.

While limited work has evaluated the location effect of sensory characteristics within the SM, the results from this study generally agree with previous work by Rhee et al. (2004), who reported that the SM was considered less tender, contained more connective tissue, appeared less juicy, and was moderate in beef flavor; however, they did not include any location effect for sensory attributes. Furthermore, this information implies that some method of tenderization, albeit chemical or mechanical, is needed to improve palatability traits of specific regions within the SM for consumer satisfaction and maximizing carcass value.

Implications

Information from the present experiment provides a detailed muscle profile of instrumental tenderness and sensory characteristics, indicating that there is a considerable amount of variation within this extremely large muscle from the beef round. These variations in meat quality can possibly be attributed to the complex interaction of biochemical traits that muscles undergo during the conversion of muscle to meat.

Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. Moreover, the authors wish to acknowledge Z. Boone, of Cargill Fresh Meat Solutions, (Oklahoma City, Okla.) for assistance with product procurement, and to S.A. Quilo, C.W. Rowe, and J. Stephenson for their assistance with SM fabrication and data collection.

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Table 1. Main effects of quality grade, muscle location, and steak region on instrumental tenderness and sensory characteristics of the *semimembranosus*.

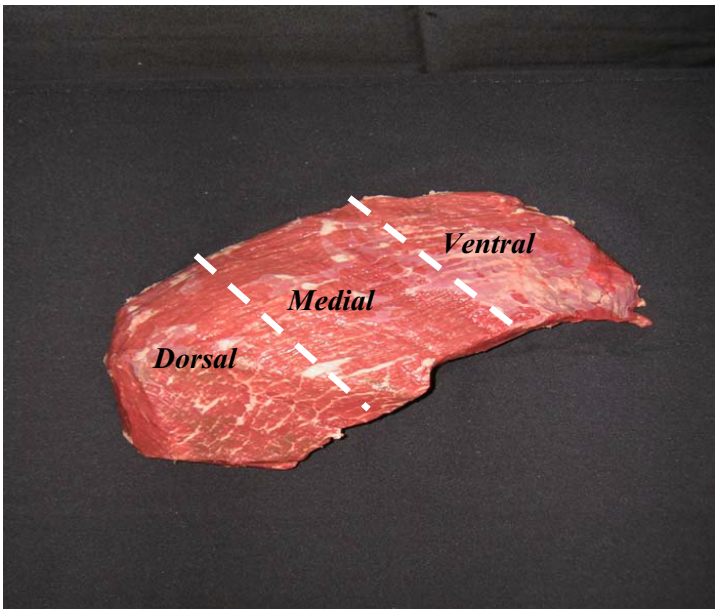
Item	Warner-Bratzeler shear force (N)	Blunt-blade shear force (N)	Connective tissue amount[1]	Myofibrillar tenderness[1]	Overall tenderness[1]	Juiciness[2]	Beef flavor[3]	Off flavor[4]
Quality Grade								
Top Choice	50.12	32.21	5.83	6.24	6.15	-	7.14	4.67
Select	51.92	32.27	5.95	6.40	6.29	-	7.12	4.75
SEM	2.27	0.94	0.10	0.09	0.08	-	0.07	0.05
Location								
Dorsal	-	-	-	-	-	-	7.13	4.67
Medial	-	-	-	-	-	-	7.16	4.74
Ventral	-	-	-	-	-	-	7.10	4.72
SEM	-	-	-	-	-	-	0.09	0.06
Caudal-distal								
Cranial-distal	-	-	-	-	-	5.81^{b}	7.11	4.73
Caudal-proximal	-	-	-	-	-	6.19^{a}	7.21	4.77
Cranial-proximal	-	-	-	-	-	5.90^{b}	7.10	4.72
SEM	-	-	-	-	-	5.75^{b}	7.10	4.61
	-	-	-	-	-	0.11	0.09	0.06

[1] 1 = extremely tough, abundant; 8 = extremely tender, none.
[2] 1 = extremely dry; 8 = extremely juicy.
[3] 1 = extremely non-beef like; 8 = extremely beef like.
[4] 1 = extreme off-flavor; 5 = no off-flavor.
[a, b] Within a main effect, within a column, means without a common superscript letter differ ($P < 0.05$).

Table 2. The interactive effects of steak location and within steak quadrant[1] on mechanical and sensory panel measurements of palatability attributes for the *semimembranosus*.

	Dorsal				Medial				Ventral				
	CaD	CrD	CaP	CrP	CaD	CrD	CaP	CrP	CaD	CrD	CaP	CrP	**SEM**
MORS (N)[2]	26.67^{d}	29.85^{cd}	29.19^{cd}	32.49^{bc}	31.24^{bc}	30.53^{c}	37.73^{a}	38.33^{a}	31.97^{bc}	31.79^{bc}	34.67^{ab}	32.38^{bc}	1.43
WBSF (N)[3]	36.65^{e}	40.46^{de}	41.97^{d}	51.87^{c}	49.47^{c}	48.84^{c}	52.30^{bc}	56.51^{ab}	61.11^{a}	57.27^{ab}	57.24^{ab}	58.60^{a}	2.47
Connective Tissue[4]	6.71^{a}	6.27^{ab}	6.36^{ab}	6.03^{bcd}	5.89^{bcd}	5.97^{bcd}	5.48^{def}	5.34^{ef}	5.71^{cde}	5.87^{bcde}	5.07^{f}	6.09^{bc}	0.20
Myofibrillar Tenderness[5]	7.13^{a}	6.79^{ab}	6.75^{abc}	6.54^{bcd}	6.12^{de}	6.43^{bcd}	6.31^{bcd}	6.17^{cde}	5.83^{e}	6.34	5.22	6.14	0.20
Overall Tenderness[5]	7.07^{a}	6.72^{ab}	6.58^{bc}	6.35^{bcd}	6.16^{cde}	6.23^{cde}	5.93^{de}	6.01^{de}	5.82^{ef}	6.20^{cd}	5.39^{f}	6.18^{cde}	0.20

[1] CaD = caudal-distal quadrant; CrD = cranial-distal quadrant; CaP = caudal-proximal quadrant; and CaD = caudal-distal quadrant.
[2] MORS =Meullenet-Owens razorblade shear force.
[3] WBSF = Warner-Bratzler shear force.
[4] 1 = abundant to 8 = none.
[5] 1 = extremely tough to 8 = extremely tender.
[a, b, c, d, e, f] Within a row, least squares means without a common superscript are different ($P < 0.05$).



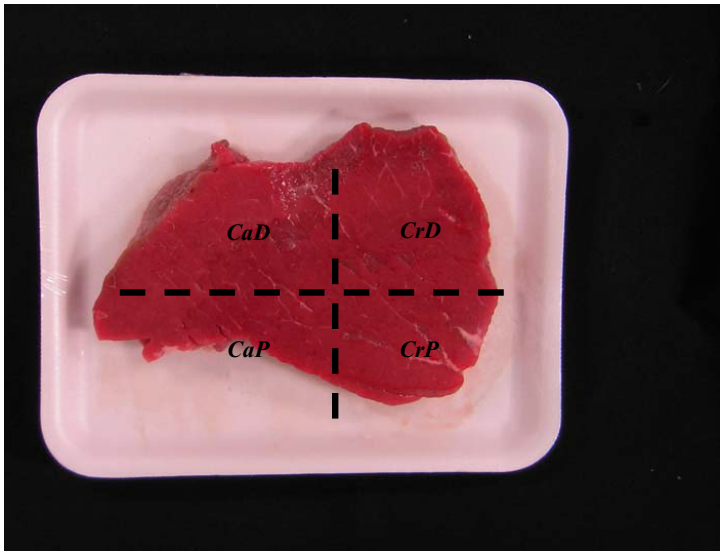


Fig. 1. Schematic illustration of the *semimembransosus* muscle location and steak regions (CaD = caudal-distal; CrD = cranial-distal; CaP = caudal-proximal; and CrP = cranial-proximal).

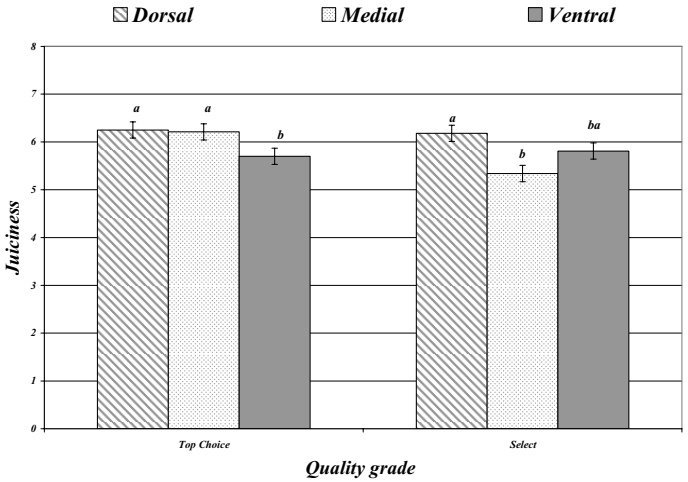


Fig. 2. The interactive effects of sensory characteristics of quality grade x muscle location for juiciness (P < 0.05). a,b Bars with no letters in common differ (P < 0.05).

Longitudinal and Lateral Characterization of Color Stability in the Beef *Semimembranosus*

J.T. Sawyer, R.T. Baublits, J.K. Apple, and Z.B. Johnson[1]

Story in Brief

The objectives of this study were to evaluate longitudinal and lateral variation of color stability within the *semimembranosus*. Beef inside rounds were selected from 2 USDA (Top Choice, and Select) quality grade categories (n = 9/quality grade), and were subsequently stored at 2°F for 14 d from the box date. Steaks (0.75-in thick) were cut from each muscle at 3 locations (dorsal, medial, and ventral), placed onto foam trays, and overwrapped with a PVC film. Steaks from each muscle location were subsequently divided into 4 regions (caudal-distal = CaD, cranial distal = CrD, caudal-proximal = CaP, and cranial-proximal = CrP). Packaged steaks were evaluated for visual color by trained panelists, instrumental color using a Hunter MiniScan XE, and lipid oxidation (TBARS) on d 0, 3, and 6 of simulated retail display. Visual scores for overall steak color during the display period were typically higher for the CaD and CrD regions of the 3 muscle sections during the first 3 days of display, whereas the CaP and CrP regions generally received lower overall visual scores. Instrumental color assessment indicated that L^* (lightness) values tended to be lower for the CaD and CrD regions of all muscle locations, with higher L^* values recorded for the CrP regions of muscle sections. TBARS values indicated that there were significant differences from d 0 to 6 within a steak region during the simulated display. These results indicate that some regions within *semimembranosus* steaks are more shelf-stable than other intra-steak regions.

Introduction

Variation in initial color, color uniformity, and shelf stability within the *semimembranosus* (SM) can be related to postmortem conditions. Due to its location, the outer SM has a faster chill rate than the inner SM, resulting in a more rapid rate of postmortem glycolysis and pH decline (Sammel et al., 2002). Follett et al. (1974) reported that superficial SM chilled faster than deep SM, indicating that the accelerated chilling rate and lower postmortem pH decline would improve muscle color and protein functionality. With differences in temperature and pH, the oxidation and reduction of myoglobin are thought to ultimately affect color stability of the sections within the SM (Ledward, 1985).

At times, the meat industry has recognized the differences in shelf stability of the SM; yet, previous research has not examined the chemical differences within this inherently large muscle. Therefore, the objectives of this study were to evaluate longitudinal and lateral variation of color stability in the SM from 3 different muscle locations, and, within each muscle location, 4 distinct regions.

Experimental Procedures

Beef inside rounds (IMPS #168), obtained from a large commercial slaughter facility, were selected from Top Choice and Select quality grade categories (n = 9/quality grade). Upon arrival at the University of Arkansas Red Meat Abattoir, inside rounds were aged at 2°F for 14 d from the box date. Muscles were then removed from vacuum-sealed bags, trimmed of external fat, and fabricated to obtain the SM. Subsequently, each SM was divided into the dorsal (D), medial (M), and ventral (V) muscle location sections, and 0.75-in thick steaks were cut perpendicular to the muscle fiber orientation (n = 2/section; n = 108 total). A fish-hook was placed into each fabricated steak marking muscle orientation, and steaks from each muscle section (D, M, and V) were further divided into 4 distinct regions (caudal-distal = CaD, cranial distal = CrD, caudal-proximal = CaP, and cranial-proximal = CrP; Fig. 1). Then individually identified steaks were placed onto foam trays with absorbent pads, over-wrapped with a polyvinyl chloride film (O_2 transmission rate = 14,000 cc $O_2/m^2/24h/atm$; Koch Supplies Inc., Kansas City, Mo.), and stored at 35.6°F. Steaks designated for instrumental and visual color analysis were stored under simulated retail display conditions (39.2°F and 1,600 lux deluxe warm white fluorescent lighting; Philips Inc., Somerset, N.J.) for 7 d. Steaks (n = 12/d) used for visual analysis were removed from retail display on d 0, 3, and 6, marked with a fish-hook, tagged with muscle section and steak number, vacuum-packaged, and stored at -4°F until analyzed for lipid oxidation.

Instrumental color readings of steaks under simulated retail display conditions were measured on d 0, 3, and 6 using a Hunter MiniScan XE (Model 45/0-L, Hunter Associates Laboratory Inc., Reston, Va.). The CIE L^* (lightness; 0 = black, 100 = white), a^* (redness; -60 = green, +60 = red), and b^* (yellowness; -60 = blue, +60 = yellow) values, were determined from the mean of 3 readings within each region (CaD, CrD, CaP, and CrP) on the cut surface of each steak using Illuminant A and a 10° standard observer.

A 6-member, trained sensory panel was used to evaluate sensory color of steaks during simulated retail display. Panelists were selected and trained according to AMSA (1991) guidelines. Sensory panelists evaluated each region (CaD, CrD, CaP, and CrP) within a steak under display for worst point and overall color (5 = bright red, 4 = dull red, 3 = slightly brownish red, 2 = moderately brownish red, and 1 = brown), and percentage surface discoloration (7 = no discoloration [0%], 6 = slight discoloration [1 to 20%], 5 = small discoloration [20 to 39%], 4 = modest discoloration [40 to 59%], 3 = moderate discoloration [60 to 79%], 2 = extensive discoloration [80 to 95%], and 1 = total discoloration [96 to 100%]) on d 0, 3, and 6 of display.

On d 0, 3, and 6 of simulated retail display, 12 steaks (n = 6 / treatment / day) were sampled for lipid oxidation (TBARS) as pre-

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viously described by Jimenez-Villarreal et al. (2003). Absorbance was measured at 531 nm with a spectrophotometer (Shimadzu Scientific Instruments, Inc., model UV-12015, Columbia, Md.) and multiplied using a factor of 12.21 to obtain the TBARS value (mg malonaldehyde/kg of meat).

Data were analyzed as a split-split plot design with quality grade as the whole plot, steak location within muscle as the sub-plot, and quadrant (region) within location of the muscle as the sub-sub-plot using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). Two-and three-way interactions among main effects were also included in the model. The muscle x grade, muscle x grade x location, and muscle x grade x location x quadrant interactions were included as random effects to generate separate error terms for main effects. Day was included in the model and fit with all main effect and main effect interactions for simulated retail display variables, whereas panelist was included in the model as a fixed effect for all sensory variables to account for panelist variation. For all variables, least squares means were generated and, when significant ($P < 0.05$) F values were observed, least squares means were separated with pair-wise t-test (PDIFF option).

Results and Discussion

There were no ($P > 0.05$) discernable differences for either L^* or b^* values between quality grades (Table 1). For L^* values (Fig. 2) the CaD, CrD, and CaP regions of the D section, the distal regions of the M section, and the CaD region of the V section were darkest ($P < 0.05$), whereas the CrP region of the M and V sections were the lightest ($P < 0.05$).

Regardless of quality grade category, steaks were redder ($P < 0.05$) on d 0 than d 3, and, by d 6 of display, Select-grade steaks received lower ($P < 0.05$) a^* values than Top Choice steaks (Fig. 3a). Redness (a^*) values (Fig. 3b) declined ($P < 0.05$) throughout the 6-d display period, and no differences ($P > 0.05$) among the 3 muscle sections were observed on either d 0 or 6 of display. Yet, after d 3 of retail display, the D section was redder($P < 0.05$) than the M and V sections.

There were no differences in a^* values associated within steak region on d 0 of display. By d 3, however, the CaD quadrant was redder ($P < 0.05$) than the CrD and CaP quadrants, and the CrP region was the least red ($P < 0.05$). After d 6 of simulated display, each muscle region had different a^* values ($P < 0.05$), with the CaD having the greatest, and the CrP having the lowest, a^* values (Table 2).

All muscle sections of the SM were more ($P < 0.05$) yellow on d 0 than d 3 or 6 of the display period (Fig. 3c). Even though the D section of the SM received higher ($P < 0.05$) b^* values than the V section on d 3 of display, no differences ($P > 0.05$) in b^* values were detected among muscle sections on d 6 of display. The CrP region was more yellow ($P < 0.05$) than the distal half on d 0 (Table 2); yet, after d 3 of display, the CaD quadrant had the highest ($P < 0.05$) b^* values, whereas the CrP quadrant had the lowest ($P < 0.05$) b^* values. By d 6, however, the CaD was only more ($P < 0.05$) yellow than the CrD.

Sensory color conducted during simulated display indicated that various regions within the muscle sections of the SM appear more shelf-stable. Surface discoloration did not ($P > 0.05$) differ between quality grades (Table 1). On d 0 the CrP region within all 3 muscle locations already exhibited greater ($P < 0.05$) discoloration than the other 3 regions (Table 3). Through d 3 and 6 of display, the CrP region of all 3 muscle locations discolored to a greater extent than the other 3 regions (Table 3).

There were no distinct differences in worst point color scores ($P > 0.05$) among quality grades; however, the D and M sections appeared less discolored than the V section (Table 1). Furthermore, on d 0 (Table 2), the CrP region received lower ($P < 0.05$) worst point color scores than the CaD region, which corroborates the early discoloration of this region. By d 3 and 6 of display, the CaP and CrP regions both exhibited lower color stability ($P < 0.05$), as evidenced by receiving lower worst point color scores than the CaD region (Table 2).

There were no ($P > 0.05$) differences in overall color scores among quality grades in the SM (Table 1). On d 0, the CrP regions of the M and V sections received the lowest ($P < 0.05$) overall visual color scores (Table 3). By d 3, the CrP region received the lowest ($P < 0.05$) overall visual score, regardless of muscle section (Fig. 4b). More importantly, the distal region (CaD and CrD) within the D and M muscle sections received higher overall visual scores on d 3 of simulated display, which was also observed on d 6 of simulated retail display (Table 3).

There were no differences ($P > 0.05$) in TBARS observed between quality grades or among muscle location (Table 1). Initial (d 0) TBAR values were the lowest ($P < 0.05$), whereas TBARS values were the highest after d 6 of simulated retail display. Even though TBARS values increased in the CaD, CaP, and CrD quadrants from d 3 to 6 of display, there were no ($P > 0.05$) differences in TBARS values among quadrants on either d 3 or 6 of display (Table 2).

Visual and instrumental color stability results concur with the results of Sammel, et al. (2002), who reported a noticeable color difference between the inner and outer portions of the SM. Moreover, Sammel et al. (2002) observed that, while the inner portion of the SM was brighter and had greater L^*, a^*, and b^* values initially, desirable visual and instrumental color waned quickly, indicating that the outer portion of the SM maintains its color for a longer period of time during retail display. These slow-chilling, large muscles are thought to have a more open structure and greater scattering coefficients, ultimately creating a paler appearance (MacDougall, 1982). More notably, temperature decline within the SM is quite variable between the superficial and the deep portions during the first 12 h postmortem; thus, decreasing the rate of postmortem muscle metabolism and pH decline and/or increasing heat dissipation during the onset of rigor mortis in the deep portions of the SM would obviously result in improved muscle color stability and protein functionality (Follett et al., 1974).

Implications

Information from the present experiment indicates that there is a considerable amount of variation within this extremely large muscle from the beef round. These variations in meat color can possibly be attributed to the complex interaction of biochemical traits that muscles undergo during the conversion of muscle to meat.

Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. Moreover, the authors wish to acknowledge Z. Boone, of Cargill Fresh Meat Solutions, (Oklahoma City, Okla.) for assistance with product procurement, and to S.A. Quilo, C.W. Rowe, and J. Stephenson for their assistance with SM fabrication and data collection.

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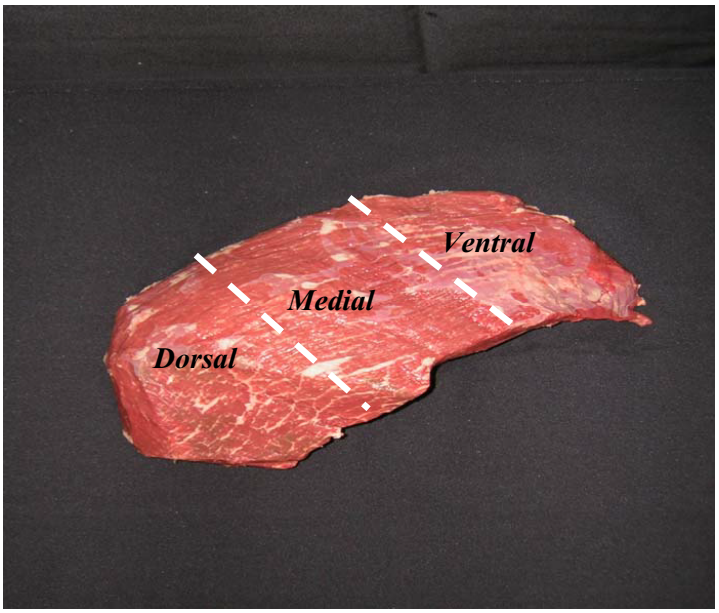

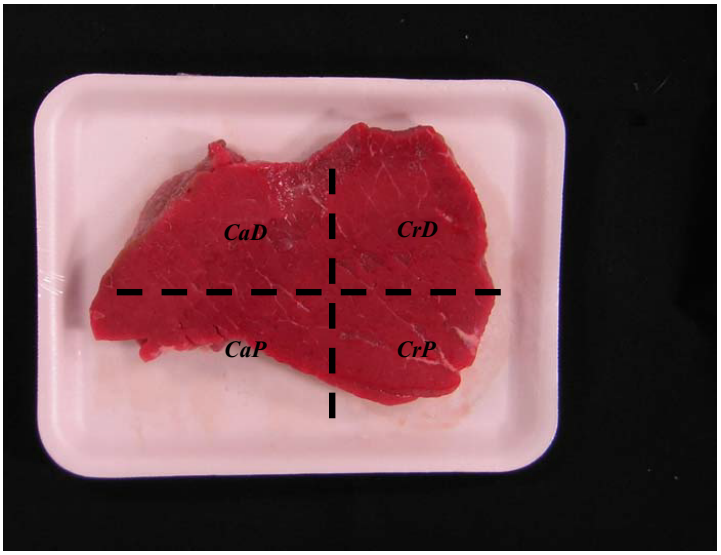

Fig. 1. Schematic illustration of the *semimembranosus* muscle location and steak regions (CaD = caudal-distal; CrD = cranial-distal; CaP = caudal-proximal; and CrP = cranial-proximal).

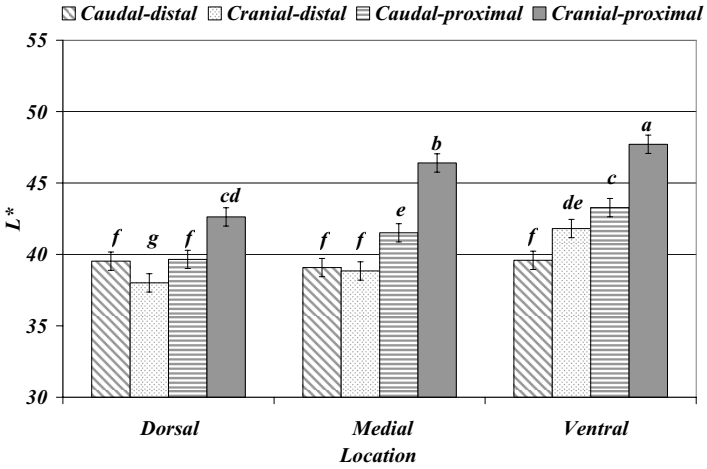

Fig. 2. Muscle location x steak region interactive effects (P < 0.05) on *L (lightness) instrumental color characteristics of the *semimembranosus*. Columns lacking common letters differ (P < 0.05).**

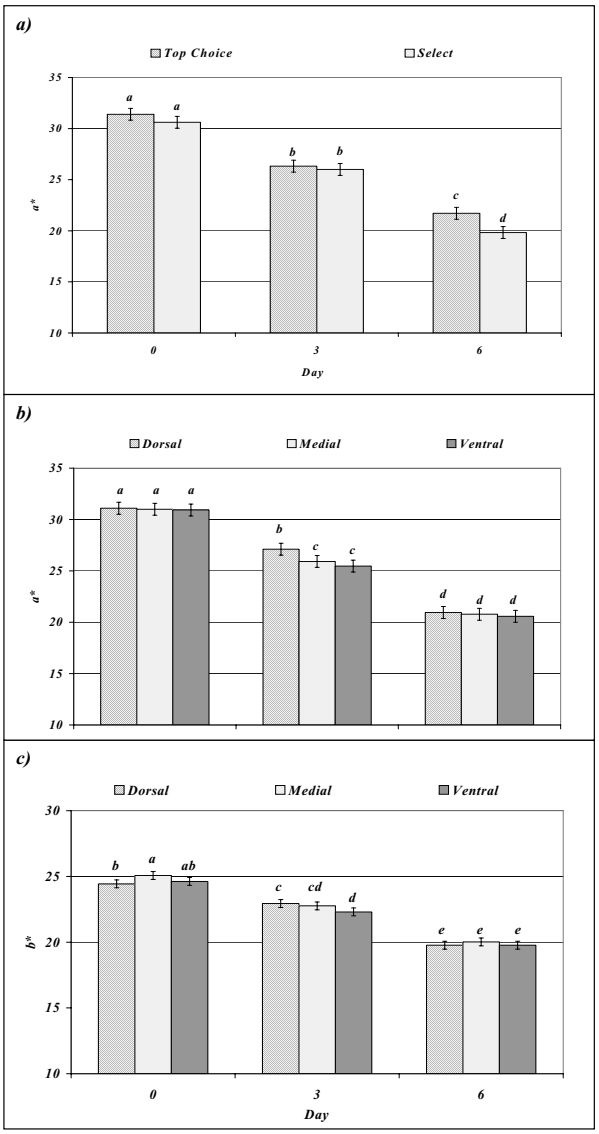

Fig. 3. Instrumental color for: a) *a (redness) values for the quality grade x day of simulated display interaction (P < 0.05); b) *a** values for muscle location x day of simulated display interaction (P < 0.05); and c) *b** (yellowness) values for the muscle location x day of simulated display interaction (P < 0.05). Columns lacking common letters differ (P < 0.05).**

Table 1. Main effects of quality grade and muscle location on instrumental and visual color characteristics[1] of the *semimembranosus*.

Item	L*	b*	Discoloration (%)[2]	Worst point color[3]	Overall color[2]	TBARS (mg/kg)[4]
Quality Grade						
Top Choice	40.95	22.47	5.57	3.46	4.02	0.62
Select	42.05	22.35	5.35	3.33	3.88	0.54
SEM	0.74	0.33	0.22	0.18	0.14	0.09
Location						
Dorsal	-	-	-	3.54[a]	-	0.58
Medial	-	-	-	3.39[ab]	-	0.56
Ventral	-	-	-	3.26[b]	-	0.61
SEM	-	-	-	0.14	-	0.07

[1] L*, 0 = black, 100 = white; b*, -60 = blue, +60 = yellow.
[2] 1 = Total discoloration (100%), 7 = No discoloration (0%).
[3] 1 = Brown, 5 = Bright red.
[4] 2-thiobarbituric acid reactive substance (TBARS) are a measure of oxidative rancidity (mg maldenaldehyde/kg of fresh tissue).
[a, b] Within a main effect, within a column, means without a common superscript letter differ (P < 0.05).

Table 2. The interactive effects of simulated retail display and within steak quadrant[1] on color measurements and TBARS values of the *semimembranosus*.

	Day 0				Day 3				Day 6				
	CaD	CrD	CaP	CrP	CaD	CrD	CaP	CrP	CaD	CrD	CaP	CrP	SEM
Worst point color[2]	4.75^{a}	4.49^{ab}	4.39^{abc}	4.16^{bc}	4.03^{cd}	3.53^{d}	3.14^{de}	2.75^{efg}	2.77^{ef}	2.44^{gh}	2.15^{h}	2.15^{h}	0.23
Redness (a*)[3]	31.26^{a}	31.23^{a}	31.09^{a}	30.46^{a}	28.67^{b}	27.02^{c}	26.30^{c}	22.69^{d}	23.23^{d}	21.64^{e}	20.61^{f}	17.60^{g}	0.57
Yellowness (b*)[3]	24.35^{b}	24.38^{b}	24.79^{ab}	25.30^{a}	23.51^{c}	22.61^{d}	22.75^{d}	21.80^{e}	20.28^{f}	19.60^{g}	19.78^{fg}	19.75^{fg}	0.29
TBARS[4]	0.26^{e}	0.23^{e}	0.23^{e}	0.28^{e}	0.57^{cd}	0.53^{d}	0.65^{cd}	0.74^{abcd}	0.95^{a}	0.79^{abc}	0.97^{ab}	0.84^{abc}	0.12

[1] CaD = caudal-distal quadrant; CrD = cranial-distal quadrant; CaP = caudal-proximal quadrant; and CaD = caudal-distal quadrant.
[2] 1 = brown to 6 = bright red.
[3] Redness (a*) values are a measure of redness (lager number indicates a more intense red color; -60 = green, +60 = red), whereas yellowness (b*) values are a measure of yellowness (larger number indicates a more yellow color; -60 = blue, +60 = yellow).
[4] 2-thiobarbituric acid reactive substance (TBARS) are a measure of oxidative rancidity (mg maldenaldehyde/kg of fresh tissue).
[a, b, c, d, e, f, g] Within a row, least squares means lacking a common superscript are different ($P < 0.05$).

Table 3. The interactive effects of steak location within steak quadrant[1] on visual and instrumental color measurements of the *semimembranosus* after 0, 3, and 6 days of simulated retail display.

	Dorsal				Medial				Ventral				
	CaD	CrD	CaP	CrP	CaD	CrD	CaP	CrP	CaD	CrD	CaP	CrP	SEM
Day 0													
Discoloration score[2]	6.75^{ab}	6.75^{ab}	6.81^{ab}	6.28^{cd}	6.83^{a}	6.61^{abc}	6.44^{bc}	5.78^{e}	6.86^{a}	6.78^{ab}	6.33^{cd}	6.00^{de}	0.13
Overall color score[3]	4.83^{a}	4.69^{abc}	4.83^{a}	4.58^{c}	4.81^{ab}	4.72^{abc}	4.75^{abc}	4.19^{d}	4.86^{a}	4.86^{a}	4.67^{bc}	4.22^{d}	0.07
Day 3													
Discoloration score[2]	6.25^{a}	6.18^{ab}	5.71^{abc}	4.40^{d}	6.39^{a}	6.00^{ab}	5.44^{bc}	3.31^{e}	6.03^{ab}	5.47^{bc}	5.06^{cd}	3.42^{e}	0.38
Overall color score[3]	4.44^{a}	4.26^{a}	4.20^{ab}	3.28^{c}	4.33^{a}	4.19^{a}	3.83^{b}	2.97^{c}	4.31^{a}	4.17^{ab}	3.83^{b}	2.94^{c}	0.21
Day 6													
Discoloration score[2]	5.39^{ab}	5.22^{abc}	4.81^{bc}	3.31^{d}	5.72^{a}	5.33^{ab}	4.83^{bc}	2.69^{d}	5.46^{ab}	4.85^{bc}	4.40^{c}	2.76^{d}	0.41
Overall color score[3]	3.72^{ab}	3.69^{ab}	3.33^{bc}	2.92^{cd}	3.86^{a}	3.61^{ab}	3.36^{abc}	2.58^{de}	3.56^{ab}	3.37^{abc}	3.06^{cd}	2.32^{e}	0.27

[1] CaD = caudal-distal quadrant; CrD = cranial-distal quadrant; CaP = caudal-proximal quadrant; and CaD = caudal-distal quadrant.
[2] 1 = total (100%) discoloration to 7 = no (0%) discoloration.
[3] 1 = brown to 6 = bright red.
[a, b, c, d, e, f] Within a row, least squares means lacking a common superscript are different ($P < 0.05$).

Empirical Modeling for Predicting Tenderness of Muscles from the Beef Round

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Story in Brief

The objective of this study was to model visible and near-infrared reflectance values on beef steaks with 2 spectroradiometers: NIRSystems (NIRS; 400 to 2,400 nm) and ASD Field Spec Pro (ASD; 350 to 1,050 nm). After aging for 0, 7, 14, 21, and 28 d, tenderness of 600 steaks (*Biceps Femoris* = 200; *semitendinosus* = 200; and *semimembranosus* = 200) from U. S. Prime, top Choice, Choice, and Select carcasses, was measured using Meullenet – Owens razor shear (MORS) and Warner-Bratzler shear force (WBSF). Partial least squares (PLS) regression models on normalized spectra were able to explain 67 (ASD) to 68% (NIRS) of variability in MORS values, and 19 (ASD) to 41% (NIRS) variability in WBSF values in the *biceps femoris*, 47 (ASD) to 46% (NIRS) of variability in MORS values, and 45 (ASD) to 41% (NIRS) of WBSF values of the *semitendinosus*, and 67 (ASD) to 88% (NIRS) of the variability in MORS values, and 61 (ASD) to 85% (NIRS) of the variability in WBSF values of the *semimembranosus*. The 2 spectroradiometers differed extremely in the predictive capability, between WBSF and MORS values; therefore, these instrumental methods could not be accurately compared. Moreover, inconsistencies in spectroradiometers may be due to differences in scanning technique and scanning angle.

Introduction

The National Cattlemen's Beef Association (NCBA) has identified tenderness as one of the primary factors affecting consumer satisfaction apart from color and texture. There is a wide variation in quality of beef products due to genetics, gender, maturity, slaughter regimes, and dietary management. Regulatory limits set by the USDA Consumer and Marketing Service demand consistency in the final product and, considering the slaughter rate of beef plants in the United States, a robust, on-line tool to classify carcasses or primal cuts is imperative.

Existing techniques, both instrumental and sensory evaluation, are time consuming and labor intensive. Therefore, a less expensive, non-invasive, rapid, accurate, and precise method to classify carcasses irrespective of complicated genetics and animal origin is important. Even though near infrared (NIR) spectroscopy provides precise prediction of beef cuts based on tenderness, there is research that indicates inconsistency in the tenderness predictability of NIR (Bryne et al., 1998; Leroy et al., 2003). Therefore, the objectives of this study were to compare and analyze 2 spectroradiometers with 2 instrumental tenderness measures (Warner-Bratzler shear force and razor blade shear force), and develop an empirical model that could accurately predict tenderness across diverse aging periods.

Experimental Procedures

Beef top (inside) and bottom (gooseneck) rounds (IMPS# 168 and 170, respectively) were obtained from a large commercial slaughter facility, and randomly collected during carcass fabrication to ensure variability. Muscles were selected from 4 (n = 10/quality grade; n = 120 total) U. S. Prime, top Choice (CAB), Choice, and Select grade carcasses. Upon arrival at the University of Arkansas Red Meat Abattoir, muscles were removed from vacuum-sealed bags, trimmed of external fat, and fabricated to obtain the *biceps femoris* (BF), *semitendinosus* (ST), and *semimembranosus* (SM). Five 1.0-in-thick steaks from each muscle within each quality grade were allotted for aging (0, 7, 14, 21, and 28 d).

Steaks were initially scanned from 400 to 2,400 nm with a NIR Systems spectroradiometer (NIRS; model 6500; Perstorp Analytical, Silver Springs, Mass.) and subsequently scanned from 350 to 1,050 nm with an ASD Field Spec Pro portable spectroradiometer (ASD Inc., Boulder, Colo). After scanning, steak outlines were traced onto acetate paper, vacuum-packaged and subsequently aged at 35.6°F for 7, 14, 21, or 28 d. At the completion of each designated aging period, steaks were frozen at -4°F until cooking and tenderness measurements could be conducted.

The Meullenet-Owens razor shear (MORS) was developed to measure tenderness in the *pectoralis major* muscle of broilers (Cavitt et al., 2005), and has been found to be a reliable measure of poultry breast meat tenderness. Steaks (1.0-in-thick) were cooked in a forced-air convection oven (Blodgett Oven Co., Burlington, Vt.) preheated to 375°F until the internal temperature of each steak reached 160°F. After cooking, steaks were allowed to cool to room temperature (72°F) for approximately 2 h. The force required to shear perpendicular to the transversely cut surface of each steak was determined using a Texture Analyzer (Model TA-XT2i; Texture Technologies, Scarsdale, N.Y.), with a 11.01 lb load cell and a blunt blade shear attachment (height = 0.94 in and width 0.31 in), a crosshead speed of 0.39 in/s and 0.022 lb of contact force initiated the test. Blade penetration depth was set at 0.78 in. Shear force was determined as the maximum force during the shearing process, and MORS measurements were repeated 4 times within each steak.

Warner-Bratzler shear force (WBSF) analysis was performed on the same steak utilized for razor shear analysis. Four 0.50-in-diameter cores were taken parallel to muscle fiber orientation from proximal locations utilized for MORS within each steak. Each core

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was sheared once with a Warner-Bratzler compression-type shear device attached to an Instron Universal Testing Machine (Instron Corp., Canton, Mass.) equipped with a 110.15-lb load cell and a crosshead speed of 9.84 in/min.

Spectral data and instrumental tenderness results were processed using partial least squares (PLS) regression, with the PLS 1 option of the multivariate regression software Unscrambler (version 7.5; CAMO, Oslo, Norway). The reflectance and its first and second derivatives were used separately to predict the texture parameters.

The mathematical treatment of derivative calculation was performed to remove baseline shift and enhance the spectral features before PLS modeling. The first and second derivatives were obtained using the Savitzky Golay alogrithim with a 20-nm averaging window (i.e., 5 points to the left and 5 points to the right) and a second order polynomial equation (CAMO, 1999). Data were centered prior to PLS regression so that all results were interpretable in terms of variation around the mean, and the full cross-validation method was used.

With cross-validation, each observation is 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 is repeated until all samples have been removed from the sample set once. The predictive models were optimized using the Jackknifing method available as an option with the Unscrambler software. The root mean square of prediction (RMSEP), the root mean square error of calibration (RMSEC), and calibration (R^2_{cal} and R^2_{val}) coefficients of determination were computed.

In addition to regression models, analysis of variance of WBSF and MORS data was conducted using the PROC GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.), with quality grade, and aging period included in the model as fixed effects. For all variables, least squares means were generated and, when significant ($P < 0.05$) F values were observed, least squares means were separated with pairwise t-test (PDIFF option).

Results and Discussion

The main effect means for WBSF values of the BF steaks were lower ($P < 0.05$) for CAB quality grade steaks than for Prime or Select steaks, but differences among all quality grades was minimal (Table 1). While no differences are reported for the WBSF across all aging periods, values decreased slightly from d 14 to 21, and are reported as the highest on d 28 (Table 1). A quality grade x aging period interaction for MORS is reported in Table 2. Select steaks required a greater amount of MORS force than Prime or CAB steaks at all days of aging. They also required a greater amount of MORS force than Choice steaks on days 21 and 28, but not on days 0, 7 or 14. Choice steaks required a greater amount of MORS force than Prime or CAB steaks on days 0 and 14. Thus, tenderness did not increase in a consistent fashion throughout the 28-d aging period across all quality grades.

For the semitendinosus, a quality grade x aging period interaction for WBSF is reported in Table 3. Warner-Bratzler shear force values were different ($P < 0.05$) among quality grades initially (d 0), but as aging period increased differences became less. Ultimately, by d 28 there were minimal, although still some significant ($P < 0.05$), differences among quality grades of ST steaks. Interestingly, shear-force appeared to be minimized by d 14 for higher quality grade ST steaks.

A quality grade x aging period interaction for MORS in the ST is reported in Table 4. Initially, on d 0, MORS values were different ($P < 0.05$) among quality grades of ST steaks. As noted for WBSF of ST steaks, MORS appears to be lowest with no discernable differences among Prime or CAB by d 14 ($P > 0.05$), but lower ($P < 0.05$) than Choice or Select ST steaks. More importantly, by d 28, although some differences did occur ($P < 0.05$), these were minimal among all quality grades of ST steaks.

The main effects for quality grade and aging period on WBSF values of SM steaks indicates that the Prime quality grade required less ($P < 0.05$) force to shear than Choice or Select steaks (Table 5). Unlike shear force values for BF and ST steaks where the lowest values occurred by d 14, WBSF values of SM steaks indicate that the least ($P < 0.05$) amount of force was required to shear on d 28, although not less ($P > 0.05$) than for steaks aged 14 or 21 days.

Main effects of quality grade and aging period on MORS values of SM steaks are reported in Table 6. Prime SM steaks required the least amount of MORS and were different ($P < 0.05$) than all other quality grades except Choice. As seen with WBSF, SM steaks required the least amount of MORS ($P < 0.05$) by d 28, although the mean value for these steaks on d 28 did not differ ($P > 0.05$) from means on d 0 or d 21.

The model statistics for BF steaks using the NIRS spectra as a predictor of instrumental tenderness appear to be adequate with an R^2_{cal} of 0.41 for WBSF and 0.68 for MORS (Table 7). Predictability of instrumental tenderness with ASD spectra, was less accurate ($R^2_{cal} = 0.19$) for WBSF than MORS values ($R^2_{cal} = 0.67$). Robustness for BF steaks ranged from 1.14 to 1.12 for NIRS and 1.01 to 1.20 for ASD indicating that the RMSEC and RMSEP were similar and the models could be validated. The discrimination index of BF steaks ranged from 0.96 to 1.22 for NIRS and 0.99 to 1.14 for ASD, concluding that there appears to be a large amount of variation among the instrumental texture parameters as noted by a greater prediction error (i.e., Discrimination index; RPD value greater than 2.0 are considered acceptable, Sitakalin and Meullenet, 2000).

Instrumental tenderness predictability of the ST was more consistent among spectral methods than of the BF (Table 8). With minimal work using specific beef muscles, the NIRS and ASD technology was quite accurate in predicting both WBSF ($R^2_{cal} = 0.41$) and MORS ($R^2_{cal} = 0.46$), whereas the ASD spectra predicted WBSF ($R^2_{cal} = 0.45$) and MORS ($R^2_{cal} = 0.47$) with a greater degree of accuracy in the ST steaks. Robustness of the ST steaks ranged from 1.09 to 1.07 with the NIRS spectra and 1.08 to 1.07 with ASD indicating that the RMSEC and RMSEP were similar and the models could be validated. The discrimination index of ST steaks ranged from 1.02 to 1.06 for NIRS and 1.05 to 1.06 for ASD, concluding that there appears to be a large amount of variation among the instrumental texture parameters as noted by a greater prediction error.

Instrumental tenderness predictability in the SM (Table 9) was more accurate ($R^2_{cal} = 0.85$) for WBSF and ($R^2_{cal} = 0.88$) for MORS than for either the BF or ST steaks. More importantly, the ASD spectra was higher for both WBSF ($R^2_{cal} = 0.61$) and MORS ($R^2_{cal} = 0.67$) than for either the BF or ST steaks, indicating that the SM appears to be an easier muscle to use for predicting instrumental tenderness with spectral values. Robustness of the SM steaks ranged from 1.37 to 1.48 with the NIRS spectra and 1.04 to 1.07 for the ASD, indicating that the RMSEC and RMSEP appear to be similar and model validation can occur. The discrimination index for SM steaks ranged from 1.44 to 1.42 for NIRS and 1.22 to 1.27 for

ASD spectra, concluding that the prediction is growing closer to a more acceptable value (i.e., RPD value greater than 2.0 are considered acceptable, Sitakalin and Meullenet, 2000).

Implications

The results from this study indicate that the best prediction of tenderness occurred in the *semimembranosus* using the NIRS spectroradiometer. Additional experiments could be useful to determine if the models developed within this study could be used to predict instrumental tenderness of beef from various quality grades more efficiently and accurately.

Acknowledgments

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Table 1. Main effects of quality grade and aging period on Warner-Bratzler shear force (WBSF) of the *biceps femoris*.

Quality grade designation[1]			Aging period (days)[2]		
QG	WBSF	SEM	Age	WBSF	SEM
Prime	50.01[a]	0.162	0	46.58	0.172
CAB	44.33[b]	0.157	7	50.01	0.178
Choice	46.78[ab]	0.155	14	48.54	0.173
Select	52.56[a]	0.159	21	46.48	0.192
			28	50.50	0.167

[1] Prime = U.S. Prime; CAB = U.S. top Choice; Choice = lower 1/3 of U.S. Choice; Select = U.S. Select.
[2] Aging period = randomly allotted BF steaks were ages in the absence of light for one of the specified periods.
[a,b,c] Main effect means, within a column, lacking a common superscript differ (P < 0.05).

Table 2. Measured razor blade shear force (MORS) values stratified across quality grades for the *biceps femoris* (QG × aging period interaction, P < 0.01).

	Quality Grade[1]			
Aging period (days)[2]	Prime	CAB	Choice	Select
0	12.55[c]	12.94[c]	14.66[b]	17.15[a]
7	13.45[bc]	12.92[c]	14.06[ab]	15.09[a]
14	12.44[b]	11.97[b]	14.00[a]	14.84[a]
21	13.16[b]	12.92[b]	14.01[b]	15.40[a]
28	13.37[b]	12.79[b]	13.23[b]	14.80[a]

[1] Prime = U. S. Prime; CAB = U. S. top Choice; Choice = lower 1/3 of U. S. Choice; Select = U. S. Select.
[2] Aging period = randomly allotted BF steaks were aged in the absence of light for one of the specified periods.
[a,b,c] Within a row, least squares means lacking a common superscript differ (P< 0.05).

Table 3. Measured Warner-Bratzler Shear Force values stratified across quality grades for the *semitendinosus* (QG × aging period interaction P < 0.01).

	Quality Grade[1]			
Aging period (days)[2]	Prime	CAB	Choice	Select
0	47.27[c]	39.03[d]	59.33[b]	68.35[a]
7	48.93[b]	44.72[b]	53.64[b]	60.80[a]
14	44.22[ab]	38.81[b]	44.23[ab]	49.52[a]
21	44.22[b]	41.38[b]	47.17[ab]	53.94[a]
28	45.01[ab]	41.87[b]	41.87[b]	49.42[a]

[1] Prime = U. S. Prime; CAB = U. S. top Choice; Choice = lower 1/3 of U. S. Choice; Select = U. S. Select.
[2] Aging period = randomly allotted ST steaks were aged in the absence of light for one of the specified periods.
[a,b,c,d] Within a row, least squares means lacking a common superscript differ (P < 0.05).

Table 4. Measured Razor Blade shear force values stratified across meat quality grades for the *semitendinosus* (QG × aging period interaction (P < 0.01).

Aging period (cays)[2]	Quality Grade[1]			
	Prime	CAB	Choice	Select
0	12.14[c]	10.79[d]	13.21[b]	14.92[a]
7	12.21[b]	10.83[a]	11.99[b]	13.58[a]
14	10.16[b]	9.75[c]	12.25[a]	13.00[a]
21	11.23[a]	11.10[a]	11.85[a]	11.70[a]
28	11.57[ab]	10.97[ab]	10.76[b]	11.94[a]

[1] Prime = U. S. Prime; CAB = U. S. top Choice; Choice = lower 1/3 of U. S. Choice; Select = U. S. Select.
[2] Aging period = randomly allotted ST steaks were aged in the absence of light for one of the specified periods.
[a,b,c,d] Within a row, least squares means lacking a common superscript differ (P < 0.05).

Table 5. Main effects of quality grade and aging period on Warner-Bratzler shear force (WBSF) of the *semimembranosus*.

Quality grade designation[1]			Aging period (days)[2]		
QG	WBSF	SEM	Age	WBSF	SEM
Prime	47.76[b]	0.163	0	53.64[a]	0.183
CAB	51.58[ab]	0.161	7	53.15[a]	0.181
Choice	53.25[a]	0.161	14	51.48[ab]	0.181
Select	53.35[a]	0.161	21	51.10[ab]	0.181
			28	48.05[b]	0.181

[1] Prime = U. S. Prime; CAB = U. S. top Choice; Choice = lower 1/3 of U. S. Choice; Select = U. S. Select.
[2] Aging period = Randomly allotted SM steaks were aged in the absence of light for one of the specified periods.
[a,b] Main effect means, within a column, lacking a common superscript differ (P< 0.05).

Table 6. Main effects of quality grade and aging period on Razor blade shear force (MORS) of the *semimembranosus*.

Quality grade designation[1]			Aging period (days)[2]		
QG	MORS	SEM	Age	MORS	SEM
Prime	13.92[b]	0.385	0	14.60[ab]	0.421
CAB	15.22[a]	0.376	7	15.32[a]	0.427
Choice	14.62[ab]	0.381	14	15.06[a]	0.421
Select	15.06[a]	0.381	21	14.84[ab]	0.427
			28	13.71[b]	0.432

[1] Prime = U. S. Prime; CAB = U. S. top Choice; Choice = lower 1/3 of U. S. Choice; Select = U. S. Select.
[2] Aging period = Randomly allotted SM steaks were aged in the absence of light for one of the specified periods.
[a,b] Main effect means, within a column, lacking a common superscript differ (P< 0.05).

Table 7. Partial least squares (PLS) regression model results of second derivative absorbance spectra for the *biceps femoris* across all quality grades*.

Spectral range[a]	Rcal[b]	Rval[c]	PC[d]	RMSEP[e]	RMSEC[f]	RPD[g]	Robust[h]
Warner-Bratzler shear force (WBSF)							
NIRS	0.41	0.05	1	1.12	0.98	0.96	1.14
ASD	0.19	0.12	1	1.09	1.07	0.99	1.01
Razor blade shear force (MORS)							
NIRS	0.68	0.56	2	1.40	1.24	1.22	1.12
ASD	0.67	0.50	4	1.50	1.24	1.14	1.20

*Total sample size (n = 200).
[a] Spectroradiometers: NIRSystems (NIRS; 400 to 2,400 nm) and ASD Field Spec Pro (ASD; 350 to 1,050 nm).
[b] Calibration coefficient of determination (R^2).
[c] Validation coefficient of determination (full-cross validation; R^2).
[d] Optimal number of principal components (PC).
[e] Root mean square error of prediction (full-cross validation).
[f] Root mean square error of calibration.
[g] Discrimination index; RPD = SD/RMSEP.
[h] Robust = RMSEP/RMSEC.

Table 8. Partial least squares (PLS) regression model results of second derivative absorbance spectra for the *semitendinosus* across all quality grades*.

Spectral range[a]	Rcal[b]	Rval[c]	PC[d]	RMSEP[e]	RMSEC[f]	RPD[g]	Robust[h]
Warner-Bratzler shear force (WBSF)							
NIRS	0.41	0.22	1	1.18	1.08	1.02	1.09
ASD	0.45	0.32	2	1.14	1.06	1.05	1.08
Razor blade shear force (MORS)							
NIRS	0.46	0.34	1	1.57	1.47	1.06	1.07
ASD	0.47	0.36	2	1.57	1.47	1.06	1.07

*Total sample size (n = 200).
[a] Spectroradiometers: NIRSystems (NIRS; 400 to 2,400 nm) and ASD Field Spec Pro (ASD; 350 to 1,050 nm).
[b] Calibration coefficient of determination (R^2).
[c] Validation coefficient of determination (full-cross validation; R^2).
[d] Optimal number of principal components (PC).
[e] Root mean square error of prediction (full-cross validation).
[f] Root mean square error of calibration.
[g] Discrimination index; RPD = SD/RMSEP.
[h] Robust = RMSEP/RMSEC.

Table 9. PLS regression model results of second derivative absorbance spectra for the *semimembranosus* across all quality grades*.

Spectral range[a]	Rcal[b]	Rval[c]	PC[d]	RMSEP[e]	RMSEC[f]	RPD[g]	Robust[h]
Warner-Bratzler shear force (WBSF)							
NIRS	0.85	0.69	3	0.81	0.59	1.44	1.37
ASD	0.61	0.57	2	0.96	0.92	1.22	1.04
Razor blade shear force (MORS)							
NIRS	0.88	0.70	3	1.911	1.29	1.42	1.48
ASD	0.67	0.61	4	2.13	1.98	1.27	1.07

*Total sample size (n = 200).
[a] Spectroradiometers: NIRSystems (NIRS; 400 to 2,400 nm) and ASD Field Spec Pro (ASD; 350 to 1,050 nm).
[b] Calibration coefficient of determination (R^2).
[c] Validation coefficient of determination (full-cross validation; R^2).
[d] Optimal number of principal components (PC).
[e] Root mean square error of prediction (full-cross validation).
[f] Root mean square error of calibration.
[g] Discrimination index; RPD = SD/RMSEP.
[h] Robust = RMSEP/RMSEC.

Arkansas Steer Feedout Program
2004-2005

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Story in Brief

The objective of the Arkansas Steer Feedout Program is to provide cow-calf producers information about the postweaning feedlot performance and carcass characteristics of their calves. For the 2004-2005 feedout, hot carcass weight, quality grade, days on feed, yield grade, medicine cost, and dressing percentage were factors that affected ($P < 0.01$) the feedlot return over specified cost. Cow-calf producers who participated in this program can use the information to evaluate how their cattle breeding programs fit the needs of the industry.

Introduction

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

Experimental Procedures

Prior to shipment, it was strongly recommended that calves be weaned for 45 days and administered a modified live virus vaccine (IBR-PI3-BVD-BRSV) at weaning. On the morning of November 4, 2004, 85 steer calves from 13 Arkansas producers representing 9 counties were accumulated and shipped to Oklahoma Feeders Inc., Coyle, Okla. The steers arrived in the afternoon of November 4 and were processed the next morning. At processing, steers were ear tagged, weighed, and received Ivomec Plus, Component, Titanium® 5 L5Covexin, and autogenous bacterin. An Arkansas Livestock Market News Reporter placed an arrival value on each calf based upon the weight taken at the feedyard and muscle and frame scores. Steers were placed in one pen. Management factors at the feedlot such as processing, medical treatments, and rations were the same as the other cattle in the feedyard. Calves were slaughtered at Tyson's Fresh Meats Inc. (Emporia, Kan.) on May 18, 2005. The cattle were sold on a carcass weight basis with premiums and discounts for quality grade, yield grade, and carcass weight. Feed, processing, medicine costs, and other feedyard expenses were financed by the feedyard. All expenses were deducted from the carcass income, and proceeds were sent to the owner. Carcass value for Choice, Yield Grade 3 carcasses was $149.87/cwt.

Statistics were computed to describe general program results. Of the 85 steers delivered in the fall, 3 died (3.5% death loss), 3 calves were deemed as chronics and sold to local markets, and 1 carcass was pulled by Tyson's for a quality control check; therefore, carcass data were not obtained from these animals. These steers were not included in the statistical analyses. The final data set analyzed consisted of feedlot performance and carcass data from 78 steers.

Carcasses were placed in 2 groups according to industry standards for carcass merit. Carcass groups were 1) fit industry standard (at least Choice, yield grade < 3.5, and a hot carcass weight between 550 and 950 lb) or 2) did not fit industry standards. The main effect of carcass group and the interaction with the dependent variables carcass value, ADG, and net return were determined using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Least-squares means were computed and reported.

Calves were sorted into categories based upon their feedlot return (income minus feedlot direct expenses). Data from calves in the top 25% and bottom 25% were sorted out for further analysis. Factors affecting feedlot return for the top 25% and the bottom 25% were determined using the Stepwise method of PROC REG of SAS. Independent variables included arrival weight; percentage Brahman, English, and Continental breeding; ADG; yield grade; quality grade; feed cost per lb of gain; hot carcass weight; days on feed; medicine cost; ribeye area; ribeye area per 100 lb of hot carcass weight; and dressing percentage. The cow-calf producer reported the breeding percentages.

Results and Discussion

The financial summary is reported in Table 1. Average gross income per head was $1,072.78 (range = $651 to $1,456). The feedlot return averaged $722.23; whereas, the calculated returns, accounting for the initial value of the calf at arrival, averaged $104.46 (range = $-179 to $339).

The sick rate was very high with 63 calves (80%) treated for sickness. Soon after the steers arrived at the feedyard, it began to rain. It rained intermittently for the first 3 to 4 weeks on feed. Consequently, the steers and the pens were very wet. Often when this situation happens, the steers appear apathetic with heads drooped, and feed intake is reduced. At this stage, it is very difficult to tell if the steer is just reacting to the wet weather conditions or if it is sick. The feedyard manager decided to implement a preventive treatment. Depending on body temperature, calves received a preventive treatment of Baytril and Banimine (101.5 to 102.5°F), NuFlor (> 102.5°F), or no treatment (normal body temperature).

[1] University of Arkansas Cooperative Extension Service, Little Rock

Sixteen (20%) steers did not receive any treatment (healthy), 33 steers (42%) received the preventive treatment and 30 steers (38%) received numerous treatments (sick). The average medicine costs for the preventive treated steers and the sick steers were $34.05 and $63.33, respectively. The average medicine cost for the entire pen was $43.78 per head.

The health status of cattle in the feedyard usually has a major impact on performance and profit. The following analysis included the calves that received the preventive treatment and calves that were pulled and treated. Healthy steers had higher feedlot net returns ($794) than steers that became sick ($672; $P < 0.002$). The feedlot net returns of the steers that received the preventive treatment were intermediate ($733). The percentage of healthy, preventive treatment and sick steers that graded USDA Choice was 44%, 58% and 37%, respectively ($P < 0.001$).

There were no differences between healthy, preventive treatment, and sick steers for average daily gain, hot carcass weight, feed cost per pound of gain, total cost per pound of gain, dressing percentage, yield grade, ribeye area, and ribeye area per cwt. of carcass weight ($P > 0.10$). Previous Arkansas Feedout data indicate that health status (healthy vs. sick) negatively impacts feedlot and carcass performance. Because these performance indicators were not affected by health status in this year's feedout and since animal behavior might have been affected by the wet weather, one could question if all of the treatments were necessary.

The performance of the steers in the top 25%, bottom 25% and average feedlot return categories are shown in Table 2. The average in-weights were 579 lb (range = 416 to 816). The overall average daily gain, days on feed, feed cost per lb of gain, and total cost per lb of gain were 3.10 lb (1.85 to 4.18), 193 days, $0.46 ($0.38 to $0.68), and $0.60 ($0.46 to $0.84), respectively.

The average steer carcass weight, ribeye area, dressing percentage, yield grade, and fat thickness were 743 lb (535 to 1,006), 12.6 in^2 (9.0 to 16.7), 62.8% (57.6% to 69.9%), 2.80 (1.56 to 3.89), and 0.41 in. (0.20 to 0.80), respectively. Forty-seven percent of the carcasses graded Choice whereas 35% and 17% graded Select and No Roll, respectively. Carcasses listed as No Rolls were not officially graded by USDA personal due to lack of marbling, blood splash, dark cutters, excessive trim, etc. Only 1% of the carcasses graded Prime.

Listed below are the factors ($P < 0.01$) that affected the feedlot return over specified costs for the steers in the 2004-2005 Steer Feedout Program. Specified costs include feed, freight, insurance, processing, Beef Council Check-off, interest, and medicine. Factors are listed from the most important to the least important.

Factors Affecting Net Returns Over Specified Cost
1. Hot Carcass Weight
2. Quality Grade
3. Medicine Cost
4. Yield Grade
5. Dressing Percentage

1. Hot Carcass Weight - As hot carcass weight increased, so did feedlot net return. The more carcass pounds that were sold, the greater the gross income and feedlot net return. Table 3 shows the relationship between hot carcass weight and total cost of gain, average daily gain, feedlot net return, and calculated return. Hot carcass weight discounts were observed for carcasses weighing less than 550 lb and greater than 950 lb.

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

2. Quality Grade - Cattle that graded Prime, Choice, Select, and No Roll had feedlot net returns of $850, $806, $683, and $561 per head ($P < 0.001$), respectively. Marbling is the primary factor that affects a calf's ability to grade Choice. Three main factors that affect marbling are: (1) the genetic ability to marble; (2) the maturity or the physiological age, not the chronological age; and (3) ration. Carcass traits such as marbling are highly heritable; therefore, selecting high marbling EPD bulls can be effective for improving the marbling ability of calves.

3. Medicine Cost – Although this year was an exception, 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. Untreated calves had a higher feedlot net return ($794 vs. $672 per steer) than calves that were treated for illness. A higher percentage of untreated steers graded Choice than did the treated calves.

4. Yield Grade – There were no differences between feedlot net returns for Yield Grades 1 and 3 ($760 and $748, respectively, $P > 0.10$), but feedlot net returns for Yield Grade 2 ($700) tended ($P < 0.09$) to be less than Yield Grades 1 and 3. There were no Yield Grades 4 or 5's. Backfat, ribeye area, hot carcass weight, and percentage of kidney, pelvic and heart fat are the factors that determine yield grade. As yield grade increases (1 to 4), the amount of fat increases in relation to the amount of lean.

For the 2004-2005 feedout, the price discount between yield grades 1 and 2 was only $4.00 per cwt and the price discount between yield grades 2 and 3 was $5.00 per cwt. There was a general trend that as the yield grades went from 1 to 3, hot carcass weights also increased (711, 718 and 793 for Yield Grades 1, 2 and 3, respectively). Therefore, the increase in hot carcass weights compensated for the decrease in selling price as yield grade increased.

5. Dressing Percentage - As dressing percentage increased, feedlot net return increased. Many of the factors that affect hot carcass weight also affect dressing percentage. The top 25% of steers (based on feedlot return) had a dressing percentage of 63.8% compared to 61.8% for the steers in the bottom 25% ($P < 0.001$).

The beef cattle industry has set the standard that quality grade should be at least Choice, yield grade should be < 3.5, and hot carcass weight between 550 and 950 lb. Forty-six percent of the steers in the 2004-2005 Steer Feedout Program met the industry standards. The average breed makeup of the steers that met the industry standards were 76% English, 7% Brahman and 17% Continental. Steers that met the industry standards averaged $130 more per head than those that did not fit the industry standards ($P < 0.001$). They had higher carcass value ($1.52 vs. $1.36; $P < 0.001$) because they graded Choice, were not discounted for yield grades greater than 4.0 and their carcasses were within the desired weight range (550 to 950 lb).

Implications

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

Table 1. Financial summary 2004-05 Arkansas steer feedout program.

Item	Average	Range
Gross income	$1,072.78	$651 to $1,456
Expenses		
Feed	$273.12	$210 to $346
Medicine	$43.78	$0 to $129
Freight, processing, yardage, interest, etc	$38.39	$33 to $44
Total feedlot expenses	$350.55	$278 to $432
Feedlot return	$722.23	$367 to $1,035
Steer calf in value[a]	$614.00	$224 to $824
Calculated return	$104.46	$-179 to $339

[a] An Arkansas Livestock Market News Reporter placed an arrival value on each calf based upon the weight taken at the feedyard and muscle and frame scores.

Table 2. The performance of the bottom 25%, top 25%, and average steers based on feedlot returns.

	Bottom 25%	Top 25%	Average
Number of steers	20	19	78[a]
In weight (lb)	528[b]	646[c]	579
Muscle score	1.8	1.7	1.7
Frame score			
Large	35%	42%	35%
Medium	65%	58%	65%
Final weight (lb)	1,045[b]	1,301[c]	1,182
Average daily gain (lb)	2.68[b]	3.39[c]	3.10
Gross income	$890[b]	$1,256[c]	$1,073
Carcass value per lb	$1.38[b]	$1.52[c]	$1.44
In value per head	$568[b]	$659[c]	$614
Hot carcass weight (lb)	646[b]	830[c]	743
Dressing percentage	61.8%[b]	63.8%[c]	62.8%
Medicine cost	$52.72[b]	$28.30[c]	$43.78
Total feed cost per head	$243[b]	$301[c]	$273
Total expense[d]	$332[b]	$370[c]	$351
Feedlot returns	$558[b]	$886[c]	$722
Calculated returns	-$10[b]	$227[c]	$104
Days on feed	193	193	193
Feed cost per lb of gain	$0.48	$0.47	$0.46
Total cost per lb of gain	$0.65[b]	$0.57[c]	$0.60
Ribeye area (in^2)	11.4[b]	13.6[c]	12.6
Fat thickness (in.)	0.35[b]	0.46[c]	0.41
Quality grade			
Prime	0%[b]	5%[c]	1%
Choice	10%[b]	89%[c]	47%
Select	40%[b]	5%[c]	35%
No Roll	50%[b]	0%[c]	17%
Yield grade	2.05	2.42	2.80

[a] Seven calves were not used in this data set. Three calves died, 3 were sold as chronics and 1 carcass was pulled by Tyson's for a quality control check.

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

[d] Total expenses includes feed, medicine costs, freight, processing, yardage, checkoff fee and interest.

Table 3. Summary of total cost of gain, average daily gain (ADG), feedlot net return and calculated return for various categories of hot carcass weights.

Hot carcass weight (lb)	n	Total cost of gain ($)	ADG (lb)	Feedlot net return per steer ($)	Calculated return per steer ($)
< 600	2	0.75	1.9	418	-145
600-699	22	0.64	2.7	612	38
700-799	34	0.56	3.2	741	131
800-899	18	0.59	3.5	864	172
≥ 900	2	0.62	3.5	940	156

Nine-Year Summary of the Arkansas Steer Feedout Program: Factors Contributing to Return

M.S. Gadberry and T.R. Troxel[1]

Story in Brief

The objective of this paper was to evaluate factors affecting return above feedlot expenses. Nine years of data from the Arkansas Steer Feedout Program was used for the analysis. Stepwise regression was conducted annually to determine which factors contributed the most to variation in annual return. Factors included arrival BW, muscle score, frame score, final BW, ADG, medical expense, days on feed, feed cost of gain, hot carcass weight, dressing percentage, loin eye area per unit of carcass weight, backfat, quality grade (assigned numerical place values), and yield grade. Variables that were included in the selection at least 4 out of 9 years were further evaluated to determine their average annual contribution to return. The average ranking for hot carcass weight was 1.1 ± 0.38 and differed ($P < 0.05$) from all other variables. Quality grade (2.3 ± 0.38), feed cost of gain (3.0 ± 0.57), and days on feed (3.5 ± 0.57) followed hot carcass weight and did not differ ($P > 0.05$). These results demonstrate that hot carcass weight has the largest impact on return, while factors such as quality grade, feed cost of gain, and days on feed may be equally important as a result of annual differences in choice-select spread and grain prices.

Introduction

The Arkansas Steer Feedout program was initiated to provide cattle producers the opportunity to evaluate calf post-weaning performance and carcass characteristics. This provided an avenue for cattle producers to evaluate growth performance and carcass quality as a mechanism to determine the direction of future breeding and selection decisions. Improving carcass characteristics was emphasized along with the growth of cattle marketing on a carcass basis. The objective of this paper was to evaluate the factors affecting return above feedlot expenses over the previous 9 years of the program.

Experimental Procedures

Cattle enrolled in the Arkansas Steer Feedout Program from 1995 to 2004 were shipped to a feedyard in the fall and marketed the following spring when determined to be market ready by the feedlot manager. The program was limited to a minimum of 5 steers per farm weighing between 550 and 850 lb.

Calves were weighed the morning after arrival at the feedyard and were sorted by the feedyard manager or livestock market reporter into different pens based on phenotype. Calves were processed according to regular receiving protocols at the respective feedyards. Calves were fed until determined market ready by the feedlot management. Calves enrolled in the program that experienced morbidity were treated according to feedyard protocol. Calves that did not respond by the third treatment were removed from the program. Performance of mortalities and calves that were removed from the program as a result of poor health were removed from the dataset prior to analysis.

Final BW was determined prior to shipment to the packer. Final BW was assessed a 4% shrink for evaluating BW gain and dressing percentage. Calves were marketed on a yield and quality grade grid based on discounts and premiums received at the time of market. Carcasses weighing less than 550 lb or more than 950 lb received discounts as well.

Evaluation of factors affecting return above feeding costs was conducted using stepwise regression (SAS Inst., Inc., Cary, N.C.). The model included return above feedlot expenses as the dependent variable and arrival BW, muscle score, frame score, final BW, ADG, medical expense, days on feed, feed cost of gain, hot carcass weight, dressing percentage, loin eye area per unit of carcass weight, backfat, quality grade (assigned numerical place values), and yield grade as independent variables for selection. Analysis was conducted by year. Variables that occurred in the selection at least 4 out of 9 years were identified for further evaluation comparing the difference in rank (step in which the variables entered the model) based on their contribution to the model R^2. The annual rank of each variable was analyzed by analysis of variance using the GLM procedure of SAS to determine if the variables selected from stepwise regression differed significantly for contribution to the model R^2. Some variables were not selected every time, resulting in missing observations.

Results and Discussion

Results from the stepwise regression analysis on 1,917 calves over a 9-yr period indicated hot carcass weight and quality grade were selected each year as a significant factor contributing to return above feedlot expense (Table 1). Medicine cost was selected 8 out of 9 years. Yield grade and ADG was selected 7 and 6 out of 9 years, respectively. Days on feed, feed cost of gain, dressing percentage and backfat percentage were each selected 4 of 9 years. Arrival BW, final BW, USDA muscle score and frame score were selected 2 or less times over the 9 years.

Variables that were included in the selection at least 4 out of 9 years were further evaluated to determine their contribution to the model by analyzing the step they entered in the selection process based on their contribution to model R^2. The average ranking for hot carcass weight was 1.1 ± 0.38 and differed significantly ($P < 0.05$) from all other variables (Table 2). Hot carcass weight was the most important factor contributing to each year's return. Calves with greater hot carcass weights received greater returns. Discount for excessive carcass weight was not received until carcasses exceeded 950 lb. Less than one percent of the calves enrolled in the program expressed carcass weights greater than 950 lb.

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Quality grade (2.3 ± 0.38), feed cost of gain (3.0 ± 0.57), and days on feed (3.5 ± 0.57) followed hot carcass weight and did not differ (P > 0.05). Days on feed, yield grade (4.1 ± 0.43), medical expense (4.7 ± 0.40), dressing percentage (5.0 ± 0.51), and backfat percentage did not differ (P > 0.05) from each other. Average daily gain (5.7 ± 0.46) and muscle score (6.0 ± 0.81) were selected toward the end of the selection process and did not differ (P > 0.05) from backfat percentage, dressing percentage, or medical expense. While factors such as muscle score and average daily gain were not ranked as high in the selection process, they remain very important from a management perspective as a result of their relationship to hot carcass weight which was identified as the single most important factor attributing to the variation in return.

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Table 1. Annual summary of stepwise regression analysis of factors affecting return above feedlot expenses for cattle enrolled in the Arkansas Steer Feedout.

	Year								
	1996	1997	1998	1999	2000	2001	2002	2003	2004
Item	Step that the variable entered Partial R-square C(p)[a]								
Arrival BW							7 0.002 5.8		4 0.02 322.5
Final BW	7 0.013 8.7					7 0.008 6.1			
Days on feed			6 0.009 39.1	2 0.072 507.5	2 0.149 935.7	4 0.046 375.3			
Hot carcass weight	1 0.622 383.0	2 0.186 128.5	1 0.612 437.1	1 0.701 753.8	1 0.599 1697.4	1 0.675 1296.4	1 0.591 803.7	1 0.647 502.6	1 0.357 992.0
Quality grade	2 0.066 294.5	1 0.304 254.1	3 0.102 114.3	3 0.04 371.7	3 0.06 632.2	3 0.073 600.3	2 0.237 247.6	2 0.184 166.7	2 0.09 589.1
Yield grade	5 0.026 61.1			4 0.047 213.6	4 0.082 214.5	6 0.025 43.1	4 0.019 68.3	3 0.034 105.9	3 0.041 407.9
Dressing percentage	4 0.037 94.7	7 0.005 10.3		5 0.037 88.8			6 0.013 8.5		
Medicine cost	6 0.028 24.6	4 0.068 29.6	5 0.019 51.9	6 0.017 32.1	5 0.02 114.7	2 0.07 955.0	5 0.014 36.4	5 0.017 23.8	
Feed cost of gain	3 0.112 143.8		2 0.097 279.8				3 0.059 110.7	4 0.029 53.9	
Average daily BW gain		3 0.082 74.0	7 0.005 32.5	7 0.007 8.6	6 0.013 47.8	5 0.043 165.0		6 0.008 11.7	
Backfat percentage		5 0.024 15.1	4 0.022 80.3		7 0.003 33.7				5 0.024 217.2
USDA muscle score		6 0.008 12.0							6 0.016 147.9
USDA frame score									7 0.019 62.8

[a] Lower C(p) values indicate a better model. This statistic is less dependent on the number of effects in the model than R-square.

Table 2. Analysis of variable ranking based on the variables contribution to the model's R-square for factors affecting the return above feedlot expense for calves enrolled in the Arkansas Steer Feedout Program.

Dependent Variable[a]	Ranking (order of entrance into model)	SEM
Hot carcass weight	1.1[b]	0.38
Quality grade	2.3[c]	0.38
Feed cost of gain	3.0[c,d]	0.57
Days on feed	3.5[c,d,e]	0.57
Yield grade	4.1[d,e]	0.43
Medical expense	4.7[e,f]	0.40
Dressing percentage	5.0[e,f]	0.51
Backfat percentage	5.2[e,f]	0.57
Average daily BW gain	5.7[f]	0.46
USDA muscle score	6.0[f]	0.81

[a]Variables selected for ranking analysis were selected by stepwise regression procedures at least 4 of the 9 years of the feedout program.
[bcdef]Least-squares means within a column with no superscript in common differ ($P \leq 0.05$).

Factors Affecting the Selling Price of Feeder Cattle Sold at Arkansas Livestock Auctions

T.R. Troxel, B. Barham, S. Cline, J. Foley, D. Hardgrave, W. Wiedower, and R. Wiedower[1]

Story in Brief

Data were collected from 15 Arkansas livestock auctions to determine factors affecting selling price in 2005. Data included gender, breed or breed type, color, muscle thickness, horn status, frame score, fill, body condition, age, health, and weight. Data were randomly collected on 52,401 lots consisting of 105,542 head. The selling prices for steers ($124.20 ± 0.07), bulls ($117.93 ± 0.12), and heifers ($112.81 ± 0.07) were different from each other (P < 0.001). Hereford x Charolais ($122.66 ± 0.41), Angus x Hereford ($121.74 ± 0.21), Angus ($121.43 ± 0.15), Charolais x Limousin ($121.33 ± 0.23), Angus x Limousin ($120.83 ± 0.74), and Angus x Charolais ($120.59 ± 0.51) feeder cattle sold for the highest price and were not different from each other (P > 0.10). The breed or breed types that sold for the lowest price were Brahman ($108.24 ± 0.52), Hereford ($107.25 ± 0.40), and 1/4 Brahman ($106.25 ± 1.05) and were not different from each other (P > 0.10) followed by Longhorn (P < 0.01; $89.38 ± 1.02). Yellow-white faced ($120.44 ± 0.26), yellow ($120.29 ± 0.16) and black-white faced ($120.03 ± 0.16) feeder cattle received the highest selling price and were not different from each other (P > 0.10). Spotted or striped feeder cattle received the lowest ($107.37 ± 0.37) selling price. Muscle score, horn status, frame score, fill and body condition impacted selling price (P < 0.001). A number of management and genetic factors affected the selling price of feeder cattle marketed through Arkansas livestock auctions in 2005.

Introduction

Cow-calf producers are challenged to produce feeder calves that are acceptable to the industry. When buyers at a livestock auction view feeder calves, they must appraise individual characteristics (muscle thickness, frame score, breed composition, etc.) as predictors of quality and animal performance and adjust their bids accordingly. Many of these factors such as breed or breed type are very subjective. Therefore, many cow-calf producers believe that feeder cattle are priced inconsistently. Producers do not understand why some phenotypic characteristics are discounted and others are not. Most feeder calf market reports list the selling prices of steers and heifers by weight groups, and frame and muscle score. Other reports have indicated that breed or breed type, health, gender, frame and muscle scores, and other noticeable factors do affect feeder calf selling price (Brown and Morgan, 1998; Neel et. al., 1998; Troxel et. al., 2002). Therefore, the objective was to determine the factors that affect the selling price of feeder cattle in Arkansas weekly livestock auctions.

Experimental Procedures

Five USDA certified livestock market reporters collected data from 15 weekly livestock auctions in Arkansas from January 1, 2005 to December 31, 2005. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fayetteville, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Ola, Ozark, Pocahontas, Ratcliff, and Springdale. The data collected included calf gender (bull, steer, or heifer), breed or breed type, color, muscle thickness, horn status (polled (dehorned) or horned), frame score (large, medium or small), fill (gaunt, shrunk, average, full or tanked), condition (very thin, thin, average, fleshy, or fat), age (calf or yearling), health (dead hair, stale, sick, bad eye(s), lame, healthy or preconditioned), and weight. A total of 581,413 feeder cattle were sold through these livestock auctions, and data were randomly collected (every 5th to 6th calf) on 52,401 lots consisting of 105,542 head (18.2%). Frame and muscle scores were determined based on the U.S. Standards for Grades of Feeder Cattle (USDA, 1980).

Data Analyses. The percent of calves within age, gender, breed or breed type, color, horn status, frame score, muscle score, fill, condition, weight group and health were determined by the frequency procedure of SAS (SAS Inst., Inc., Cary,N.C.) based on the number of lots sold (n = 52,401). All feeder calves in this study were sold as individuals. The final data set included 50,872 feeder calves. Due to the unbalanced nature of the data, calf characteristics were analyzed individually as independent variables in which the model included month and weight as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares. The analysis of variance was performed with the GLM procedure of SAS. Least-squares means were generated, separated based on predicted differences, and both are reported throughout. Since all colors are not represented within each breed or breed type, color and breed or breed type data are somewhat inherently confounded. All selling prices reported are in US dollars/100 lb.

Results and Discussion

The mean selling price for all calves in 2005 was $118.10, and all main effects reported were significant sources of variation (P < 0.001). Over 65% of the feeder cattle were classified as calves and 34.3% were classified as yearlings. The selling price of calves ($118.73 ± 0.07) was greater (P < 0.001) than the selling price of yearlings ($116.89 ± 0.10). Selling price varied by month with greater prices recorded in the spring (March, April, and May) and lesser prices in the summer and early fall (July, August, September

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and October; $P < 0.001$; Figure 1.) This seasonal trend followed the 5-, 10- and 20- year average seasonal trend (Cheney and Troxel, 2006). Over 71% of the cattle sold weighed less than 550 lb (Figure 2). As selling weight increased, price per cwt decreased.

Heifers made up 45.8% of the cattle sold whereas steers and bulls made up 40.0% and 14.1%, respectively (Table 1). The selling prices for steers ($124.20 ± 0.07), bulls ($117.93 ± 0.12) and heifers ($112.81 ± 0.07) were all different ($P < 0.001$). Castration is a common practice to reduce management problems associated with aggressive and sexual behavior associated with commingling bull calves. The prices received for bulls were lower due to the expected reduction in animal performance experienced with these animals subsequent to castration as well as the costs associated with the actual procedure.

Table 1 summarizes the percentage of the population sampled and selling price based on muscle score horn status, health status, frame score, body fill and body condition. All factors affected the selling price. Buyers discounted feeder calves that were light muscled, horned, unhealthy, small framed, appeared to have the potential for excessive shrinkage and over-conditioned.

Twenty-three breeds or breed types represented 97.7% of the total feeder cattle. The breed or breed types was based upon common industry perception rather than actually knowing the breed composition. This, however, is what a buyer must do before a bid price can be offered. The main effect of cattle breed or breed type on the selling price of feeder cattle was significant ($P < 0.001$; Table 2). Hereford x Charolais ($122.66 ± 0.41), Angus x Hereford ($121.74 ± 0.21), Angus ($121.43 ± 0.15), Charolais x Limousin ($121.33 ± 0.23), Angus x Limousin ($120.83 ± 0.74), and Angus x Charolais ($120.59 ± 0.51) feeder cattle sold for the highest price and were not different from each other ($P > 0.10$). There was an approximate $32.00 difference between the breed or breed types selling for the highest price and Longhorn feeder cattle, which sold for the least price ($89.38 ± 1.02). Only 7 cattle breeds or breed types had selling prices greater ($P < 0.01$) than the overall mean ($118.10).

When reviewing the breeds or breed combinations above the average, many of the breeds or breed combinations were not significantly different from each other. The same was true with the breeds or breed combinations below the average. The selling prices of Brahman, Hereford, and 1/4 Brahman Cross are not different from each other but these breeds or breed types were different than the price received for Longhorn calves. The discounts on the breeds or breed types listed on the bottom are far greater than the premium for the breeds or breed types listed at the top.

Breeds or breed types do affect the selling price of feeder cattle. This is due to the perception by the order buyer as to how different breeds or breed types perform (gain, sick rate, quality grade, etc.). For many years, a perception existed that if cattle were black they had some degree of Angus breeding. Today that may or may not be true. Many beef breeds have animals that are black, such as Limousin, Simmental, and Gelbvieh, to name a few. The perceptions regarding certain breeds and subsequent performance may be right or wrong, but they exist. With a high percentage of feeder cattle sold in livestock auctions weighing less than 550 lb, the majority of these cattle are purchased for placement in a backgrounding grazing program. Backgrounding programs are forage based (native pasture, wheat, etc.), and buyers are looking for the breeds or breed combinations that perform best under those conditions. Cow-calf producers should be aware that the breeds or breed types that perform best under backgrounding programs might not be the breeds or breed types that make good replacements. Cow-calf producers must be attentive of this and design an appropriate breeding program.

Ten colors represented 94.1% of the total population (Table 3). Yellow white- faced ($120.44 ± 0.26), yellow ($120.29 ± 0.16) and black white-faced ($120.03 ± 0.16) feeder cattle received the greatest selling price and were not different from each other ($P > 0.10$). Black ($119.24 ± 0.08) calves brought a higher selling price than grey ($117.66 ± 0.18). Grey and grey-white faced ($116.79 ± 0.54) calves were similar in value ($P > 0.10$). Spotted or striped calves ($107.37 ± 0.37) brought the lowest price. Unlike breed or breed combinations, most colors were different from each other.

Implications

The majority of cow-calf producers in Arkansas sell feeder cattle at local livestock auctions. The major factors affecting selling prices of feeder cattle were calf health, perceived breed or breed type, muscle thickness, frame score, fill, color and body condition, calf gender, and horn status. The combination of all these factors determines the final selling price. Most of the major factors affecting selling price can be addressed through genetic selection and management. Once the impact of these factors are identified and understood, cow-calf producers can make cost effective management changes that can improve feeder calf value and total returns.

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Table 1. The percentage of the sampled population and 2005 Arkansas selling prices (mean ± SE) due to calf gender, muscle score, health, frame score, body condition, horn status and body fill.

Item	Percentage of the sampled population	Selling price ($cwt)
Calf gender:[a]		
Bulls	14.1	$117.93 ± 0.12
Steers	40.0	$124.20 ± 0.07
Heifers	45.8	$112.81 ± 0.07
Muscle score:[a]		
1	75.3	$120.45 ± 0.05
2	22.6	$111.31 ± 0.10
3	1.1	$96.28 ± 0.45
4	0.06	$82.21 ± 1.87
Health status:		
Preconditioned	3.3	$122.36 ± 0.28[b]
Healthy	95.5	$118.21 ± 0.05[c]
Dead hair	0.2	$105.55 ± 1.16[d]
Bad eyes	0.3	$104.39 ± 0.88[d]
Stale	0.4	$100.01 ± 0.83[e]
Lame	0.2	$84.74 ± 1.05[f]
Sick	0.1	$80.22 ± 1.70[f]
Frame score:		
Large	64.6	$118.27 ± 0.06[b]
Medium	34.3	$118.15 ± 0.09[b]
Small	0.6	$95.43 ± 0.63[c]
Body condition:[a]		
Very thin	21.7	$119.55 ± 0.11
Thin	12.2	$116.80 ± 0.15
Average	63.2	$118.14 ± 0.06
Fleshy	2.9	$112.28 ± 0.30
Fat	0.1	$101.98 ± 1.97
Horned status:[a]		
Polled/ dehorned	85.8	$118.57 ± 0.05
Horned	12.8	$114.87 ± 0.14
Body fill:[a]		
Gaunt	21.4	$119.63 ± 0.11
Shrunk	26.5	$120.22 ± 0.10
Average	49.4	$116.77 ± 0.07
Full	2.7	$110.05 ± 0.31
Tanked	0.1	$92.80 ± 2.04

[a] All least-squares means within an item are different from each other ($P < 0.001$).
[b,c,d,e,f] Least-squares means without a common superscript differ ($P < 0.01$).

Table 2. The percentage of the sampled population and 2005 Arkansas selling prices (mean ± SE) of feeder calves sold based on breed or breed type[a]

Breed or breed type[b]	Percentage of the sampled population	Selling price ($/cwt)
HC	2.1	$122.66 ± 0.41[c]
AH	7.2	$121.74 ± 0.21[c]
A	11.1	$121.43 ± 0.15[c]
CLm	4.7	$121.33 ± 0.23[c]
ALm	0.5	$120.83 ± 0.74[c, d]
AC	3.2	$120.59 ± 0.51[c, d]
HBA	2.9	$120.01 ± 0.32[d]
C	11.7	$118.12 ± 0.14[e]
CBq	3.0	$117.91 ± 0.28[e]
HLm	2.5	$117.87 ± 0.32[e]
ABq	5.3	$117.69 ± 0.21[e, f]
Lm	8.3	$116.86 ± 0.17[f]
Bx	4.8	$116.62 ± 0.76[f, g]
AB	13.6	$116.15 ± 0.33[f, g]
LmBq	2.3	$115.29 ± 0.33[g]
HBq	1.8	$114.94 ± 0.37[g]
HSm	0.4	$114.15 ± 1.47[g, h]
Sm	0.9	$111.91 ± 0.52[h]
S	0.6	$110.17 ± 0.63[h]
B	0.9	$108.24 ± 0.52[i]
H	1.5	$107.25 ± 0.40[i]
Bq	7.8	$106.25 ± 1.04[i]
Lg	0.6	$89.38 ± 1.02[j]

[a] Main effect of breed or breed type on selling price ($P < 0.0001$).
[b] Breed type = HC - Hereford x Charolais, AH - Angus x Hereford, A - Angus, CLm - Charolais x Limousin, ALm – Angus x Limousin, AC - Angus x Charolais, HBA - Hereford x Brahman x Angus, C - Charolais, CBq - Charolais x ¼ Brahman, HLm - Hereford x Limousin, ABq - Brangus, Lm - Limousin, Bx - Brahman x other crosses, AB - Angus x Brahman, LmBq – Limousin x ¼ Brahman, HBq – Hereford x ¼ Brahman, HSm – Hereford x Simmental, Sm – Simmental, S – Saler, B - Brahman, H - Hereford, Bq - ¼ Brahman x other crosses, Lg - Longhorn.
[c, e ,f, g,....j] Least-squares means without a common superscript differ ($P < 0.01$).

Table 3. The percentage of the sampled population and 2005 Arkansas selling prices (mean ± SE) of feeder calves sold based on calf color[a]

Calf color	Percentage the of sampled population	Selling price ($/cwt)
Yellow-white face	3.7	$120.44 ± 0.26[b]
Yellow	10.2	$120.29 ± 0.16[b]
Black-white Face	10.2	$120.03 ± 0.16[b]
Black	35.4	$119.24 ± 0.08[c]
Gray	7.5	$117.66 ± 0.18[d]
Gray-white Face	0.8	$116.79 ± 0.54[d, e]
White	5.7	$116.01 ± 0.21[e]
Red-white Face	7.0	$114.58 ± 0.19[f]
Red	11.8	$113.92 ± 0.14[g]
Spots or Stripes	1.8	$107.37 ± 0.37[h]

[a] Main effect of calf color on selling price ($P < 0.0001$).
[b, c, d, e, .., h] Least-squares mean without a common superscript differ ($P < 0.01$).

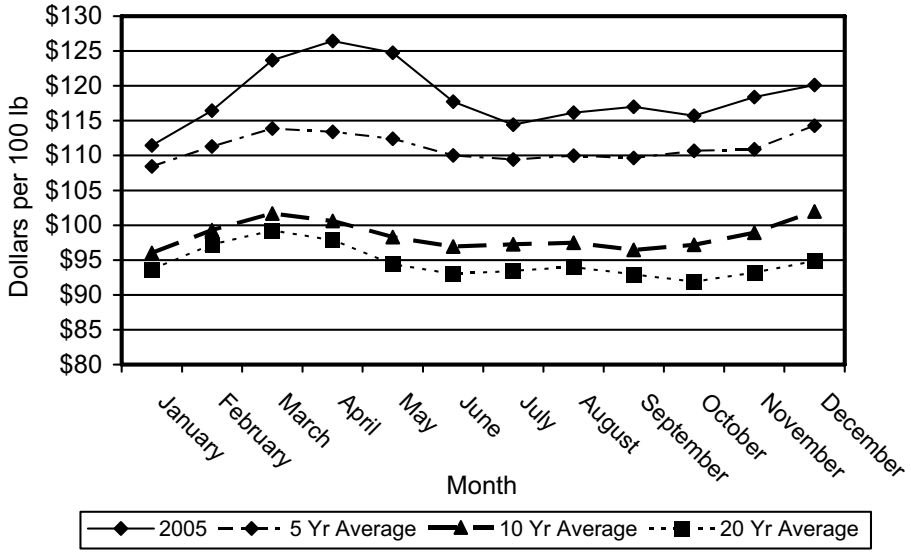

Fig. 1. The mean selling price for year 2000 and the 5-, 10-, and 20-yr averages for 400 to 500 lb feeder cattle by month. Main effect of month on selling price (P < 0.0001). All least-squares means for 2005 are different (P < 0.01) except February and August.

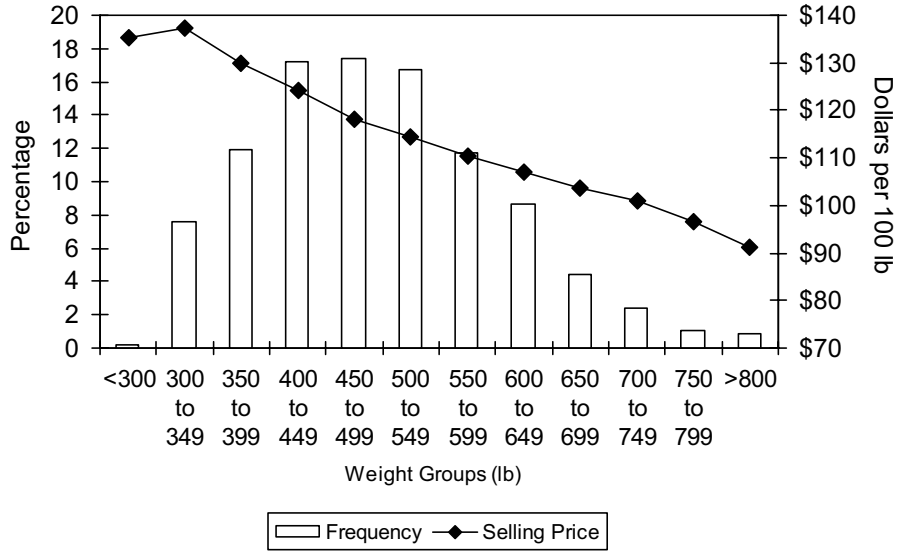

Fig. 2. The percentage of the sampled population and mean selling price of calves by weight groups. Main effect of weight groups on selling price (P < 0.001).

Effect of Livestock Auction Location, Number of Buyers, and Grouping on the Selling Price of Arkansas Feeder Cattle

T.R. Troxel, B. Barham, S. Cline, J. Foley, D. Hardgrave, W. Wiedower, and R. Wiedower[1]

Story in Brief

Data were collected from 15 Arkansas livestock auctions to determine if livestock auction location, number of buyers, and selling in groups affected the selling price of feeder cattle. Data collected included how calves were sold (single or groups), gender, breed or breed type, color, muscle thickness, horn status, frame score, fill, body condition, age, health, BW, and price. Longitudinal and latitudinal coordinates and the number of buyers were determined for each livestock auction. Selling prices differed ($P < 0.001$) across livestock auctions. The distance of livestock auctions to Oklahoma City and longitude were not related ($P > 0.10$) to feeder calf prices. The livestock auctions with greater than average selling prices sold a greater percentage (34%) of feeder cattle breeds or breed types that sold for a higher than average selling price ($P < 0.005$) compared to livestock auction with below average selling prices (20%). A positive linear relationship existed between livestock auction sales volume and selling price ($P < 0.02$) and number of buyers present ($P < 0.01$). Feeder calves sold in groups received a greater selling price than feeder calves sold individually ($P < 0.0001$). Therefore the perceived quality of feeder cattle, sales volume and number of buyers influenced livestock auction selling prices whereas the location of livestock auctions had only a slight effect on selling price. Selling feeder cattle in groups returned a higher selling price than selling single feeder cattle.

Introduction

The majority of Arkansas cow-calf producers market feeder cattle through local livestock auctions. Many cow-calf producers believe that the factors that affect the selling price of feeder cattle are subjective and are priced inconsistently from one livestock auction to another. Cattle producers are concerned with where the calves are sold, how the calves are handled at the livestock auction, and if these factors affect selling price.

The objective was to determine if livestock auction location, number of buyers, and grouping of calves affected the selling price of feeder cattle across weekly Arkansas livestock auctions.

Experimental Procedure

Five USDA certified livestock market reporters collected data weekly from 15 livestock auctions in Arkansas from January 1, 2005 to December 31, 2005. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fayetteville, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Ola, Ozark, Pocahontas, Ratcliff, and Springdale. A total of 581,413 feeder cattle were sold through these livestock auctions, and data were randomly collected (every 5th to 6th calf) on 52,401 lots consisting of 105,542 head (18.2%).

Longitudinal and latitudinal coordinates for each livestock auction were used to determine the relationship between location and selling price using a regression analysis. Regression analysis was also used to determine the relationship between 2005 sales volume and the number of buyers, 2005 sales volume and selling price, number of buyers and selling price, and selling price and the driving distance between livestock auctions and Oklahoma City. Analysis of variance was performed using the General Linear Model (GLM) procedure of SAS (SAS, Inst., Inc, Cary, N.C.). Due to the unbalanced nature of the data, the model included month and weight as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares. Sale lots included calves sold as individuals, groups of 2 to 5 calves and groups of 6 or more calves. Chi square analysis (PROC FREQ of SAS) was used to determine if the livestock auctions that sold feeder calves above the mean price sold a higher percentage of higher priced breed or breeds types and calf color and polled feeder calves than livestock auctions that sold feeder calves below the mean price. All selling prices are reported in US dollars/100 lb.

Results and Discussion

There was a difference in the selling price of feeder calves across weekly livestock auctions ($P < 0.001$); however, selling price for the top 5 livestock auctions were not different ($P > 0.10$). The mean selling price by livestock auctions ranged from \$115.39 ± 0.21 to \$119.88 ± 0.18 (Table 1). The average livestock auction selling prices were less variable in 2005 than in previous data from a similar study conducted in 2000 (Troxel et at., 2002).

The livestock auctions with higher than average selling prices sold a higher percentage (34%) of feeder cattle breeds or breed types that sold for a higher than average selling price ($P < 0.005$) compared to livestock auctions with below average selling prices (20%). The higher than average selling price livestock auctions sold more feeder calves with the more desirable colors (55% vs. 51%; $P < 0.005$) and more polled feeder calves (86% vs. 84%; $P < 0.005$) than the below average selling price livestock auctions.

The longitude (degrees west) and the distance to Oklahoma City were not related ($P > 0.10$) to feeder calf selling prices. Latitude or the degrees north tended to be related to feeder calf selling price ($P = 0.08$; Fig. 1). This suggests the livestock auctions located in the northern regions of Arkansas may have a slighter greater selling price than livestock auctions located in the southern region. Therefore, the quality of feeder cattle influenced livestock auction selling prices; whereas, the location of livestock auctions had only a slight effect on selling price.

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There was a positive linear relationship ($P < 0.02$) between the 2005 sales volume and feeder calf selling price (Fig. 2). As sales volume increased, so did feeder calf selling price. Perhaps the larger livestock auctions (in term of sales volume) sold feeder cattle for greater prices because more buyers were present. The number of buyers increased linearly ($P < 0.01$) with increasing sales volume (Fig. 3). Therefore, livestock auctions that sold more cattle during 2005 had more buyers present. The relationship between the number of buyers and feeder calf selling price only tended ($P = 0.08$) to be significant (Fig. 4). Therefore, simply having more buyers present during a livestock auction did not insure greater selling prices.

The main effect of how cattle were sold was significant ($P < 0.0001$; Table 2). The selling price for feeder cattle sold individually, groups of 2 to 5 head, and groups with 6 or more was \$117.26 ± .06, \$120.12 ± 0.12, and \$122.61 ± 0.22, respectively. Therefore, it is clear that buyers paid more for cattle sold in groups with groups of 6 or more being the most advantageous.

Implications

The majority of cow-calf producers in Arkansas sell feeder cattle at local livestock auctions. Selling prices for feeder cattle are different across livestock auctions in Arkansas. That difference is due to cattle quality and 2005 sales volume. Grouping cattle into uniform groups will improve selling price compared to selling feeder cattle as singles.

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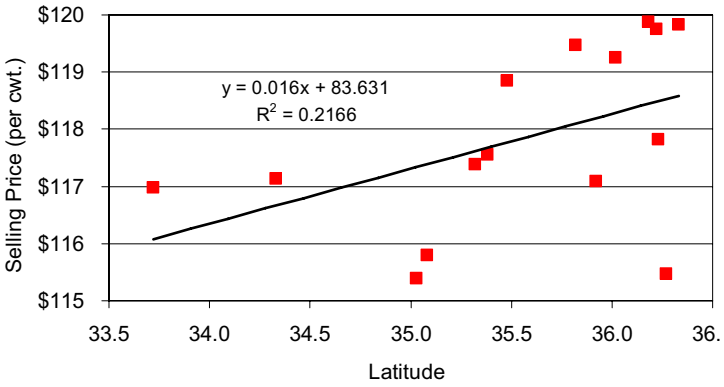

Fig. 1. The relationship between feeder calf prices and latitude (P = 0.08).

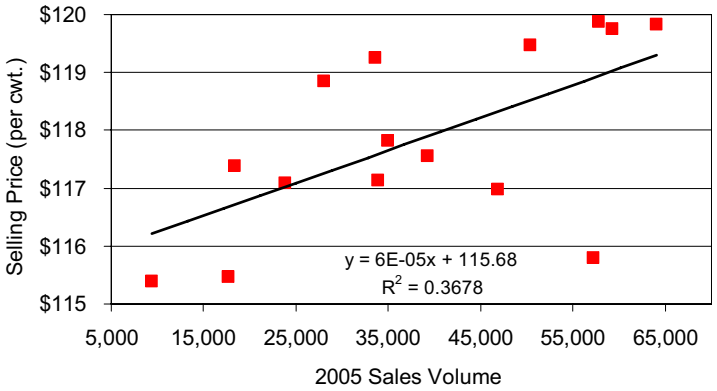

Fig. 2. The relationship between 2005 sales volume and feeder calf prices (P < 0.02).

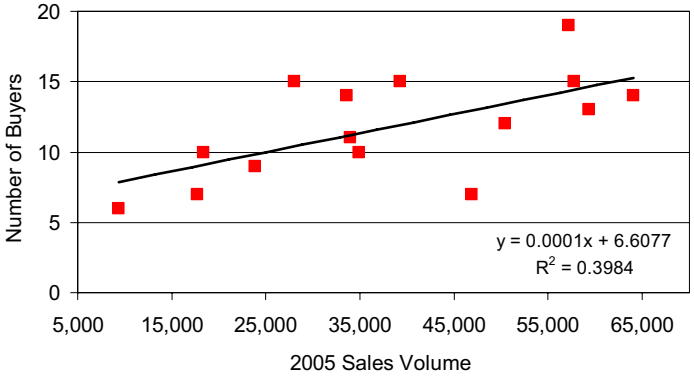

Fig. 3. The relationship between 2005 sales volume and the number of buyers (P < 0.01).

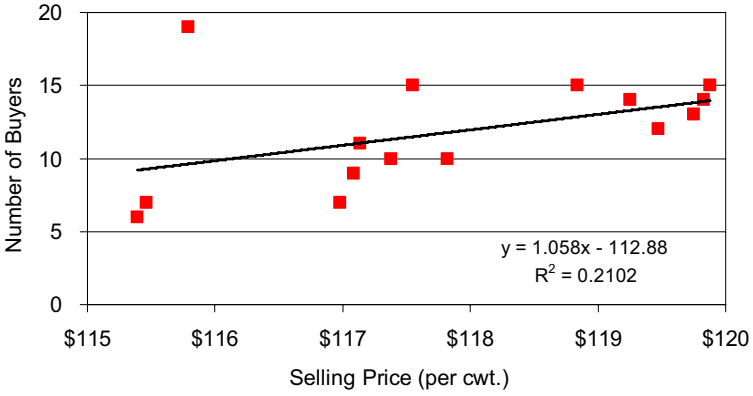

Fig. 4. The relationship between the number of buyers and feeder calf selling price (P = 0.08).

Table 1. The mean ± SE selling price of the livestock auctions participating in 2005 survey[a].

Item	Selling price[b]
Livestock Auction	
1	$119.88 ± 0.18[c]
2	$119.83 ± 0.18[c]
3	$119.75 ± 0.17[c]
4	$119.47 ± 0.18[c]
5	$119.25 ± 0.22[c]
6	$118.84 ± 0.17[d]
7	$117.82 ± 0.23[e]
8	$117.55 ± 0.15[e,f]
9	$117.38 ± 0.19[e,f]
10	$117.14 ± 0.24[e,f]
11	$117.09 ± 0.24[f]
12	$116.98 ± 0.21[f]
13	$115.79 ± 0.21[g]
14	$115.46 ± 0.27[g]
15	$115.39 ± 0.21[g]

[a] Main effect of livestock auctions on selling price ($P < 0.001$).
[b] Least -squares mean ± SE (US dollars/100 lb).
[c, d, e, f, g] Least-squares means within column without a common superscript differ ($P < 0.01$).

Table 2. The mean ± SE selling price of feeder calves based on grouping[a].

Item	Selling price[b]
Grouping	
Singles	$117.26 ± 0.06[c]
2 to 5 head	$120.12 ± 0.12[d]
6 or more	$122.61 ± 0.22[e]

[a] Main effect of calf grouping on selling price ($P < 0.0001$).
[b] Least-squares mean ± SE (US dollars/100 lb).
[c, d, e] Least-squares means within column without a common superscript differ ($P < 0.0001$).

Factors Affecting the Selling Price of Calves Sold in Arkansas Livestock Markets: 2000 vs. 2005

B.L. Barham, T.R. Troxel, S. Cline, J. Foley, D. Hardgrave, R. Wiedower, and W. Wiedower[1]

Story in Brief

Five USDA certified livestock market reporters collected data from weekly livestock auctions in Arkansas from January 1 to December 31 in both 2000 and 2005. The data collected included calf gender, breed or breed type, color, muscle thickness, horn status (polled (dehorned) or horned), frame score, fill, condition, age, health, and weight. More number 2 muscle score cattle and fewer number 3 and 4 muscle score cattle were sold in 2005 than 2000 ($P< 0.01$). In 2005, buyers paid a higher premium for muscle score 1's than in 2000. The Arkansas cow-calf producer marketed more large-framed and fewer medium- and small-framed calves in 2005 than in 2000 ($P < 0.01$). The cattle breeds or breed types that increased in value from 2000 to 2005 were Angus x Hereford, Angus, Charolais x Limousin, Angus x Charolais, Charolais x 1/4 Brahman, 1/2 Brahman Cross, Angus x Brahman, Limousin x 1/4 Brahman and Hereford x 1/4 Brahman ($P < 0.01$). The only calf colors that increased in frequency from 2000 to 2005 were black-white face, black, and gray ($P < 0.01$). Cattle buyers discounted horned cattle more in 2005 than in 2000. Arkansas cow-calf producers sold more calves in groups and fewer calves individually in 2005 than they did in 2000 ($P < 0.01$). Buyers paid a higher premium for cattle sold in groups in 2005 than in 2000. Cow-calf producers can do more to improve the quality and selling price of feeder cattle by making genetic selection and management changes.

Introduction

The Arkansas beef cattle industry consists of cow-calf operations with approximately 80 percent of the farms having less than 50 cows. Most of these producers market feeder calves through local livestock auctions. As feeder calves are viewed, buyers must look at the feeder calf/calves, make some assessment regarding the makeup of the calf and potential production, and then place a bid. At most livestock auctions, buyers must make a rapid assessment of the animal's production potential.

Although cattle producers are "price takers," there are ways to improve the value of feeder calves. When buyers look at feeder calves, they must assess the muscle thickness, frame score, breed composition, and any other management factors to determine a sale price. This survey will address the importance of these factors and provide guidelines on how cow-calf producers can improve feeder calf value.

Experimental Procedures

Data Collection. Five USDA certified livestock market reporters collected data from weekly livestock auctions in Arkansas from January 1 to December 31 in both 2000 and 2005. The market reporters collected information from 17 markets in 2000 and 15 markets in 2005. The livestock auctions surveyed in 2000 were located in Ash Flat, Charlotte, Conway, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Morrilton, Nashville, Ola, Ozark, Pocahontas, Ratcliff, Springdale, and Texarkana. The livestock auctions surveyed in 2005 were located in Ash Flat, Charlotte, Conway, Fayetteville, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Ola, Ozark, Pocahontas, Ratcliff, and Springdale. The data collected included calf gender (bull, steer, or heifer), breed or breed type, color, muscle thickness, horn status (polled (dehorned) or horned), frame score (large, medium or small), fill (gaunt, shrunk, average, full or tanked), condition (very thin, thin, average, fleshy, or fat), age (calf or yearling), health (dead hair, stale, sick, bad eye(s), lame, healthy or preconditioned), and weight. A total of 533,283 feeder cattle were sold through these livestock auctions in 2000, and data were randomly collected (every 5th to 6th calf) on 81,703 (15.3%) head. A total of 581,413 feeder cattle were sold through these livestock auctions in 2005, and data were randomly collected (every 5th to 6th calf) on 52,401 lots consisting of 105,542 (18.2%) head. Frame and muscle scores were determined based on the U.S. Standards for Grades of Feeder Cattle (USDA 1980, 2000).

Data Analyses. The percent of calves within age, gender, breed or breed type, color, horn status, frame score, muscle score, fill, condition, weight group, and health were determined by the frequency procedure of SAS (SAS Inst., Inc., Cary, N.C.) based on the number of lots sold. Calf characteristics were analyzed individually as independent variables in which the model included month and weight as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares. The analysis of variance was performed with the General Linear Model (GLM) procedure of SAS. Least-squares means were generated, separated based on predicted differences, and both are reported throughout. Since all colors are not represented within each breed or breed type, color and breed or breed type data are somewhat inherently confounded. All selling prices reported are in US dollars/100 lb.

Results and Discussion

*Muscle Score*s. The frequency distribution and selling price comparisons by muscle scores are reported in Table 1. More number 2 muscle score cattle and fewer number 3 and 4 muscle score

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cattle were sold in 2005 than 2000 ($P < 0.01$). It appears that Arkansas cow-calf producers have identified light-muscled cattle and emphasized selecting against them. In 2005, buyers paid a higher premium for muscle score 1's than in 2000. The discount for muscle score 2 cattle was less in 2005 than in 2000. Conceivably buyers paid more for muscle score 2 cattle because of a short supply and high demand of cattle. Regardless of the supply of cattle, buyers discounted muscle score 3's and 4's the same amount in both years.

Frame Scores. The Arkansas cow-calf producer produced more large-framed and fewer medium- and small-framed calves in 2005 than in 2000 ($P < 0.01$; Table 2). In 2005, buyers did not pay the premium for large-framed cattle as in 2000, but they paid more for medium-framed cattle. This could be attributed to feeder cattle supplies, or it could be a sign that the cattle industry is moving back toward a medium-framed calf. Small-framed cattle were heavily discounted in both years, but a higher discount was detected in 2005. Therefore, although feeder calf supplies were tight, the discounts for small-framed cattle were greater.

Breeds and Breed Types. The cattle breeds or breed types that increased in value from 2000 to 2005 were Angus x Hereford, Angus, Charolais x Limousin, Angus x Charolais, Charolais x 1/4 Brahman, 1/2 Brahman Cross, Angus x Brahman, Limousin x 1/4 Brahman and Hereford x 1/4 Brahman ($P < 0.01$; Table 3). All other breeds or breed types either did not change ($P > 0.10$) or decreased ($P < 0.01$) from 2000 to 2005. Buyers paid more for Angus x Hereford, Angus, Angus x Charolais and Brahman breed or breed types. Buyers discounted Charolais x Limousin, Charolais, Charolais x 1/4 Brahman, Hereford x Limousin, Limousin, Simmental and 1/4 Brahman Cross more in 2005 than in 2000. It is apparent that cattle buyers must rely on breed type when determining the appropriate price to pay for a calf.

Color. The only calf colors that increased in frequency from 2000 to 2005 were black-white face, black and gray ($P < 0.01$; Table 4). The can be largely attributed to the rise in the popularity and number of black Angus sires. The colors that received an increase in selling price were yellow-white face, black-white face, black and gray. White, red-white face and red were discounted in 2005 compared to 2000.

Sex of Calf. Arkansas cow-calf producers castrated more bull calves before selling in 2005 than in 2000 ($P < 0.01$; Table 5). Buyers paid a higher premium for steers and paid less for bull calves in 2005 than in 2000. Stocker operators and feedyards have heavily emphasized the need to castrate male caves through prices. Therefore, market signals to the cow-calf producer continue to reinforce castration of bull calves.

Fill. The increase in the frequency of gaunt and shrunk calves in 2005 was probably related to the drought conditions experienced in much of Arkansas ($P < 0.01$; Table 6). Arkansas experienced the second driest year on record in 2005. Even with short feeder cattle supplies in 2005, buyers discounted full and tanked calves more in 2005 than in 2000. Gaunt and average fill calves did not receive the premiums in 2005 as they did in 2000. Buyers are unwilling to absorb the shrink on full and tanked calves and will not pay market price for those calves. The producer not only absorbs the extra feed cost that resulted in the extra fill, but also the calf was discounted when it was sold.

Condition. Calf body condition was probably also affected by the droughty conditions in 2005 resulting in an increase in the frequency of gaunt calves compared to 2000 (Table 7). The percentage of very thin and average body condition increased from 2000 to 2005; whereas, the percentage of thin, fleshy and fat body conditioned calves decreased ($P < 0.01$). Thin cattle in 2000 received a discount but in 2005 received a premium. Very thin cattle received a premium in 2005, but fleshy and fat calves were discounted more in 2005 than in 2000. Thin calves offer an opportunity for cattle buyers to increase profits due to compensatory gains after purchase and are typically offered a higher price.

Horn Status. Although feeder cattle supplies were tight, buyers discounted horned cattle greater in 2005 than 2000 (Table 8). Polled calves brought just about the average price for both years, but polled cattle received a larger premium in 2005. Arkansas cow-calf producers produced more polled calves in 2005 ($P < 0.01$). This may be due to the increased use of Angus bulls.

Health. The percentage of calves with dead hair, stale, sick, bad eye(s) and lame was low in 2000 and even lower in 2005 ($P < 0.01$). Buyers discounted unhealthy cattle more in 2005 compared to 2000 except for calves with bad eye(s) (Table 9). Healthy cattle for both years received the same premium.

Groups. Arkansas cow-calf producers sold more calves in groups and fewer calves individually in 2005 than they did in 2000 ($P < 0.01$; Table 10). Buyers paid a higher premium for cattle sold in groups in 2005 than in 2000. Buyers are continuing to send an economic signal for selling calves in groups rather than individually.

Implications

Cow-calf producers can do more to improve the quality and selling price for the feeder cattle sold through Arkansas livestock auctions. Through genetic selection and management changes, feeder calf value can be improved and overall total returns increased. Buyers desire large and medium framed calves, that are heavily muscled (muscle scores 1 & 2). They are also willing to pay premiums for calves that are polled or dehorned, castrated and are in thin to average condition and fill. Breed and color price differences were noted in both years, however producers are encouraged not to make selection decisions based on breed and color alone. Breeds should be chosen by how they fit in your breeding program and operational goals not by their coat color.

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Table 1. Muscle score frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Muscle score	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
1's	76.7	75.3%	$0.02	$2.58	< 0.0001
2's	14.7	22.6%	-$8.98	-$6.12	< 0.0001
3's	8.3	1.1%	-$21.30	-$20.04	ns[b]
4's	0.3	0.06%	-$33.80	-$30.40	ns

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant

Table 2. Frame score frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Frame score	Frequency percentage		Deviation from the respective averages [a]		P-value
	2000	2005	2000	2005	
Large	56.8%	64.6%	$1.07	$0.52	< 0.0001
Medium	42.1%	34.3%	-$0.40	$0.36	< 0.0001
Small	1.1%	0.6%	-$18.52	-$20.96	< 0.003

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.

Table 3. Breed or breed type frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Breed or breed type	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
Angus x Hereford	5.1%	7.2%	$2.13	$3.66	< 0.0001
Angus	7.2%	11.1%	$0.45	$3.71	< 0.0001
Charolais x Limousin	3.9%	4.7%	$4.70	$2.90	< 0.0001
Angus x Limousin	0.8%	0.5%	$4.32	$3.42	ns[b]
Angus x Charolais	2.5%	3.2%	-$0.30	$2.24	< 0.0001
Hereford x Brahman x Angus	2.8%	2.9%	$1.19	$1.80	ns
Charolais	15.7%	11.7%	$2.38	$1.07	< 0.0001
Charolais x ¼ Brahman	2.3%	3.0%	$0.51	-$0.07	ns
Hereford x Limousin	4.6%	2.5%	$1.47	$0.29	< 0.004
Hereford x Charolais	2.5%	2.1%	$3.51	$3.03	ns
Brangus	6.1%	5.3%	-$0.09	-$0.24	ns
Limousin	10.4%	8.3%	$1.70	-$0.79	< 0.0001
½ Brahman Cross	2.4%	4.8%	-$1.46	-$1.84	ns
Angus x Brahman	8.8%	13.6%	$1.30	$1.28	ns
Limousin x ¼ Brahman	1.4%	2.3%	$0.10	-$2.49	< 0.0001
Hereford x ¼ Brahman	1.3%	1.8%	-$1.59	-$2.60	ns
Hereford x Simmental	0.8%	0.4%	-$2.98	-$2.61	ns
Simmental	2.8%	0.9%	-$2.98	-$4.73	< 0.005
Saler	0.8%	0.6%	-$2.98	-$7.60	< 0.0001
Brahman	1.3%	0.9%	-$11.85	-$9.38	< 0.0002
Hereford	2.6%	1.5%	-$9.81	-$10.51	ns
¼ Brahman Cross	13.1%	7.8%	-$1.97	-$3.47	< 0.0001
Longhorn	0.9%	0.6%	-$17.92	-$22.35	< 0.03

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant

Table 4. Calf color frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Calf color	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
Yellow-white face	5.6%	3.7%	$1.85	$3.01	< 0.0001
Yellow	12.1%	10.2%	$3.03	$2.80	ns[b]
Black-white face	9.3%	10.2%	$1.78	$2.60	< 0.001
Black	24.8%	35.4%	$0.78	$1.58	< 0.001
Gray	5.0%	7.5%	-$1.44	$0.51	< 0.0001
Gray-white face	1.3%	0.8%	-$2.05	-$0.77	ns
White	7.9%	5.7%	$1.72	-$1.84	< 0.0001
Red-white face	11.5%	7.0%	-$1.49	-$2.68	< 0.0001
Red	15.7%	11.8%	-$0.77	-$3.61	< 0.001
Spotted or striped	3.1%	1.8%	-$9.83	-$9.42	< 0.001

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant

Table 5. Calf gender frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Calf gender	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
Steers	33.2%	40.0%	$6.02	$6.48	< 0.0001
Bulls	23.0%	14.1%	$1.68	$0.30	< 0.0001
Heifers	44.7%	45.8%	-$4.68	-$5.00	< 0.002

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.

Table 6. Body fill frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Body fill	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
Gaunt	14.3%	21.4%	$2.83	$1.71	< 0.0001
Shrunk	21.4%	26.5%	$2.09	$1.82	ns[b]
Average	52.4%	49.4%	$0.02	-$0.52	< 0.0001
Full	11.5%	2.7%	-$4.15	-$7.47	< 0.0001
Tanked	0.5%	0.1%	-$8.01	-$23.96	< 0.0001

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant

Table 7. Body condition frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Body condition	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
Very thin	1.4%	21.7%	-$7.06	$1.54	< 0.0001
Thin	22.8%	12.2%	$1.67	-$1.91	< 0.0001
Average	58.9%	63.2%	$0.41	$0.58	< 0.08
Fleshy	15.7%	2.9%	-$1.35	-$5.79	< 0.0001
Fat	1.3%	0.1%	-$4.80	-$16.48	< 0.0001

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant

Table 8. Horned status frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Horn status	Frequency percentage		Deviation from the respective average[a]		P-value
	2000	2005	2000	2005	
Horns	27.6 %	12.8%	-$0.51	-$2.86	< 0.0001
Polled	71.1 %	85.8%	$0.48	$0.83	< 0.0001

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.

Table 9. Health status frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Health status	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
Dead hair	0.3%	0.2%	-$25.64	-$37.28	< 0.04
Stale	1.2%	0.4%	-$26.73	-$33.78	< 0.0001
Sick	0.2%	0.1%	-$10.85	-$16.14	< 0.0001
Bad eye (s)	0.2%	0.3%	-$11.75	-$12.38	ns[b]
Lame	0.3%	0.2%	-$9.69	-$13.02	< 0.0001
Healthy	97.8%	95.5%	$0.57	$0.55	ns
Preconditioned	na[c]	3.3%	na	$4.01	

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant
[c] na = data was not collected in 2000

Table 10. Group size frequency distribution and the 2000 and 2005 Arkansas price deviation from the respective averages.

Group size	Frequency percentage		Deviation from the respective averages[a]		P-value
	2000	2005	2000	2005	
1	81.2%	74.8%	-$0.22	-$0.12	ns[b]
2 to 5	14.7%	19.4%	$2.02	$2.78	< 0.0001
≥ 6	4.1%	5.8%	$4.16	$5.32	< 0.0001

[a] The average selling prices for 2000 and 2005 were $92.91 and $118.32/cwt., respectively.
[b] ns = not significant

Self-Assessment of the Arkansas Beef Industry: Large and Small Cow-Calf Industries

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Story in Brief

A survey was conducted to determine the current strengths and weaknesses and future opportunities and threats for small cow-calf (≤ 50 cows) and large cow-calf (> 50 cows) industries in Arkansas. Producers with small cow-calf herds placed a high value on the "lifestyle" often associated with cattle production. They managed their herd as much for heritage's sake—maintenance of a family legacy—as for profitability. This group believed they were isolated from other segments of the beef cattle industry. The respondents with small cow-calf herds expressed concerns with rising production costs and decreasing opportunities to buy land. Improving genetics, adapting to change, and education were seen as waysto make improvements in the small cow-calf industry. Without economies of scale, the profitability of small cow-calf herds was especially vulnerable to increased feed/fuel/fertilizer costs. Respondents with large cow-calf herds listed marketing as a major strength, followed by a favorable climate and land resources. Large-scale production also allowed for increased ability to spread input costs over a larger number of animals which reduced investments and inputs per cow. Increasing environmental regulations, including regulations on phosphorus levels, and the increasing number of active environmental activist groups were found to be possible limitations. Producers were worried about increased cost of production; therefore, the use of production technology to increase efficiency was an extremely important future opportunity for producers with large cow-calf herds. Producers with large cow-calf herds rated animal disease and loss of consumer confidence as threats to the industry.

Introduction

Beef cattle are grown on more farms than any other commodity produced in Arkansas. Of the state's 48,000 farms, nearly 30,000 produce cattle. In 2004, sales of cattle and calves generated cash receipts exceeding $555 million or 8.4% of the state's total farm cash receipts. As those farm revenues were spent for goods and services, more than $850 million of economic activity was created in the state, primarily in rural areas (USDA, 2002; Troxel et al., 2006). Beef cattle have been and will likely remain the most prevalent agricultural enterprise in Arkansas' economy. Rapidly evolving changes in cattle marketing and innovations in beef industry technology will challenge Arkansas cattle producers in the future. The objective of this study was to determine the current strengths and weaknesses and future opportunities and threats for the small cow-calf (≤ 50 cows) and large cow-calf (> 50 cows) industries. The results should provide a sound basis for identifying and addressing educational needs for these industries.

Experimental Procedures

A survey instrument was used to determine the current strengths and weaknesses and future opportunities and threats for the small (≤ 50 cows) and large (> 50 cows) segments of the cow-calf industries in Arkansas. Survey questions were developed during an Arkansas Beef Audit Leadership Conference. Key leaders from each industry segment were assembled to list and prioritize the current strengths and weaknesses and future opportunities and threats for their respective industry. The rating scale was 1 = not important at all to 5 = extremely important.

A master mailing list for each industry segment was obtained from the University of Arkansas Cooperative Extension Service. From these databases, 100 names and addresses were randomly selected to receive a survey. Four days prior to mailing the survey with a stamped returned addressed envelope, a letter was mailed to introduce and explain the purpose of the survey. Two weeks following the mailing of the survey, reminder post cards were mailed. A second survey was mailed 26 days following the reminder post cards. Each survey was coded so that reminder postcards and second surveys were not mailed to an individual that had already returned a survey. Two surveys from the small cow-calf segment were returned due to insufficient addresses. The response rate was 73.5% and 70% for the small cow-calf and large cow-calf segments, respectively.

Data Analysis. Data from the Arkansas Beef Industry Survey were analyzed using both the Microsoft Excel 2003 (Microsoft Corp, Redmond, Wash.) and the SPSS 13.0 (SPSS Inc., Chicago, Ill.) software packages. Descriptive statistics were calculated to describe the frequencies and distributions of variables in the survey. Respondent demographic information (e.g., age category, industry experience category) were calculated using frequencies and percentages. Respondents' ratings of educational methods, preferences for meeting times, and knowledge of and attitude about the Beef Check Off Program were calculated using means and standard deviations to represent the average rating and distribution of ratings for each of these items.

To determine if any differences existed in the ratings of educational method preferences, meeting time preferences and knowledge and attitude about the Beef Check Off Program, based on the age and the years in the industry reported by respondents, the categories for both the respondent age and the years in the industry

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items were collapsed into two categories. This was done because the distributions of responses for both of these items were skewed toward the upper categories, leaving few respondents in the lower categories. The age category item was collapsed from five (30 years old or less, 31 to 40 years old, 41 to 50 years old, 51 to 60 years old, and more than 60 years old) to three categories (50 years old or less, 51 to 60 years old and more than 60 years old). Analyses to determine if significant differences existed in educational method preferences, program time of day preferences, and knowledge and approval of the Beef Check Off Program were conducted using a one-way analysis of variance (ANOVA), with age category as the independent variable.

The years in the industry category was collapsed from four (5 years or less, 6 to10 years, 11 to 20 years, and more than 20 years) to two categories (20 years or less and more than 20 years). Analyses to determine if significant differences existed in educational method preferences, program time of day preferences, and knowledge and approval of the Beef Check Off Program based on respondents' years in the industry were conducted using an independent samples t-test procedure, with years in the industry as the independent variable.

Results and Discussion

Small Cow-Calf. A high value was placed on the "lifestyle" and family-operation often associated with cattle production (Table 1). While the group indicated that current high cattle prices were a strength, it was clear from the survey findings that they managed their herd as much for heritage's sake—maintenance of a family legacy—as for profitability. Marketing and expanding marketing opportunities were viewed as important to the group, though they believed they were disadvantaged compared to larger producers. They also believed that they were somewhat isolated from other segments of the beef cattle industry. The group understood that they made up the largest volume of beef producers in our state, and believed that the general public had a positive impression of producers with small cow-calf herds. They also understood they had the ability to impact public policy, because of their large numbers and the standing they had in their communities.

The respondents with small cow-calf herds expressed a concern with the rising production costs and a decreasing opportunity to buy land (Table 2). They recognized that they spent less time than needed in improving their herd and facilities and certainly less time than large cow-calf operations.

Future opportunities identified by the small cow-calf industry dealt with improved production efficiency (Table 3). They recognized that they could improve their herds and that the Extension Service was there to help them. Improving genetics, adapting to change, and education were seen as ways to make improvements in the small cow-calf industry.

The value (and cost) of land held a significant importance to the group. Increasing land prices were making it more difficult to acquire land with an interest of putting together a small herd unless the land was transferred from family members or rented (Table 4). They saw this as a future threat to their "lifestyle." As with all groups, the producers with small cow-calf herds had strong concerns about increasing production costs. Without the scale needed to spread these costs out over a larger herd, the profitability of small cow-calf herds was especially vulnerable to increases in feed/fuel/fertilizer costs. In spite of these perceptions, the producer with small cow-calf herds saw more strengths than weaknesses to their industry segment.

The respondents with small cow-calf herds were interested in their interaction with production management systems. They saw a tremendous opportunity to improve, but economics alone does not impact their production management decisions. Genetics, production management in a system approach, and natural resource stewardships were educational opportunities for this group (Table 3).

Large Cow-Calf. Marketing was rated as a major strength of the producers with large cow-calf herds (Table 5). Having more calves to market was a strong advantage for producers with large cow-calf herds. Other strengths of the industry were a favorable climate and greater land resources. Large-scale production also allowed for increased ability to spread input costs over a larger number of animals thereby reducing investments and inputs per cow. The availability of by-products for the use in animal feeds or as fertilizer was also listed as a strength of producing cattle in the state.

Operators with large cow-calf herds were extremely concerned about rising input costs. Rising energy costs, in addition to having a direct effect on transportation costs, also affected the cost of other inputs such as fertilizer needed for efficient operation (Table 6). Recent years have seen a great deal of volatility in cattle markets. Survey participants felt that unpredictable market prices and our current lack of export markets were important limitations. Additionally, survey responses indicated that environmental issues were somewhat of a limitation. Increasing urban pressure was another limitation identified in the survey. Urban sprawl continues to limit the land available for herd expansion in terms of both quantity and price. Increasing environmental regulations, including regulations on phosphorus levels, and the increasing number of environmental activist groups were found to be possible limitations.

Use of production technology to increase efficiency was an extremely important future opportunity for producers with large cow-calf herds. Maximizing forage growth and utilization, and taking advantage of improved cattle genetics to meet consumer demands were listed as important opportunities (Table 7). The ability to take advantage of scientific knowledge will become increasingly important in cattle production. Other future opportunities identified were related to marketing, which included taking advantage of contracts and other marketing options.

Producers with large cow-calf herds also identified several future threats to their industry (Table 8). Increased input costs, especially fuel and fertilizer, were identified as the number one threat. Animal health and disease issues were listed as another large threat to the industry. The loss of consumer confidence in beef, whether related to disease or other issues, also was recognized as an important future threat. Since the beef industry is consumer driven, loss of consumer support would directly impact producers' profitability. Recent efforts to change the method of determining land value for the purpose of assessing property taxes were cited as a major threat. Educational opportunities for the large cow-calf industry centered on marketing issues, managing input costs, public confidence in the beef cattle industry (biosecurity and animal health threats) and environmental issues. Marketing issues, which could also include input costs were seen by the large cow-calf industry as a both strength and threat. This industry was very concerned with their future profitability and how they could manage costs.

Educational Methods. Producers of both small and large cow-calf herds clearly preferred printed material and newsletters as the desired means of educational delivery methods. On-farm demonstrations, one-on-one consultation and experiment station field days, and group meetings/workshops were the second most pre-

ferred educational methods identified. These producer groups like to see the result(s) for themselves. Radio programs, online web-based information, displays and posters, email, and distance education were all ranked low, indicating that these methods were not preferred methods of delivery of educational materials. Large and small cow-calf producers clearly felt that night meetings were more acceptable than afternoon or morning meeting times.

Beef Check Off Program. The respondents with large cow-calf herds were very knowledgeable and favorable of the Beef Check Off Program (3.9; 1 = no knowledge to 4 = very knowledgeable). Respondents with small cow-calf herds knew less about the Beef Check Off Program (2.8; $P < 0.05$). Approval ratings for the Check Off Program was not different ($P > 0.10$) between the two groups.

Demographics. The producers with large and small cow-calf herds surveyed were very similar in age (69% and 74% were ≥ 51 years of age, respectively; $P > 0.10$). Producers with larger cow-calf herds had more experience than the producers with small cow-calf herds (58% and 83% with ≥ 20 years experience, respectively; $P < 0.02$). Only 9.0% and 5.7% of the small and large cow-calf respondents, respectively, were less than 40 years of age.

Implications

This study identified educational opportunities, demographics, and preferred educational methods (newsletter, etc) for the producers with large and small cow-calf herds of the Arkansas cattle industry. This information can assist the Arkansas Beef Council and Animal Science in the planning of educational programs and delivery methods.

Literature Cited

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Table 1. Current strengths as identified by the respondents of small cow-calf (≤ 50 head) herds.

Strength	Average ± SD[a]
Ability to improve quality of herd	4.6 ± 0.53
Record high prices	4.5 ± 0.65
Producer independence	4.5 ± 0.70
Ability to improve facilities	4.4 ± 0.63
Good grazing opportunities	4.4 ± 0.65
Low property taxes	4.4 ± 0.95
Marketing opportunities	4.3 ± 0.79
Positive public perception of small cow/calf operations	4.3 ± 0.88
Family involvement	4.2 ± 0.96
Better utilization of marginal land	4.1 ± 0.84
Supports local economies	4.1 ± 0.88
Opportunities for sales through local cooperatives	3.9 ± 1.12
Largest segment of AR cattle industry	3.8 ± 0.93
Available off-farm employment opportunities	3.7 ± 1.09
Equipment sharing opportunities	3.4 ± 1.18

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 2. Current limitations as identified by the respondents with small cow-calf (≤ 50 head) herds.

Limitations	Average ± SD[a]
Rising costs	4.5 ± 0.75
Decreasing opportunities to buy land	4.2 ± 0.99
Not following a calf health program	4.1 ± 0.76
Need for better management skills	4.1 ± 0.78
Not capitalizing on market opportunities	4.1 ± 0.88
Lack of capital	4.1 ± 0.94
Lack of knowledge of other segments of the beef industry (stocker, feedlot, etc)	3.9 ± 0.84
Lack of large animal veterinarians	3.9 ± 1.05
Children leaving the farm	3.9 ± 1.27
Single sire herd management	3.8 ± 0.90
Lack of flexibility of marketing	3.8 ± 0.90
Lack of connections with large processors, packers, etc	3.7 ± 1.14
Lack of industry diversification	3.5 ± 0.98

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 3. Future opportunities as identified by the respondents with small cow-calf (≤ 50 head) herds.

Opportunities	Average ± SD[a]
Improve genetics of cow/calf herd	4.5 ± 0.63
Education of cow/calf producers	4.4 ± 0.64
Improve production efficiency	4.4 ± 0.69
Adapt to change	4.2 ± 0.76
Age and source verification	3.9 ± 0.86
Establish stronger connections with Extension Service	3.9 ± 0.87
Establishment of cooperative marketing	3.8 ± 0.94
Use of diagnostic tools to manage herd health	3.7 ± 0.90
Bred heifer sales	3.6 ± 0.91
Alliances with seedstock producers	3.5 ± 0.92
Niche markets	3.5 ± 1.11
Pooling of resources	3.4 ± 0.99

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 4. Future threats as identified by the respondents with small cow-calf (≤ 50 head) herds.

Threats	Average ± SD[a]
Increasing production costs	4.6 ± 0.62
Export and import trade issues	4.5 ± 0.72
Disease outbreak	4.5 ± 0.78
Fuel costs	4.5 ± 0.80
Taxes (land use valuation)	4.4 ± 0.93
Decrease in public confidence	4.3 ± 0.92
Cost of mandatory programs	4.2 ± 0.89
Increase in regulations (water quality, land use, zoning)	4.1 ± 1.11
Environmental and animal rights activists	4.0 ± 1.10
Undesirable cattle	3.8 ± 1.21
Failure to comply with consumer demands	3.7 ± 1.08
Integration of the industry	3.6 ± 1.09
Competition for other meats (poultry, pork, etc.)	3.5 ± 1.15

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 5. Current strengths as identified by the respondents with large cow-calf (> 50 head) herds.

Strength	Average ± SD[a]
Marketability of product	4.6 ± 0.67
Climate and land favorable to forage	4.3 ± 0.76
Lower investment per cow	4.3 ± 0.86
Ability to diversify marketing	4.2 ± 0.78
Ability to select specific genetics	4.1 ± 0.88
Availability of by-products for feed & fertilizer	4.0 ± 0.98
Availability of educational opportunities	3.9 ± 0.90
Better economics of scale	3.8 ± 0.79
Infrastructure of the industry	3.7 ± 0.87

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 6. Current limitations as identified by the respondents with large cow-calf (> 50 head) herds.

Limitations	Average ± SD[a]
Fuel costs	4.7 ± 0.58
Rising input costs	4.3 ± 0.90
Unpredictable market prices	4.2 ± 0.94
Export limitations	4.0 ± 1.01
Limited land for expansion	3.9 ± 1.01
Beef cattle and land management complexities	3.8 ± 0.92
Environmental regulations	3.8 ± 1.11
Increased urban pressure and encroachment	3.8 ± 1.28
Phosphorus issues	3.6 ± 1.11
Animal rights and environmental activists	3.6 ± 1.50

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 7. Future opportunities as identified by the respondents with large cow-calf (> 50 head) herds.

Opportunities	Average ± SD[a]
Maximize forage utilization	4.5 ± 0.74
Increased marketing option opportunities	4.4 ± 0.86
Improvement of genetics to meet consumer demand	4.3 ± 0.77
Take advantage of scientific knowledge	4.1 ± 0.93
Advertising to promote products	4.1 ± 0.97
Take advantage of government programs	3.9 ± 0.99
Cooperative programs to pool resources	3.8 ± 1.07
Pooling larger herds to market	3.7 ± 1.07
Increase size of operations	3.6 ± 0.96
Contractual agreements	3.5 ± 1.06

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 8. Future threats as identified by the respondents with large cow-calf (> 50 head) herds.

Threats	Average ± SD[a]
Rising input costs	4.6 ± 0.73
Animal health issues (disease outbreaks, antibiotic resistance, etc)	4.4 ± 0.81
Downturn in calf prices	4.4 ± 0.82
BSE and other animal diseases	4.4 ± 0.83
Loss of agricultural value vs. commercial value in determining property taxes	4.4 ± 0.86
Environmental issues	4.3 ± 0.95
Loss of consumer confidence in beef	4.3 ± 0.99
Over-regulation by government	4.1 ± 1.11
Cheaper to raise beef in other countries	4.1 ± 1.07
Animal rights and environmental activists	4.1 ± 1.10
Urban encroachment	3.9 ± 1.08

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Self Assessment of the Arkansas Beef Industry: Stocker, Purebred, and Support Industries

T.R. Troxel[1], K. Lusby[2], S. Gadberry[1], B. Barham[1], T. Riley[1], R. Poling[1], S. Eddington[3], and T. Justice[4]

Story in Brief

A survey was conducted to determine the current strengths and weaknesses and future opportunities and threats for Arkansas' stocker, purebred, and support industries. The stocker respondents cited location related to feeder calf supplies and demand as marketing advantages. Input costs, cattle health, lack of cattle uniformity, and small margins were listed as current limitations. Improving calf quality, grouping cattle into uniform groups, and building alliances were identified as future opportunities to enhance Arkansas' beef cattle reputation. Cost of production was the number one future threat for the stocker cattle industry. Purebred respondents identified themselves as a genetic resource to improve the genomics of the cattle population. The main limitation suggested was the low value commercial cow-calf producers placed on herd sires. Opportunities could be summarized as genetic advancements and education. The purebred industry was concerned with profitability, environmental issues, consumer confidence, disease outbreak, border closures, and animal rights groups. Support industry saw themselves as a primary component of the producer education system for production management practices. The support industries believed the small cattle producer was not as involved in the cattle industry as the large cattle producer. Time constraints and business efficiencies did not allow a close working relationship between small producers and the support industry. The support industry was concerned with an uninformed public as the greatest threat to the industry. The support industry's future success was dependent on understanding and acceptance of production enhancing technologies and services. The support industries expressed some apprehension regarding the continuing consolidation of the support industry itself.

Introduction

Beef cattle are grown on more farms than any other commodity produced in Arkansas. Of the state's 48,000 farms, nearly 30,000 produce cattle. In 2004, sales of cattle and calves generated cash receipts exceeding $555 million or 8.4% of the state's total farm cash receipts. As those farm level revenues were spent for goods and services, more than $850 million of economic activity was created in the state, primarily in rural areas (USDA, 2002; Troxel et al., 2006a).

Beef cattle have been and will likely remain the most prevalent agricultural enterprise in Arkansas' economy. Emerging development in cattle marketing, and innovations in beef industry technology will challenge Arkansas cattle producers in the future. The objective of this study was to determine the current strengths and weaknesses, and future opportunities and threats for the stocker, purebred, and support industries. The results may provide educational needs for these industries.

Experimental Procedures

The instrument used to determine the current strengths and weaknesses, and future opportunities and threats for the stocker, purebred, and support industries was a survey. The survey procedure and description of data analysis were previously reported (Troxel et al. 2006b).

Out of the 100 surveys mailed for each segment of the industry, three, six, and two surveys from the stocker, purebred, and support industry were returned due to insufficient addresses, respectively. The response rate was 64.0, 70.2 and 54.1% for the stocker, purebred and support industry segments, respectively.

Results and Discussion

Stocker Respondents. The Arkansas stocker cattle group saw the geographic location of Arkansas as a major advantage for their industry (Table 1). Location related to supplies and demand of feeder calves gave Arkansas stocker operators marketing advantages. Arkansas' natural resources were also cited as an advantage to stocker operators. Favorable climate conditions, long forage growing season, proximity to low cost feed ingredients, and the availability of poultry litter for fertilizer were cited as advantages. Availability of supporting infrastructure was cited as a current strength. Input costs, cattle health, lack of cattle uniformity, and small margins were listed as current limitations (Table 2).

The two highest ranked future opportunities were closely connected and dealt with gleaning value from cattle during the stocker ownership period (Table 3). Improving calf quality and grouping cattle into uniform groups were identified as future opportunities. It was difficult to ascertain if these were future opportunities for the stocker industry or suggestions for the cow-calf industry for the betterment of the stocker cattle industry. The stocker cattle industry did see an opportunity to build alliances and enhance Arkansas' beef cattle reputation.

Cost of production was the number one future threat for the stocker cattle industry (Table 4). Environmental regulations and animal rights/environmental activists were tied for second. Stocker cattle operators were very concerned with animal disease followed

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[3] Arkansas Farm Bureau
[4] Arkansas Beef Council

closely by volatile markets. Stocker operators expressed concern with farms turning into housing developments and thus reducing available land for lease or purchase.

Educational opportunities that interest the stocker cattle industry were cattle health and managing the cost of production. Costs of production included, but were not limited to, purchase price, health and vaccine cost, forage cost, and labor cost. Stocker operators recognized how volatile markets could be and perhaps were looking for ways to manage market volatility.

Newsletters were the preferred educational method, having the highest ranking, consistent with other production segments of the industry. One-on-one was the second rated method, probably indicating that stocker producers were likely to call advisors when they had problems. Printed publications ranked third. Stocker operators quickly identify problems, usually need rapid help and are not hesitant to call for advice. On-farm demonstrations, experiment station field days and group meetings were listed with similar frequency just below those mentioned above. The least preferred educational methods included on-line web-based information, radio program, e-mail, distance education and display/posters. With respect to meeting time, night was preferred, followed by afternoon. Morning was not preferred.

These stocker respondents had a high familiarity with the Beef Checkoff Program (3.1 ± 0.72; 1 = no knowledge to 4 = very knowledgeable) and a high level of approval (4.1 ± 1.06; 1 = strongly disapprove to 5 = strongly approve). This group had one of the highest percentages of membership in the National Cattlemen Beef Association (23%).

Compared to cow-calf and other segments (Troxel et al., 2006b), stocker respondents were younger ($P < 0.02$) with only 33% over the age of 60. They were an experienced group with 72% being in the business more than 20 years and 13% in the business from 11 to 20 years.

Purebred Respondents. The purebred industry identified itself as a genetic resource that aimed to improve the genomics of the cattle population by supplying better genetics to the cow-calf industry and by adopting technology that related to carcass quality, product consistency, EPD-based selection, and marketing (Table 5). A second strength of purebred cattle production within the state was the good production and marketing environment. Arkansas' climate was conducive to adaptation of various breeds. In addition, because there are a large number of small cow-calf operations (< 50 head) there is a strong demand for herd sires.

The main underlying limitation theme suggested a concern with the value that commercial cow-calf producers placed on herd sires (Table 6). Buyers were not willing to pay more for better genetics and were not concerned with the quality of genetics (growth, carcass, etc.) they purchased.

Opportunities for the future of the purebred industry could be summarized as genetic advancements and education (Table 7). Their focus included educating producers (purebred and commercial cow-calf) on improved genetics through better sire selection and emphasizing selection programs based on actual performance and EPD.

The future threats to the purebred industry reiterated some of the threats identified by the large and small cow-calf producer (Troxel et al., 2006b), stocker industry, and support industry (Table 8). The main underlying threats were profitability and environmental and public issues. Environmental issues not only included regulations but land encroachment concerns as rural areas became more urbanized. Public issues included consumer confidence, disease outbreak, border closures, and animal rights groups that had the potential to affect red meat consumption and negatively impact the sustainability of production as a result of reduced demand for beef.

Educational opportunities that would benefit the purebred industry included increasing the knowledge level of the cow-calf producer on sire selection methods that improved the genetics (growth characteristics and carcass composition) of the cow herd. Producing calves with greater demand would in turn demonstrate to the producer the added value of paying more for quality genetics that would help improve the profitability of the purebred cattle industry. A second educational opportunity included the continuation of maintaining consumer confidence and demand for U.S. beef.

Newsletters and printed material were highly preferred as a delivery method for educational material by the purebred producers. Group meeting/workshops and on-farm demonstrations were listed together. Experiment Station field days and one-on-one consultation were also highly preferred. E-mail, display/posters, distance education, and radio programs were not preferred as educational methods. Night and afternoon programs were preferred. Morning was not preferred.

The purebred producer respondents were very familiar with the Beef Checkoff Program (3.0 ± 0.77; 1 = no knowledge to 4 = very knowledgeable) and had a high level of approval (4.1 ± 0.97; 1 = strongly disapprove to 5 = strongly approve) of the overall program.

Sixty-four percent of the purebred producer respondents were over 51 years of age, and 70% had over 20 years experience in the purebred industry. Only 12% of the respondents were less than 40 years of age. A number of purebred producers wrote in comments expressing their concern with the lack of young people in the purebred industry.

Support Industries Respondents. The beef cattle support industries saw themselves as a primary component of the producer education system for production management practices (Table 9). They believed they had the knowledge and the duty to provide educational opportunities for cattle producers. Through its understanding of beef production, the support industry acted to address public health and food quality assurance concerns and defended publicly the economic and social value of the system. Support industry components provided a widely diverse set of resources and values to the overall industry. This range included banking, and finance to production support and animal health support.

The support industries believed the small cattle producer was not as involved in the cattle industry as the large cattle producer which made them a more difficult audience for support industries to reach (Table 10). Therefore the small cattle operators were not as open to new animal health products, genetics, and/or management strategies as compared to large cattle operators. Time constraints and business efficiencies did not allow a close working relationship between small producers and the support industry, compounding the problem. Support industry consolidation also added to the limited potential for interaction between the support industry and smaller producers and would decrease interaction over time.

As the support industry looked into the future, they continued to see themselves as public advocates for the beef industry as a primary importance (Table 11). Consumer confidence in the products of the industry and communication links both within the industry and between the industry and the consuming public were two important roles that would continue. The support industry saw itself as essential to the introduction of improved genetics, expanded products and markets, and more educated and progressive pro-

ducers. They also saw themselves as giving direction to research from universities and independent industry sources. Implementation of an effective animal identification program was another aspect of the beef industry where the support industry deemed itself to have an important future role.

The support industry was concerned with an uninformed public as the greatest threat to the industry (Table 12). Whether it came in the form of media influence or the growing disconnect between agriculture and the general public, public perceptions (accurate or not) would dramatically influence the future direction of the industry. Increased cost of production was an additional concern of the support industry. Cost of production came in many forms including: increased fuel costs, regulatory costs, decreased competition due to industry concentration, and increased cost/competition for available land. The seeming disconnect between producers and the available production enhancing technologies and knowledge was also a continuing concern. The support industry's future success was dependent on understanding and acceptance of production enhancing technologies and services. The demographics of the beef production industry made this a challenge. The support industries expressed some apprehension regarding the continuing consolidation of the support industry itself. Whether it was in the form of company mergers, larger service areas or more strategic approaches to targeted segments of the production system, the support industry seemed to be feeling the pressure of the marketplace.

The support industry did not identify any educational opportunities for themselves. They were very supportive of educational programs, etc., for the cattle producers. They believed that a more educated producer would be more receptive to new products and technology.

Representatives of the support industry generally mirrored the educational preferences of other industry groups. Their preferences were primarily the printed page (newsletters, etc.) followed closely by experiential learning activities such as demonstrations and field days. Their least preferred methods for receiving educational information was through electronic means – e-mail and distance education. They preferred night meetings to other options with morning and afternoon meetings being about equal as a second option.
Compared with the producer categories (purebred, large cow-calf (Troxel et al., 2006b), small cow-calf (Troxel et al., 2006b) and stocker) the support industry was not as knowledgeable of the Beef Checkoff Program ($P < 0.05$; 2.7 ± 0.78; 1 = no knowledge to 4 = very knowledgeable). There were no differences detected between the support industry and the producer categories for the approval rating for the program as it was being administered (3.8 ± 0.81; 1 = strongly disapprove to 5 = strongly approve).

Overall, the people involved with the support industry were younger with less experience than the producer categories ($P < 0.02$; purebred, large cow-calf (Troxel et al., 2006b), small cow-calf (Troxel et al., 2006b) and stocker). Only 44% of the support industry respondents were older than 51 years of age. The age group with the largest percentage was the 41 to 50 year old age group (35%). Twelve percent of the respondents had less than 5 years in the industry while 28 and 56% had 11 to 20 years and more than 20 years, respectively, in the industry.

Implications

The study identified educational opportunities, demographics, and preferred educational methods (newsletter, etc) for the stocker, purebred and support industries of the Arkansas cattle industry. This information can assist the Arkansas Beef Council and Animal Science in the planning of educational programs and delivery methods.

Literature Cited

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Table 1. Current strengths as identified by the stocker respondents.

Strength	Average ± SD[a]
High demand for stocker cattle	4.4 ± 0.74
Vaccination programs	4.4 ± 0.83
Low cost feed ingredients	4.4 ± 0.87
Long growing season	4.2 ± 0.76
Availability of poultry litter for fertilizer	4.2 ± 0.84
Selection of stocker cattle	4.1 ± 0.78
Availability of stocker cattle	4.1 ± 0.82
University research and support	4.1 ± 0.87
Favorable climate/long growing season	4.0 ± 0.78
Livestock auction support	4.0 ± 0.89
Financial resources are available	4.0 ± 0.94
Research on carcass quality	3.9 ± 0.90
Market news is available	3.9 ± 1.00
Market proximity	3.8 ± 0.91
Stocker cattle advertising	3.3 ± 0.97

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 2. Current limitations as identified by the stocker respondents.

Limitations	Average ± SD[a]
Input costs	4.3 ± 0.91
Cattle health	4.2 ± 0.99
Small margins	4.1 ± 0.98
Lack of calf uniformity and quality	4.0 ± 0.78
Start-up costs	3.9 ± 1.05
Lack of alternative fertilizers	3.8 ± 1.04
Availability of work force	3.5 ± 0.95
Unwillingness to change	3.5 ± 0.13
Changing rural surroundings (urbanization)	3.4 ± 1.18
No state branded verification program	3.3 ± 1.09
Carcass disposal	3.1 ± 0.90
Computer knowledge	2.9 ± 1.03
Too many breeds	2.9 ± 1.11

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 3. Future opportunities as identified by the stocker respondents.

Opportunities	Average ± SD[a]
Improving the quality of cattle	4.4 ± 0.68
Grouping cattle for sale	4.3 ± 0.79
Lower cost of gain than feedlots	4.2 ± 0.85
Developing identifiable reputation	4.2 ± 0.90
Growing with beef promotion industry	4.1 ± 0.79
Opportunity to grow	4.0 ± 0.77
Building alliances from supplier to processor	3.9 ± 1.08
Direct links to feedlots	3.7 ± 0.92
Return to small feedlots for finishing cattle	3.6 ± 1.04
Grass finished cattle	3.5 ± 1.06

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 4. Future threats as identified by the stocker respondents.

Threats	Average ± SD[a]
Cost of production	4.5 ± 0.72
Environmental regulations	4.2 ± 1.00
Animal rights/environmental activists	4.2 ± 1.26
Disease	4.1 ± 1.12
Volatile markets	4.0 ± 1.01
Urban expansion	3.8 ± 1.15
Low quality of Arkansas cattle	3.6 ± 1.10
Required health records	3.5 ± 1.01
Distance to markets	3.5 ± 1.24
Division among beef organizations	3.3 ± 1.19
Cost of disposal of dead animals	3.2 ± 1.10
Term limits of politicians	3.0 ± 1.32

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 5. Current strengths as identified by the purebred respondents.

Strength	Average ± SD[a]
Better genetics	4.6 ± 0.66
Understanding of EPD information	4.4 ± 0.75
More informed customers/buyers	4.3 ± 0.79
Industry knows the value of consistent product	4.2 ± 0.90
Adoption of new information and technology	4.2 ± 0.94
Purebreds emphasize carcass data	4.2 ± 0.94
Seedstock adapted to regional climate	4.1 ± 0.93
Competitive land costs and tax rates	4.1 ± 1.06
High bull demand from smaller cow-calf herds	4.0 ± 1.02
Good locations for seedstock	3.9 ± 0.86
Several breeds raised in Arkansas	3.5 ± 0.99

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 6. Current limitations as identified by the purebred respondents.

Limitations	Average ± SD[a]
Bull buyers will not pay for quality genetics	4.5 ± 0.84
Breeding stock value is low in Arkansas	4.4 ± 0.87
Bull buyers not concerned with genetic quality (carcass, growth data, etc.)	4.2 ± 0.91
Capital investment is high-profit potential is low	4.1 ± 0.93
Limited number of bulls available for buyers	3.6 ± 1.06
Variety of bulls	3.3 ± 0.96

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 7. Future opportunities as identified by the purebred respondents.

Opportunities	Average ± SD[a]
Education about better bull selection	4.7 ± 0.49
Educating producers on improved genetics	4.6 ± 0.68
Increased demand for breeding stock	4.3 ± 0.72
New technology and research	4.3 ± 0.77
Emphasize bull selection by using actual data (birth wt, weaning wt, yearling wt, etc)	4.3 ± 0.98
Emphasize bull selection by using EPD's	4.2 ± 0.91
Marketing for branded programs or alliances	4.1 ± 0.98
Opportunity to form alliances	3.7 ± 1.07

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 8. Future threats as identified by the purebred respondents.

Threats	Average ± SD[a]
Lack of profit	4.6 ± 0.66
Consumer confidence in beef safety	4.5 ± 0.71
National disease outbreak	4.4 ± 0.86
Environmental regulations	4.2 ± 0.94
Border closure issues	4.1 ± 0.96
Land encroachment	4.0 ± 1.11
Animal rights groups	3.7 ± 1.41
Monopolization of particular breeds	3.3 ± 1.26
Composite bulls	3.2 ± 1.13
Alliances that exclude a particular breed	3.2 ± 1.26

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 9. Current strengths as identified by the support industries.

Strength	Average ± SD[a]
Recognizes beef industry's importance to local economies	4.3 ± 0.78
Encourages, supports, and provides producer education	4.2 ± 0.78
Understanding the beef industry and how it works	4.2 ± 0.82
Addresses public health concerns	4.2 ± 0.87
Support for improved management and producer success	4.1 ± 0.79
Beef industry provides economic diversity	3.9 ± 0.87
Supports information dissemination	3.9 ± 0.95
Provides product research and competition	3.9 ± 0.96
Strong support network across support industries	3.8 ± 0.80
Support industries link producer and other resources	3.7 ± 0.99
Facilitates change in the beef industry	3.6 ± 0.96

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 10. Current limitations as identified by the support industries.

Limitations	Average ± SD[a]
Lack of herd health management	4.1 ± 0.78
Market influence on producer behavior	3.8 ± 0.87
Difficulty and expense of introducing new animal health products	3.8 ± 0.98
Traditional independence of producers	3.7 ± 0.97
Limitations of farm beef genetics	3.6 ± 0.84
Lack of producer interest in change	3.6 ± 0.88
Limited connection between small part-time producers and support industries	3.5 ± 1.11
Lag in developing new consumer products	3.4 ± 0.93
Fewer support industries reduce competition	3.4 ± 0.99
Small producer has limited time and interest	3.4 ± 0.99
Limited producer involvement in political process	3.4 ± 1.14
Small producers invest less in the industry than larger producers	3.2 ± 1.05

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 11. Future opportunities as identified by the support industries.

Opportunities	Average ± SD[a]
Consumer confidence in beef industry products	4.5 ± 0.87
Improved communication within industry and with the public	4.2 ± 0.80
Bull genetics available to small producers	4.0 ± 0.74
Improved genetics for product uniformity and quality	4.0 ± 0.82
More educated/progressive producers	4.0 ± 0.82
Expanded by-products market	3.9 ± 0.92
International markets	3.9 ± 1.20
Greater demand for in-depth research	3.6 ± 0.96
Coordinate marketing alliances	3.6 ± 1.00
Animal ID program	3.6 ± 1.22
Niche markets	3.4 ± 0.97
Bio-engineering's potential	3.2 ± 1.05

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

Table 12. Future threats as identified by the support industries.

Threats	Average ± SD[a]
Media influences on public opinion	4.4 ± 0.77
Cost and availability of fossil fuels	4.3 ± 0.79
Producers not being replaced	4.2 ± 0.85
Environmental regulations	4.2 ± 0.98
Loss of land to development/recreation	4.1 ± 1.09
Limited public knowledge about agriculture	4.0 ± 0.93
Lack of producer knowledge for selecting right things to do	3.8 ± 0.79
Lack of acceptance for new technology	3.8 ± 0.84
Other states' environmental rules	3.8 ± 0.92
Alternative production enterprises for cattle production	3.6 ± 0.94
Consolidation of agricultural industries	3.4 ± 0.98

[a] SD = Standard deviation; Scale: 1 = not important at all to 5 = extremely important

2005 Dairy Herd Improvement Program in Arkansas

J.A. Pennington[1]

Story in Brief

During 2005, 52 (26%) of the 202 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. All 52 herds completed at least 4 DHI tests and averaged 9.7 tests with rolling herd averages of 17,402 lb of milk, 628 lb of fat (3.6%), and 542 lb (3.1%) of protein; mature equivalent averages were 19,179 lb of milk with 3.7% fat and 3.2% protein. This compares to 2004 averages of 17,485 lb of milk, 639 lb of fat (3.5%), and 549 lb (3.1%) of protein with 58 herds; mature equivalent averages were 18,930 lb of milk with 3.6% fat and 3.1% protein.

Quartile data of milk production for the Holstein herds with DHI records showed that income over feed costs was about $1,000/cow greater for the highest producing quartile of herds compared to the lowest producing quartile of herds. Average income-over-feed costs (IOF$) was $1,377 in 2005; previous years' IOF$ were $1,796 in 2004 and $1,139/cow in 2003, with the variation due primarily to varying milk and feed prices. Udder health and reproduction were enhanced in higher herds and contributed to this difference in income/cow.

The Arkansas average for milk/cow was 13,458 lb/year on all cows in 2005, which indicates that non-DHI herds averaged less than 12,000 lb/cow/year. This difference in milk/cow/year of over 5,000 lb would affect income by almost $700/cow, or approximately $84,000 in a 120-cow herd. Approximately 30% of the state's herds were enrolled in the DHI record-keeping program, thus 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

Successful dairy producers must have accurate and reliable records to make sound management decisions. The Dairy Herd Improvement (DHI) program provides a comprehensive herd analysis and management report that includes information concerning production, reproduction, genetics, herd health, animal and feed inventory, and finances. Data obtained from DHI can be used to improve efficiency of milk production by: 1) identifying least profitable cows for culling; 2) feeding for more efficient production; 3) selecting animals with the greatest genetic potential for production as replacements; and 4) utilizing summaries of the data to make precise management decisions that improve net income.

Herds on DHI produce 4,500 to 5,000 lb more milk per year nationally than herds not on DHI. Although many factors affect production per cow, this difference in production has a significant effect on net income for the dairies. Increased income-over-feed costs (IOF$) is associated with greater profitability for the individual cow and herd. Dairy herd summaries from DHI allow dairy producers to compare production, health, reproduction, and financial aspects with respect to other dairies, so that areas of management that need improvement can be detected.

Experimental Procedures

Dairy cattle herds on test (n = 52) were used to report production and management data for DHI herds. The test milking (or day) for each cow included weighing milk, taking a sample of milk to be analyzed for percentage of fat, protein, and somatic cell count (SCC), and recording of other management parameters as indicated in Table 1. Milk samples were analyzed at the Heart of America DHI Lab (Manhattan, Kan.). Records were processed at Dairy Records Management Services (DRMS), Raleigh, N.C., and analyzed by State Management DART (Direct Address to Records via Telephone) for all breeds (Table 1) and by SAS (SAS Institute, Inc., Cary, N.C.) for quartile data of Holstein herds in Table 2.

Results and Discussion

Fifty-two herds completed at least 4 DHI tests and averaged 9.7 tests per year, with a rolling herd average of 17,402 lb milk, 628 lb of (3.6%) fat, and 542 lb of (3.1%) protein. Mature equivalent averages for the herds were 19,179 lb milk containing 3.7% fat and 3.2% protein.

Rolling herd averages for 41 DHI herds on supervised tests with 6 tests are shown in Table 1. Income dollars from milk minus feed costs for the milking cows or IOF$ averaged $1,377/cow for 2005 for all herds; Holstein herds averaged $1,571 (Table 2). The IOF$ for Holstein herds was $1,796/cow for 2004, $1,139/cow in 2003, and $1,044/cow in 2002. The variation in IOF$ is due primarily to varying milk prices but also to fluctuations in feed costs. Milk prices were slightly higher in 2005 compared to the very low prices in 2002 and 2003 but slightly lower than the record high prices in 2004. Brown Swiss herds averaged $1,325/cow/year for income minus feed costs; however, only 2 herds were included in the Brown Swiss summary for 2005. One Jersey herd was included. Twelve herds had various crossbreeds which averaged $978/cow for IOF$. Few non-Holstein herds had DHI records in Arkansas, but other states have shown similar trends in IOF$ with greater numbers of herds. In the United States, 93 to 94% of the cows on test are Holsteins or crossbreeds with Holstein influence, 3% of cows on

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test are Jerseys, and less than 1% of cows are Brown Swiss.

The DHI averages for some of the most economically important production traits of Holstein herds with 10 tests are presented in Table 2 by quartile of milk production for 2004 and 2005. The quartile data for the Holstein herds illustrate the relationship of higher milk production to greater IOF$. The top quartile of Holstein herds for milk production showed that IOF$ was $1,206/cow greater compared to the lowest producing quartile of herds. Herds in the high quartile had higher peak milk levels, lower somatic cell counts, less days open, greater percentage of cows in milk, and lower calving intervals than herds in the low quartile.

For quartile data, 24 Holstein herds were official herds with 10 tests during the year, compared to 27 herds in 2004 and 23 in 2003. The total percentage of herds (n = 52) on DHIA was 26%, which was similar to the percentage of total farms in 2004. Additionally, 2 dairy cattle herds used the PC DART on-farm computer program for production testing, and were not included in the 52 herds currently processed through DRMS. Only 26% of the 220 herds in 2004 were involved in the DHI program. If the cows from herds using PC DART are combined with the cows in the 52 DHIA, then over 31% of the state's 24,000 cows were on test. This number is higher than the goal (set for many years) of 30% of the cows in Arkansas that was exceeded only in 2003.

Herds on DHI averaged 17,402 lb milk/cow/year compared to the Arkansas average of 13,458 lb/milk/year (Arkansas Agricultural Statistics Service, Little Rock). Omitting DHI herds from the state average indicates that the non-DHI herds averaged less than 12,000 lb milk/year, equating to a difference in milk production of over 5,000 lb milk/cow/year between DHI and non-DHI herds which would affect income by almost $700/cow/year or $84,000 per year in a 120-cow herd.

Implications

The DHI program affords dairy producers an opportunity to maintain records of milk production on individual cows and other management practices. Herds utilizing DHI records averaged 17,402 lb milk/cow/year versus less than 12,000 lb/cow for herds not on DHI test, indicating much more profitable herds on DHI. Producers are strongly encouraged to enroll in the DHI testing program.

Table 1. 2005 Arkansas DHIA average for all breeds.

Item	n	Mean	SD	Minimum	Maximum
Rolling herd average, milk (lb)	41	16,614	3,678	10,917	24,711
Services per pregnancy, pregnant cows	41	1.8	0.8	0	3.3
Services per pregnancy, all	41	2.8	1.8	0	8.8
Projected calving interval	41	15.6	1.2	12.0	21.0
Number of cow years	41	129.8	111.16	2.4	579.3
Rolling herd average, fat (lb)	41	590	130	316	906
Peak milk (lb)-1st lactation	40	62.1	12.0	43.0	96.0
Peak milk (lb)-2nd lactation	40	74.8	14.3	49.0	107.0
Peak milk (lb)-avg	40	73.2	12.1	51.0	103.0
Average days dry	41	81.7	32.2	51.0	189.0
All lactations -% cows SCC[1] 0-3	40	50	16	0	76
1st lactation 305-2x-ME milk (lb)	40	18,563	3,627	13,313	27,179
1st lactation 305-2x-ME fat (lb)	40	648	138	381	971
2nd lactation 305-2x-ME milk (lb)	40	18,868	4,021	11,909	27,280
2nd lactation 305-2x-ME fat (lb)	40	656	132	422	1,012
All lactation 305-2x-ME milk (lb)	41	18,633	3,635	13,402	27,352
All lactation 305-2x-ME fat (lb)	41	647	128	403	967
1st lactation -% cows SCC 0-3	39	61	17	30	100
Days to 1st service, current	41	92	56	0	210
Rolling herd average, protein (lb)	41	518	106	335	762
IOF $[2]	34	1,377	482	355	2,820
Peak milk -3rd lactation (lb)	39	82.5	13.7	54.0	109.0
3+ Lactation 305-2x-ME milk (lb)	40	18,503	3,617	13,244	27,559
3+ Lactations 305-2x-ME fat (lb)	40	647	124	410	956
2nd Lactation- % cows SCC 0-3	39	50	19	14	86
Days to 1st service, total	41	95	45	0	188
Days open	41	195	55	84	358
% Successful first service	41	42	24	0	100
% Successful total	41	42	23	0	100
% Herd bred to proven sires	41	42	36	0	100
% Herd bred to AI young sires	41	7	11	0	40
% Herd bred to other sires	41	38	37	0	100
1st Lactation- AIPL PTA$[3]-cows	33	-2	73	-216	107
2nd Lactation- AIPL PTA$-cows	33	-27	87	-308	130
3+ Lactations- AIPL PTA$-cows	34	-73	102	-431	68
All lactations- AIPL PTA$-cows	37	-51	98	-431	74
1st Lactation- AIPL PTA$-sires	34	121	79	-72	309
2nd Lactation- AIPL PTA$-sires	34	81	115	-317	349
3+ Lactations- AIPL PTA$-sires	32	-10	122	-432	124
All lactations- AIPL PTA$-sires	37	52	92	-199	192
1st Lactation 305-2x-ME protein(lb)	41	553	132	0	803
2nd Lactation 305-2x-ME protein (lb)	41	559	139	0	788
3+ Lactations 305-2x-ME protein (lb)	41	553	131	0	819
All lactation 305-2x-ME protein (lb)	41	568	100	405	804
Average test day milk (lb-milking cows)	41	55	10	40	77
Average standardized 150-d milk (lb)	41	60	11	41	83
3+ Lactations - % cows SCC 0-3	39	40	18	0	100
Average days in milk	41	193	26	109	254
Average % cows in milk	41	84	6	71	93
SCC average	40	466	308	154	1875
Average % heats observed	36	29	14	5	55

[1]Somatic cell count
[2]IOF$ = income over feed costs; income from milk minus feed costs
[3]Animal Improvement Programs Laboratory --predicted transmitting ability for dollars

Table 2. 2005 Arkansas DHI averages for official Holstein herds.

	Quartile 1		Quartile 2		Quartile 3		Quartile 4	
Production traits	2004	2005	2004	2005	2004	2005	2004	2005
Rolling herd average, milk (lb)	23,307	23,229	19,824	18,999	16,633	16,303	14,152	14,316
Peak milk-1st lactation (lb)	78.7	79.7	62.5	68.9	58.2	62.0	57.0	56.9
Peak milk-2nd lactation (lb)	96.3	93.7	73.0	84.4	71.5	774	65.5	69.7
Peak milk-3rd lactation (lb)	102.7	105.0	85.2	91.4	77.0	81.5	70.7	75.7
Peak milk-average (lb)	83.0	90.2	70.7	81.4	67.0	72.8	63.5	70.3
IOF$[1]/year	**2,384**	**2,250**	**2,037**	**1,609**	**1,483**	**1,380**	**1,279**	**1,044**
SCC[2] average	283	272	329	410	498	576	431	500
Days to 1st service	75.5	88.2	110.2	99.1	111.5	116.0	94.5	75.1
Days open	144.0	166.7	178.0	183.4	158.7	194.3	200.7	189.3
Average % in milk	-	89.3	-	86.4	-	85.8	-	82.4
Projected calving interval (mo)	13.9	14.7	15.1	15.2	14.4	15.6	15.8	15.4

[1]Income from milk minus feed costs
[2]Somatic cell count

DairyMetrics for Arkansas Herds in May, 2006

J.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 traits, highest and lowest herd for the traits, and number of herds in the comparison for Holstein herds and all dairy herds in Arkansas on the Dairy Herd Improvement (DHI) program. DairyMetrics also was used to compare groups of Arkansas Holstein herds to illustrate the importance of days open, percentage died, rolling herd averages for milk, calving interval, and somatic cell count (SCC) in milk on efficiency of producing high levels of milk yield as indicated by daily income-over-feed costs (IOF$). DairyMetrics demonstrated that percentages in milk, cull rate, and days to first service had little effect on IOF$ per cow this year in Arkansas. Cull rate can affect the total costs of replacements. Generally, conception rate and other reproductive parameters have had small but varying effects on daily IOF$ for milking cows but can affect profitability of the dairy herd.

Many factors in DairyMetrics are interrelated and can affect herd profitability without affecting daily IOF$. Arkansas dairy producers are now paid a premium for maintaining a SCC of less than 300,000 in the herd. One of the largest difference in IOF$ resulted in herds with less than 300,000 somatic cell counts ($5.30/day IOF$) compared to herds with greater than 300,000 somatic cell counts ($4.31/day IOF$). The largest difference in IOF$ resulted when comparing herds with cows that had a greater than $0 net merit ($5.26 IOF$) to herds with cows that had less than $0 net merit ($3.95 IOF$), indicating that the use of superior sires with artificial insemination increased IOF$.

Introduction

DairyMetrics is a benchmarking tool that allows producers on the Dairy Herd Improvement (DHI) program to compare 72 variables on their DHI records to other herds in the state or region concerning general herd traits, such as milk production, reproduction, udder health and genetics. Data obtained from DairyMetrics can be used to 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. For example, Arkansas herds of various sizes can be compared to determine the relationship of herd size with other traits included in DairyMetrics. These comparisons of variables can be used for within herd comparisons and group comparisons in extension meetings to illustrate the importance of recommended practices on the efficiency of producing milk, especially daily income-over-feed costs (IOF$). Of the variables in DHI records, IOF$ is most correlated with the profitability of milk production.

Experimental Procedures

DairyMetrics was used to obtain the average, standard deviation, and low and high herds for various general, production, reproduction, udder health, and genetic variables for Holstein herds in the state (n = 30; Table 1) and for herds of all breeds (n = 39 or 9 additional herds; Table 2) in Arkansas in May, 2006.

DairyMetrics also was used to compare groups of Arkansas herds for selected variables (Table 3) to illustrate the importance of these variables on efficiency of milk production, using daily IOF$ as the indicator of efficiency.

Results and Discussion

The average, standard deviation, low herd, and high herd for 72 variables from DairyMetrics for Holstein herds in Arkansas are shown in Table 1 and for all breeds in Table 2. 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).

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 breeds had decreased to $13.14/cwt in 2006 from $15.69/cwt in 2005 (compared to $14.91 in 2002, $11.98 in 2003, and $14.12 in 2004). This decrease in milk prices for all breeds was the primary cause of daily IOF$ per cow decreasing from $6.00 in 2005 to $4.59 in 2006 (compared to $5.18 in 2002, $3.61 in 2003, and $4.94 in 2004). Daily feed costs/milk cow increased from $2.97 in 2002 to $3.15 in 2003 to $3.24 in 2004 to $3.28 in 2005 to $3.50 in 2006.

Table 3 shows the effects on daily IOF$ for groups of Arkansas Holstein herds with different levels of the variables in DairyMetrics. It was surprising that the Holstein herds exceeded the non-Holstein herds by $0.85 for IOF$. These summaries also showed the positive effect on IOF$ of fewer cows with long dry

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periods, fewer days open, less deaths, greater rolling herd average for milk, shorter calving intervals, lower somatic cell counts in milk, and having cows of superior genetics. Additionally, rolling herd average, calving interval, percentage of cows leaving the herd, and somatic cell count are shown to illustrate the importance of these independent variables on efficiency of producing milk. In total, these data illustrate the importance of having herds with optimal udder health, decreased days open, and increased days in milk (DIM).

Data from DairyMetrics also illustrate that daily IOF$ costs per cow for Holstein herds were not greatly affected by percentage of fat in the milk. This relationship between fat percentage and IOF$ varies from year-to-year, but dairy producers are paid for additional fat. This year's relationship is positive for milk fat percentage in milk and IOF$, but milk per cow is often greater in lower fat percentage herds. DairyMetrics also was used to compare groups of Arkansas Holstein herds to illustrate the importance of days open, percentage died, rolling herd averages for milk, calving interval, and somatic cell count in milk on efficiency of producing high levels of milk production as indicated by daily IOF$ (Table 3). Also, percentage in milk, cull rate, and days to first service had little effect on IOF$ per cow this year in Arkansas. Cull rate can affect the total costs of replacements, especially if the cull rate exceeds the replacements raised on the dairy and additional animals need to be purchased. Similarly, conception rate and other reproduction parameters have had less effect on daily IOF$ for milking cows but can affect profitability of the dairy herd.

Many factors in milk production are interrelated and can affect herd profitability without affecting daily IOF$ on DHI records. For example, milk production and conception rate are often inversely related, but both traits affect herd income. Some traits may positively affect income in more than one way, but are always detectable with DHI records. Arkansas dairy producers are now paid a premium for maintaining a herd somataic cell count (SCC) of less than 300,000. This affects income of the dairy through milk quality as well as milk production. One of the greatest differences in IOF$ resulted in herds with less than 300,000 SCC ($5.30/day IOF$) compared to herds with greater than 300,000 SCC ($4.31/day IOF$). The largest difference in IOF$ resulted when comparing herds with cows that had a greater than $0 net merit ($5.26 IOF$) to herds with cows that had less than $0 net merit ($3.95 IOF$), indicating that the use of superior sires with artificial insemination increased IOF$.

Implications

DairyMetrics 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. As expected, most variables relating to routinely recommended management practices correlated with greater daily income-over-feed costs.

Table 1. DairyMetrics for Holstein herds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
General					
Number of cows	30	133	82	38	323
Number of 1st lactation cows	30	50	35	12	148
Number of 2nd lactation cows	30	37	24	10	97
Number of 3rd+ lactation cows	27	51	29	17	139
PCT number of cows-year change	26	3	24	-31	83
PCT in milk on test day	30	92	4	86	100
Days in milk	30	204	31	150	277
Age of 1st lactation cows (mo)	30	27	2	24	34
PCT cows left herd-overall	30	33	17	0	84
PCT cows left herd-1st lactation	26	26	20	4	90
PCT cows left herd-2nd lactation	26	33	18	0	74
PCT cows left herd-3rd+ lactation	25	51	19	23	110
PCT cows died-all lactation	26	6	5	1	25
PCT cows died-1st lactation	28	3	4	0	18
PCT cows died-2nd lactation	26	5	6	0	30
PCT cows died-3rd+ lactation	25	10	8	0	34
PCT cows left for repro-overall	26	6	5	0	20
PCT cows left for repro-1st lactation	28	4	4	0	17
PCT cows left for repro-2nd lactation	26	5	6	0	23
PCT cows left for repro-3rd+ lactation	25	8	10	0	43
Daily val prod-milk cows ($)	30	8.19	1.46	5.5	10.27
Daily feed cost-milk cows ($)	23	3.56	0.63	2.67	4.98
Daily feed cost/CWT ($)	25	5.51	1.39	2.31	8.21
Daily income/feed-milk cows ($)	25	4.71	1.4	2.16	7.21
Milk blend price ($)	30	13.18	1.06	11.22	15.25

Table 1 (Continued). DairyMetrics for Holstein herds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
Production					
Rolling milk (lb)	26	18,679	3,355	14,536	25,356
Year change in rolling milk (lb)	30	840	4,041	-2,124	21,696
Rolling fat (lb)	26	655	118	463	903
Rolling protein (lb)	26	575	101	448	771
Daily milk 1-40 d-1st lactation (lb)	25	57	11	32	76
Daily milk 1-40 d-2nd lactation (lb)	22	79	16	34	112
Daily milk 1-40 d-3rd+ lactations (lb)	20	72	18	31	106
Daily milk-milk cows (lb)	30	62.2	9.1	46.9	77.6
Daily milk-all cows (lb)	30	57.8	8.9	45.3	76.6
Daily PCT fat	30	3.5	0.5	2.5	4.8
Daily PCT protein	30	3.0	0.1	2.8	3.3
Summit milk 1st lactation (lb)	30	61	9	43	81
Summit milk 2nd lactation (lb)	30	74	13	43	101
Summit milk 3rd+ lactations (lb)	27	82	12	63	106
Peak milk 1st lactation (lb)	28	65	10	44	92
Peak milk 2nd lactation (lb)	29	78	15	42	110
Peak milk 3rd+ lactations (lb)	27	86	13	66	114
Projected 305 day ME milk (lb)	30	20,567	3,451	13,367	27,454
Standard 150-d milk (lb)	30	67	10	47	86
Fat-Protein ratio 1-40 d-1st lactation	25	1.22	0.24	0.88	1.92
Fat-Protein ratio 1-40 d-2nd lactation	22	1.19	0.26	0.77	1.68
Fat-Protein ratio 1-40 d-3rd+ lactations	20	1.22	0.27	0.89	2.00
Fat-Protein ratio 41-100 d-1st lactation	26	1.19	0.16	0.81	1.44
Fat-Protein ratio 41-100 d-2nd lactation	26	1.19	0.26	0.70	1.86
Fat-Protein ratio 41-100 d-3rd+ lactations	27	1.23	0.21	0.82	1.73
Fat-Protein ratio 101-199 d-1st lactation	29	1.17	0.20	0.58	1.65
Fat-Protein ratio 101-199 d-2nd lactation	29	1.15	0.17	0.68	1.64
Fat-Protein ratio 101-199 d-3rd+ lactations	27	1.15	0.18	0.93	1.81
Fat-Protein ratio 200-305 d-1st lactation	28	1.14	0.16	0.72	1.48
Fat-Protein ratio 200-305 d-2nd lactation	30	1.14	0.15	0.91	1.65
Fat-Protein ratio 200-305 d-3rd+ lactations	27	1.13	0.13	0.90	1.43
Fat PCT 1-40 d-1st lactation	25	3.7	0.9	2.5	6.9
Fat PCT 1-40 d-2nd lactation	22	3.6	0.7	2.3	4.8
Fat PCT 1-40 d-3rd+ lactations	20	3.0	0.0	2.0	5.0
Fat PCT 41-100 d-1st lactation	26	3.4	0.5	2.6	4.2
Fat PCT 41-100 d-2nd lactation	25	3.4	0.8	2.5	5.9
Fat PCT 41-100 d-3rd+ lactations	27	3.0	0.0	2.0	4.0
Fat PCT 101-199 d-1st lactation	28	3.5	0.5	2.7	5.1
Fat PCT 101-199 d-2nd lactation	29	3.4	0.5	2.1	4.6
Fat PCT 101-199 d-3rd+ lactations	27	3.0	0.0	2.0	4.0
Fat PCT 200-305 d-1st lactation	28	3.6	0.5	2.3	5.0
Fat PCT 200-305 d-2nd lactation	30	3.6	0.5	2.8	5.1
Fat PCT 200-305 d-3rd+ lactations	27	3.0	0.0	2.0	4.0

Table 1 (Continued). DairyMetrics for Holstein herds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
Udder Health					
SCC[1] actual	30	342	142	112	738
SCC score	30	3.2	0.7	2.1	4.8
SCC score for 1st lactation	30	2.8	0.7	1.4	4.0
SCC score for 2nd lactation	30	3.1	0.8	1.4	4.3
SCC score for 3rd lactation	27	3.7	0.8	2.4	5.6
SCC score for cows 41-100 d	29	2.5	0.9	1.3	4.7
SCC score for cows 101-199 d	29	3.1	0.8	2.0	4.9
SCC score for cows 200-305 d	30	3.3	0.8	1.8	5.1
SCC score for cows 306+ d	30	3.5	0.9	2.2	5.0
PCT cows (SCCS of 0-3)	30	58	14	21	79
PCT cows (<41D with SCCS >4)	28	37	23	0	100
PCT 1st lactation (SCCS of 0-3)	30	66	13	40	93
PCT 2nd lactation (SCCS of 0-3)	30	59	16	30	95
PCT 3rd lactation (SCCS of 0-3)	27	47	16	8	72
PCT cows culled for mastitis	26	2	4	0	22
PCT value prod lost >from SCC	30	2	1	0	8
Reproduction					
Pregnancy rate-current (%)	25	18	9	1	41
Pregnancy rate-year avg (%)	30	42	180	0	999
Days open-proj min-all	30	185	38	132	287
Projected calving interval (mo)	30	15.3	1.3	13.5	18.7
Current actual calving interval (mo)	30	14.4	1.9	10.2	21.9
PCT cows calving-current test	30	8	7	0	30
PCT birth 4+ calving difficulty -1st lactation	23	2	4	0	14
Days open-proj min-1st lactation	30	194	42	130	314
Days open-proj min-2nd lactation	30	179	47	110	325
Days open-proj min-3rd+ lactations	27	179	33	127	241
Voluntary waiting period(VWP)(d)	30	50	7	40	60
Days to 1st service (%herd< than VWP)	24	11	11	1	45
Days to 1st service (%herd VWP to 100 d	27	53	18	21	87
Days to 1st service (%herd> than 100 d)	27	37	15	3	71
Days to 1st service-total herd	27	103	20	66	145
Days to 1st service (%herd <100 d)-1st lactation	26	61	15	35	96
Days to 1st service (%herd <100 d)-2nd lactation	27	67	17	31	100
Days to 1st service (%herd <100 d)-3rd+ lactations	25	61	18	17	97
Conception rate for past 12 mo-1st service (%)	30	33	21	0	77
Conception rate for past 12 mo-2nd service (%)	30	35	23	0	78
Conception rate for past 12 mo-3rd+ service (%)	30	37	25	0	100
Services per pregnancy-all lactations	26	3.0	1.0	1.0	5.0
Services per pregnancy-1st lactation	26	3.0	1.0	1.0	6.0
Services per pregnancy-2nd lactation	26	3.0	1.0	1.0	5.0
Services per pregnancy-3nd+ lactations	25	3.0	1.0	1.0	7.0
PCT of heats observed for year	27	31	15	4	51
PCT of heats observed last test	25	32	16	2	63
Number of abortions in past year	30	0	0	0	3
Number of calvings in past year	30	127	79	35	348
PCT dry less than 40 d	26	15	10	1	40
PCT dry more than 70 d	27	29	16	5	64

[1]Somatic cell count/1000

Table 1 (Continued). DairyMetrics for Holstein herds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
Genetics					
PCTile rank of proven AI bulls	30	36	26	0	78
PCTile rank of young AI bulls	30	30	36	0	99
PCT of herd bred to proven AI bulls	22	62	23	18	100
PCT of herd bred to young bulls	30	7	9	0	29
PCT of herd bred to non-AI bulls	30	36	36	0	100
Net merit$ for 1st lactation	26	18	83	-233	152
Net merit$ for all cows	28	-27	108	-426	85
Net merit$ for heifers	23	65	73	-49	189
PCT of heifers ID'd by sire	24	69	28	0	100
PCT of cows ID'd by sire	30	60	39	0	100
Replacement rate(#heifers/#cows)*100	30	63	45	0	125
Replacement rate(#heifers 0-12 mo/#cows)*100	30	28	19	0	58
Replacement rate(#heifers 13+ mo/#cows)*100	30	35	29	0	86

Table 2. DairyMetrics for all breeds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
General					
Number of cows	39	148	113	38	576
Num of 1st lactation cows	39	56	47	4	207
Num of 2nd lactation cows	39	40	31	7	153
Num of 3rd+ lactation cows	35	57	44	17	250
PCT number of cows-year change	35	6	26	-31	88
PCT in milk on test day	39	90	7	66	100
Days in milk	39	202	28	150	277
Age of 1st lactation cows (mo)	39	27	2	24	34
PCT cows left herd-overall	39	32	16	0	84
PCT cows left herd-1st lactation	35	26	20	4	90
PCT cows left herd-2nd lactation	35	31	17	0	74
PCT cows left herd-3rd+ lactation	33	48	18	20	110
PCT cows died-all lactation	35	7	5	1	25
PCT cows died-1st lactation	37	3	3	0	18
PCT cows died-2nd lactation	35	5	6	0	30
PCT cows died-3rd+ lactation	33	11	9	0	38
PCT cows left for repro-overall	35	6	5	0	20
PCT cows left for repro-1st lactation	37	4	4	0	17
PCT cows left for repro-2nd lactation	35	5	6	0	23
PCT cows left for repro-3rd+ lactation	33	8	8	0	43
Daily value prod-milk cows ($)	39	7.92	1.47	5.17	10.27
Daily feed cost-milk cows ($)	28	3.50	0.61	2.51	4.98
Daily feed cost/CWT ($)	32	5.42	1.37	2.31	8.21
Daily income/feed-milk cows ($)	32	4.59	1.27	2.16	7.21
Milk blend price ($)	39	13.14	1.02	11.22	15.25

Table 2 (Continued). DairyMetrics for all breeds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
Production					
Rolling milk (lb)	35	17,603	3,602	11,510	25,356
Year change in rolling milk (lb)	39	1,183	4,639	-2,124	21,696
Rolling fat (lb)	35	625	131	333	903
Rolling protein (lb)	35	545	106	364	771
Daily milk 1-40 d-1st lactation (lb)	32	56	10	32	76
Daily milk 1-40 d-2nd lactation (lb)	30	75	17	26	112
Daily milk 1-40 d-3rd+ lactation (lb)	27	73	16	31	106
Daily milk-milk cows (lb)	39	60.1	9.2	46.6	77.6
Daily milk-all cows (lb)	39	54.5	10.2	35.8	76.6
Daily PCT fat	39	3.5	0.5	2.4	4.8
Daily PCT protein	39	3.0	0.1	2.8	3.4
Summit milk-1st lactation (lb)	39	58	9	39	81
Summit milk-2nd lactation (lb)	39	72	13	43	101
Summit milk-3rd+ lactation (lb)	35	79	13	56	106
Peak milk-1st lactation (lb)	37	62	11	39	92
Peak milk-2nd lactation (lb)	38	75	15	42	110
Peak milk-3rd+ lactation (lb)	35	83	14	56	114
Projected 305-d ME milk (lb)	39	19,734	3,514	13,367	27,454
Std 150-d milk (lb)	39	65	10	47	86
Fat-Protein ratio 1-40 d-1st lactation	32	1.21	0.24	0.70	1.92
Fat-Protein ratio 1-40 d-2nd lactation	30	1.21	0.27	0.77	1.74
Fat-Protein ratio 1-40 d-3rd+ lactation	27	1.23	0.28	0.79	2.00
Fat-Protein ratio 41-100 d-1st lactation	32	1.20	0.19	0.81	1.63
Fat-Protein ratio 41-100 d-2nd lactation	34	1.20	0.25	0.70	1.86
Fat-Protein ratio 41-100 d-3rd+ lactation	35	1.22	0.23	0.70	1.73
Fat-Protein ratio 101-199 d-1st lactation	37	1.16	0.21	0.58	1.65
Fat-Protein ratio 101-199 d-2nd lactation	38	1.16	0.17	0.68	1.64
Fat-Protein ratio 101-199 d-3rd+ lactation	35	1.14	0.18	0.83	1.81
Fat-Protein ratio 200-305 d-1st lactation	35	1.15	0.16	0.72	1.52
Fat-Protein ratio 200-305 d-2nd lactation	35	1.14	0.17	0.81	1.65
Fat-Protein ratio 200-305 d-3rd+ lactation	35	1.14	0.14	0.90	1.52
Fat PCT 1-40 d-1st lactation	32	3.7	0.9	2.1	6.9
Fat PCT 1-40 d-2nd lactation	30	3.7	0.7	2.3	4.8
Fat PCT 1-40 d-3rd+ lactation	27	3.0	0.0	2.0	5.0
Fat PCT 41-100 d-1st lactation	32	3.5	0.6	2.3	4.9
Fat PCT 41-100 d-2nd lactation	33	3.5	0.8	2.3	5.9
Fat PCT 41-100 d-3rd+ lactation	35	3.0	0.0	2.0	4.0
Fat PCT 101-199 d-1st lactation	36	3.5	0.6	2.4	5.1
Fat PCT 101-199 d-2nd lactation	38	3.5	0.5	2.1	5.1
Fat PCT 101-199 d-3rd+ lactation	35	3.0	0.0	2.0	4.0
Fat PCT 200-305 d-1st lactation	35	3.7	0.6	2.3	5.0
Fat PCT 200-305 d-2nd lactation	35	3.6	0.5	2.8	5.1
Fat PCT 200-305 d-3rd+ lactation	35	3.0	0.0	2.0	5.0

Table 2 (Continued). DairyMetrics for all breeds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
Udder Health					
SCC[1] actual	39	388	219	112	1,116
SCC score	39	3.3	0.7	2.1	5.0
SCC score for 1st lactation	39	2.9	0.7	1.4	4.2
SCC score for 2nd lactation	39	3.2	0.9	1.2	5.5
SCC score for 3rd lactation	35	3.8	0.8	2.4	6.1
SCC score for cows 41-100 d	38	2.7	1.0	1.3	5.4
SCC score for cows 101-199 d	38	3.2	0.9	2.0	5.3
SCC score for cows 200-305 d	38	3.5	0.8	1.8	5.1
SCC score for cows 306+ d	39	3.6	0.9	2.2	5.0
PCT cows (SCCS of 0-3)	39	57	14	21	79
PCT cows (<41 d with SCCS >4)	37	35	21	0	100
PCT 1st lactation (SCCS of 0-3)	39	65	15	37	100
PCT 2nd lactation (SCCS of 0-3)	39	58	17	21	95
PCT 3rd lactation (SCCS of 0-3)	35	46	16	8	72
PCT cows culled for mastitis	35	2	4	0	22
PCT value prod lost >from SCC	39	2	2	0	8
Reproduction					
Pregnancy rate-current (%)	33	17	9	1	41
Pregnancy rate-year avg (%)	39	35	158	0	999
Days open-proj min-all	39	192	46	132	334
Projected calving interval (mo)	39	15.5	1.5	13.5	20.2
Current actual calving interval (mo)	39	14.7	2.1	10.2	21.9
PCT cows calving-current test	39	8	7	0	30
PCT birth 4+ calving diff-1st lactation	29	3	5	0	22
Days open-projected min-1st lactation	39	207	57	130	359
Days open-projected min-2nd lactation	39	191	63	73	350
Days open-projected min-3rd+ lactations	35	184	40	127	308
Voluntary waiting period(VWP) (d)	39	51	7	40	60
Days to 1st service (%herd< than VWP)	32	12	12	1	45
Days to 1st service (%herd VWP to 100d)	35	50	18	21	87
Days to 1st service (%herd> than 100 d)	35	38	17	3	71
Days 1st service-total herd	35	106	25	66	164
Days 1st service(%herd <100 d)-1st lactation	33	60	16	32	96
Days 1st service(%herd <100 d)-2nd lactation	35	64	20	25	100
Days 1st service(%herd <100 d)-3rd+ lactations	32	59	20	17	97
Conception rate for past 12 mo-1st service (%)	39	36	21	0	77
Conception rate for past 12 mo-2nd service (%)	39	38	23	0	78
Conception rate for past 12mo-3rd+ service (%)	39	39	25	0	100
Services per pregnancy-All lactations	34	2.0	1.0	1.0	5.0
Services per pregnancy-1st lactation	34	2.0	1.0	1.0	6.0
Services per pregnancy-2nd lactation	34	2.0	1.0	1.0	5.0
Services per pregnancy-3nd+ lactations	32	3.0	1.0	1.0	7.0
PCT of heats observed for year	35	30	15	4	51
PCT of heats observed last test	32	31	18	2	63
Number of abortions in past year	39	0	2	0	14
Number of calvings in past year	39	139	112	35	553
PCT dry less than 40 d	35	15	10	1	40
PCT dry more than 70 d	36	34	18	5	80

[1] SCC = Somatic cell count/1000

Table 2 (Continued). DairyMetrics for all breeds in Arkansas, May, 2006.

Item	Number of herds	Average of herds	SD	Lowest herd	Highest herd
Genetics					
PCTile rank of proven AI bulls	39	36	25	0	78
PCTile rank of young AI bulls	39	30	35	0	99
PCT of herd bred to proven AI bulls	29	57	23	18	100
PCT of herd bred to young bulls	39	9	12	0	39
PCT of herd bred to non-AI bulls	39	37	34	0	100
Net merit$ for 1st lactation	33	3	90	-252	152
Net merit$ for all cows	36	-34	105	-426	85
Net merit$ for heifers	31	52	78	-123	189
PCT of heifers ID'd by sire	32	68	29	0	100
PCT of cows ID'd by sire	39	61	39	0	100
Replacement rate(#heifers/#cows)*100	39	66	42	0	125
Replacement rate(#heifers 0-12 mo /#cows)*100	39	29	18	0	58
Replacement rate(#heifers 13+ mo /#cows)*100	39	36	29	0	110

Table 3. Comparison of Arkansas Holstein herds using DairyMetrics.

Trait for herds	Trait avg	RHA[1]-milk (lb)	Daily IOF [2] ($)	Calving interval (mo)	% Cows left herd	SCC[3] /1000
Holstein	---	18,679	5.00	14.0	33	342
NonHolstein	---	14,496	4.15	15.6	28	542
Herds with % dry < 70 days	17	20,133	4.75	14.2	35	328
Herds with % dry > 70 days	43	16,983	4.30	14.3	38	383
Herds < 149 days open	151	20,489	5.53	13.7	35	328
Herds > 150 days open	207	17,548	4.32	14.9	31	351
Herds < 5% died	2	18,632	4.95	13.7	32	334
Herds > 5% died	9	18,704	4.18	14.4	40	369
Herds < 16,000 lb RHA milk	15,524	15,524	3.72	14.3	31	409
Herds > 16,000 lb RHA milk	20,170	20,170	4.89	14.1	39	334
Herds < 15 mo calving interval	13.5	18,904	4.89	13.5	35	354
Herds > 15 mo calving interval	16.4	18,069	4.32	16.4	29	315
Herds < $4 IOF	2.90	15,877	2.90	14.1	35	410
Herds > $4 IOF	5.41	19,641	5.41	14.6	28	315
Herds < 300,000 SCC	225	20,490	5.30	14.9	30	225
Herds > 300,000 SCC	432	17,547	4.31	14.0	30	432
Herds < $0 net merit for cows	-100	16,753	3.95	14.8	37	351
Herds > $0 net merit for cows	46	20,865	5.26	14.0	30	324

[1] Rolling herd average
[2] Income-over-feed costs (milk$-feed$)
[3] Somatic cell count

Report of Research Trial with Tasco at Rose Ark Dairy in Arkansas During Summer 2005[1]

D.W. Kellogg[2], K. Anschutz[2], and J. Pennington[3]

Story in Brief

Cows at the Rose Ark Dairy in central Arkansas fed Tasco™, a brown seaweed meal, had lower respiration rates on August 3rd, 10th, 31st, and September 7th. Respiration rates were reduced on both large and small cows, although the effect appeared dependent upon time. Larger cows fed brown seaweed meal responded with about 5 lb/d greater ($P < 0.01$) milk production during August and September compared to control cows, but the effect was not evident with smaller cows. With brown seaweed meal in the diet, the pregnancy rate of the larger cows was enhanced ($P < 0.01$) dramatically (21 of 55) compared to control cows (3 of 50) but did not differ for smaller cows (31 of 60 in the treated group and 27 of 59 in the control group). The results in central Arkansas indicate that brown seaweed meal is beneficial to large milking cows during moderate to severe heat stress.

Introduction

Summer heat and humidity reduce feed intake, depress milk production, and reduce reproductive performance of dairy cows in Arkansas. A brown seaweed meal (Tasco™, Acadian Agritech, Dartmouth, Nova Scotia, Canada) *Ascophyllum nodosum* tended to increase milk yield of heat-stressed dairy cows in Florida (Staples et al., 2004) and Kansas but did not effectively relieve symptoms of mild heat stress in Kansas (Brouk et al., 2005). The meal is a known source of cytokinins, and it has been used to alleviate symptoms of fescue toxicosis such as depressed monocyte immune function, rough hair coat, and elevated rectal temperatures during grazing in Mississippi and Virginia (Saker et al., 2001). A field trial was initiated at Rose Ark Dairy Farm near Rosebud in central Arkansas to evaluate the effects of feeding brown seaweed meal to high-producing dairy cows under moderate to severe heat stress.

Experimental Procedures

The Rose Ark Farm (elevation 802 ft) had about 600 cows—with about 525 lactating, and the herd was divided on July 1, 2005 and housed in 4 free-stall barns. Two barns had stalls that were configured for large breeds and housed cows that were primarily Holstein with some Brown Swiss and Ayrshire cows. Two other barns with shorter stall length housed cows that were primarily Jersey, Milking Shorthorn, and F-1 crossbreds (mostly Jersey X Holstein crosses). All 4 barns had cooling fans and passive ventilation ridges above the cows. Water sprinklers were not used. Cows had ample space in the barns. Feed and water were available near the free stalls.

Many first-lactation cows were smaller in size and stature than mature cows and were housed with the Jerseys. The cows were divided to achieve 2 similar groups of larger cows (H) and smaller cows (J) in the 4 free stall barns. Cows were moved to the holding area and were cleaned (and cooled) by water sprinklers before being milked 3 times daily. Milk yield was measured and recorded automatically for each milking. The cows wore an electronic monitor that permitted automatic recording of the milk yield. The computerized system (Westfalia-Surge, Oelde, Germany) accumulated and displayed the milk yield by individual cows or by groups for the previous week and the previous month. Additionally, the milk was measured on all milkings on 1 d each month and was sampled for components [milk fat and protein percentage and somatic cell score (SCS)].

All groups received a total mixed ration (TMR), and the TMR fed to the 2 treatment groups contained 0.25% Tasco (Table 1). Feed was sampled weekly for dry matter and nutrient analyses. The laboratory analyses were 58.6% dry matter, 15.9% crude protein, 34.4% acid detergent fiber, and 57.3% neutral detergent fiber. Drinking water was available free-choice at each end of the free stall barn and in the center of the barn.

Approximately 15 cows in each group were chosen at random each week to determine respiration rate. Skin temperatures were measured on the shoulder, thurl, and rear udder using an infrared instrument (Raynger ST, Raytek, Santa Cruz, Calif.). There was no attempt to use the same cows each week of the trial. Personnel from the University of Arkansas made the respiration rate observations during August and September.

Breeding of cows was by artificial insemination using routine methods by employees of the farm. Pregnancy diagnosis was by an independent reproductive specialist employed by the farm. All decisions about pregnancy of cows were by the same specialist during scheduled visits to the farm. Data available in mid-November (45 d after the trial ended) were used initially. The results were confirmed by actual birth of calves and/or later pregnancy examinations conducted by the same specialist through early May, 2007.

Temperatures were recorded outside near the barn and at 4 locations inside the barns. Additionally, official daily weather records in North Little Rock (AR) were obtained, the regional location (30 miles south of the Rose Ark Dairy Farm) with an official weather station. The trial ended on September 30, 2005 to coincide with declining temperatures.

Data for milk yields, milk fat percentages, milk protein percentages, and SCS for months July through September were analyzed using PROC GLM of SAS (SAS Inst., Inc., Cary, N.C.) with a model that included treatment, size of cow, and the interaction. Days in milk (DIM) and June data (as a preliminary period) for each trait were included as a covariant. When significant ($P < 0.05$) effects were observed, means were separated using the PDIFF option of GLM.

[1] This research was partially supported by Rose Ark Dairy Farm, Rosebud, Ark., and Acadian Agritech, Dartmouth, Nova Scotia, Canada
[2] Department of Animal Science, Fayetteville
[3] University of Arkansas Cooperative Extension Service, Animal Science Section, Little Rock

Results and Discussion

Milk yield of cows averaged 70 lb/d for the large cows and 57 lb/d for the small cows during June, the preliminary period (Table 2). This is quite good production for cows in the region during early summer, especially considering this was the 4th month of average production. The owner divided the cows uniformly by milk yield, as seen in Table 2. Milk yield declined during the hotter summer months, and the large cows were especially affected adversely. Instead of a 13-lb difference initially, production of larger cows and smaller cows was not different during August and September (Table 2). This highlights the negative impact of hot, humid weather on the larger cows.

The maximum highs averaged 91°F with 65% humidity and 2 m/h of wind during June, averaged 92°F with 70% humidity and 1 m/h of wind during July, averaged 96°F with 64% humidity and 2 m/h of wind during August, and averaged 89°F with 70% humidity and 4 m/h of wind during September. However, there were 5 weeks when the afternoon temperature exceeded 100°F, The highest of 102°F was matched on 3 separate days in August and September (http://www.weatherunderground.com).

Cows fed brown seaweed meal produced more ($P < 0.01$) milk during July, August, and September (Table 2). However, there was an interaction with size of cows during August ($P < 0.01$) and September ($P < 0.05$) caused by approximately a 5-lb difference for the larger cow groups compared to similar yield for smaller cows, and that should be considered in making recommendations. Brown seaweed meal prevented the steep decline in milk yield of the larger cows.

Weekly means of milk production are shown in Figure 1. Dramatic declines occurred at times of increased heat stress, either during, or immediately preceding, the period.

Milk fat percentages were abnormally low during June and were quite high during September (Table 3). The sorghum silage that was harvested in 2004 was of low nutritive quality and probably affected the milk fat composition. The values in June would be low for Holsteins in the region—even with relatively high milk. yield—and certainly the milk fat percentage of cows of smaller breeds should have been higher. Silage harvested in 2005 was available in September and may have positively influenced milk fat percentages that would normally increase during later stages of lactation.

Milk fat percentages responded inconsistently to the experimental treatment during July and August, being higher ($P < 0.01$) for control cows in July and tending to be higher ($P < 0.10$) for cows fed brown seaweed meal during August. There is no logical explanation for these opposing results in consecutive months, and it may be a reflection of the dynamic changes occurring that were not related to the dietary treatment.

The milk protein percentages are shown in Table 4. Cows fed brown seaweed meal produced similar percentages of protein compared to control cows.

Cows produced milk with similar SCS during July. The SCS was lowered during August for cows fed brown seaweed meal compared to control cows (Table 5). The SCS is an indicator of the amount of intramammary infections (mastitis).

The averages of respirations per minute that were taken during August and September are shown in Figure 2. Cows fed brown seaweed meal had improved respirations per minute on August 3rd (77.3 compared to 88.5 for control cows; $P < 0.05$), on August 10th (80.0 compared to 91.4 for control cows; $P < 0.01$), on August 31st (66.6 compared to 71.5 for control cows; $P < 0.05$), and on September 7th (60.6 compared to 68.1 for control cows; $P < 0.01$). There was some variation weekly, perhaps because the cows were chosen at random each week. However, it was consistent with both sizes of cows, so there may have been a more dramatic effect earlier in the experiment compared to later weeks. The greatest difference was 11 respirations per minute in early August.

The respirations per minute of control cows declined weekly until the final week (September 23). The maximum afternoon temperature had declined from 102°F (38°C) in August to 91°F (32°C) in early September and—perhaps more importantly—the minimum night temperature dropped from 73°F (22°C) to 61°F (16°C) (http://www.weatherunderground.com). It is likely that DM intake of cows was stimulated during this time. When hot afternoon temperatures returned from September 18th to 23rd—reaching a high of 102°F (38°C) on September 20th—apparently the cows did not adapt quickly enough, and some very high respirations per minute were recorded on September 23rd. Skin temperature data varied greatly and were not useful.

The data relating to breeding of cows are in Table 6. These cows were bred, but the number of pregnancies from the larger breeds was very low (3 of 50) for control cows. That is probably typical of Holstein cows in the region, and many herd managers in the region do not even try to breed cows during hot weather because of low breeding efficiency. With brown seaweed meal in the diet, the pregnancy rate was enhanced ($P < 0.01$) dramatically (21 of 55). While that is not an exceptionally high percentage, it is quite high for summer months in central Arkansas. The number of breedings per conception and the days open before first service did not vary ($P > 0.05$) among treatment groups. It may be of interest to determine if the effect was expressed in implantation of the embryo or in survival of the young embryo.

Implications

There were positive effects of feeding brown seaweed meal in the Rose Ark Dairy in central Arkansas. Cows fed brown seaweed meal had lower respiration rates on August 3rd, 10th, 31st, and September 7th. Respiration rates were reduced on both large and small cows, although the effect appeared dependent upon time. Larger cows fed brown seaweed meal responded with about 5 lb/d greater milk production during August and September compare to control cows, but the effect was not evident with smaller cows. With brown seaweed meal in the diet, the pregnancy rate of the larger cows was enhanced dramatically (21 of 55) compared to control cows (3 of 50).The results in central Arkansas indicate that brown seaweed meal is beneficial to large milking cows during heat stress.

Acknowledgments

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Table 1. Feed ingredients and composition at Rose Ark Dairy Farm during the summer of 2005.

Item	Large cows Barns 1 & 2	Small cows Barns 4 & 5
Whole cottonseed	5.5	4.5
EXT-Nugget supplement[1]	5.0	4.5
Soybean meal	6.1	4.4
Corn grain	7.6	7.0
Hominy feed	6.0	5.0
Wet brewers grains	15.0	13.5
Cottonseed hulls	3.0	3.5
Molasses	1.0	1.0
Bermudagrass hay	4.0	3.0
Sorghum silage, 32% DM	45.0	38.0
[1]Purina Mills, LLC, St. Louis, MO		
As-fed, lb	98.2	84.4
Dry matter intake	52.3	45.0
Crude protein, %	17.0	16.2
Crude protein, lb	8.9	7.3
Metabolizable energy, Mcal/lb	1.28	1.28
Fat, lb	3.2	2.8
Acid detergent fiber, %	25.2	25.8
Non fiber carbohydrates, %	28.6	28.5
Forage, %	40.1	40.6

Table 2. Least squares means of milk yields at Rose Ark Dairy Farm during summer months of 2005.

Item	n	DIM	June[1]	July	August	September
		d	lb			
Control (Con)	133	149	63.4	59.4 ± 0.4	52.4 ± 0.5	47.8 ± 0.8
Tasco[2]	135	146	63.4	61.1 ± 0.4 **	55.2 ± 0.5 **	50.8 ± 0.8 **
Large cows (H)	125	152	70.0	61.1 ± 0.5	53.8 ± 0.6	49.8 ± 0.8
Small cows (J)	143	140	57.0	59.1 ± 0.4 **	53.7 ± 0.5 n.s.	48.8 ± 0.7 n.s.
Con H	117	156	70.0	60.0 ± 0.6	51.3 ± 0.8 c	47.2 ± 1.2 b
Tasco H	108	149	70.0	62.7 ± 0.7	56.3 ± 0.8 a	52.5 ± 1.3 a
Con J	116	137	57.0	58.8 ± 0.8	53.4 ± 0.7 b	48.4 ± 1.0 b
Tasco J	127	142	56.9	59.5 ± 0.6 n.s.	54.0 ± 0.7 b **	49.1 ± 1.0 b *

[1]Days in milk (DIM) and milk yield during June were the preliminary data used as covariants.
[2]Brown seaweed extract, Acadian Agritech, Dartmouth, Nova Scotia, Canada.
a,b,c Interaction means for August and September with no letters in common differ ($P < 0.05$).
*($P < 0.05$)
**($P < 0.01$)

Table 3. Least squares means of milk fat percentage at Rose Ark Dairy Farm during summer months of 2005.

Item	June[1]	July	August	September
	---------- % ----------			
Control	3.17	3.40 ± 0.08	3.30 ± 0.07	4.84± 0.14
Tasco[2]	2.79	3.14 ± 0.08	3.46 ± 0.07	4.97 ± 0.15
		**	(*P* = 0.10)	n.s.
Large cows (H)	2.92	3.06 ± 0.08	3.17 ± 0.08	4.66 ± 0.16
Small cows (J)	3.44	3.47 ± 0.07	3.58 ± 0.06	5.15 ± 0.14
		**	**	*
Control H	2.80	3.16 ± 0.12	3.00 ± 0.10 c	4.54 ± 0.21
Tasco H	2.79	2.97 ± 0.12	3.44 ± 0.09 b	4.77 ± 0.23
Control J	3.54	3.64 ± 0.10	3.59 ± 0.11 a	5.14 ± 0.19
Tasco J	3.34	3.31 ± 0.10	3.57 ± 0.09 a	5.17 ± 0.21
		n.s.	(*P* = 0.06)	n.s.

[1]Days in milk (DIM) and milk fat percentage during June were the preliminary data used as covariants.
[2]f seaweed extract, Acadian Agritech, Dartmouth, Nova Scotia, Canada.
a,b,c Interaction means for August with no letters in common differ (P < 0.05).
*(*P* < 0.05)
**(*P* < 0.01)

Table 4. Least squares means of milk protein percentage at Rose Ark Dairy Farm during the summer months of 2005.

Item	June[1]	July	August	September
	---------- % ----------			
Control	3.00	3.04 ± 0.02	3.10 ± 0.02	3.34 ± 0.02
Tasco	3.04	3.05 ± 0.02	3.11 ± 0.02	3.40 ± 0.02
		n.s.	n.s.	n.s.
Large cows (H)	2.86	3.02 ± 0.02	3.05 ± 0.02	3.31 ± 0.03
Small cows (J)	3.16	3.08 ± 0.02	3.16 ± 0.02	3.43 ± 0.02
		*	**	**
Control H	2.86	3.01 ± 0.03	3.05 ± 0.03	3.28 ± 0.04
Tasco H	2.87	3.02 ± 0.03	3.05 ± 0.03	3.34 ± 0.04
Control J	3.13	3.07 ± 0.03	3.16 ± 0.02	3.41 ± 0.03
Tasco J	3.20	3.09 ± 0.03	3.17 ± 0.02	3.45 ± 0.04
		n.s.	n.s.	n.s.

[1]Days in milk (DIM) and milk yield during June were the preliminary data used as covariants.
[2]Brown seaweed extract, Acadian Agritech, Dartmouth, Nova Scotia, Canada.
*(*P* < 0.05)
**(*P* < 0.01)

Table 5. Least squares means of somatic cell score (SCS) at Rose Ark Dairy Farm during summer months of 2005.

Item	June[1]	July	August	September
	---------- % ----------			
Control	3.12	3.23 ± 0.20	2.74 ± 0.16	4.39 ± 0.15
Tasco[2]	2.96	3.03 ± 0.21	2.28 ± 0.15	4.08 ± 0.16
		n.s.	*	n.s.
Large cows (H)	3.11	3.30 ± 0.17	2.65 ± 0.16	4.34 ± 0.17
Small cows (J)	2.92	2.96 ± 0.19	2.37 ± 0.14	4.14 ± 0.15
		n.s.	n.s.	n.s.
Control H	3.43	3.34 ± 0.31	2.71 ± 0.23	4.65 ± 0.23
Tasco H	2.78	3.24 ± 0.27	2.59 ± 0.21	4.02 ± 0.20
Control J	2.80	3.12 ± 0.32	2.77 ± 0.23	4.13 ± 0.20
Tasco J	3.13	2.80 ± 0.26	1.97 ± 0.19	4.14 ± 0.21
		n.s.	n.s.	n.s.

[1]Days in milk (DIM) and milk yield during June was the preliminary data used as a covariant.
[2]Brown seaweed extract, Acadian Agritech, Dartmouth, Nova Scotia, Canada.
*(*P* < 0.05)

Table 6. Breeding efficiency means at Rose Ark Dairy Farm during summer months of 2005.

Item	n	Number of breedings per conception	Days open before 1st service	Number of cows pregnant[1]	Number of cows pregnant[2] (May, 2006)
Control	109	2.4	80.5	30	80
Tasco[3]	119	2.3	76.2	52	100
		n.s	n.s.	**	
Larger cows (H)	105	2.2	77.0	24	75
Small cows (J)	119	2.5	80.0	58	115
		n.s.	n.s.	**	
Control H	50	2.1	79.7	3	32
Tasco H	55	2.2	74.3	21	43
Control J	59	2.6	81.3	27	48
Tasco J	60	2.4	78.6	31	57
		n.s.	n.s.	**	

[1]Number of cows bred during the summer trial that were diagnosed pregnant after 45 d (mid-November) and confirmed in early May, 2006.
[2]Number of cows bred during the summer trial plus those bred after the trial ended during the cooler weather and diagnosed pregnant in early May, 2006. Data in this column was not analyzed statistically.
[3]Brown seaweed extract, Acadian Agritech, Dartmouth, Nova Scotia, Canada.
**($P < 0.01$)

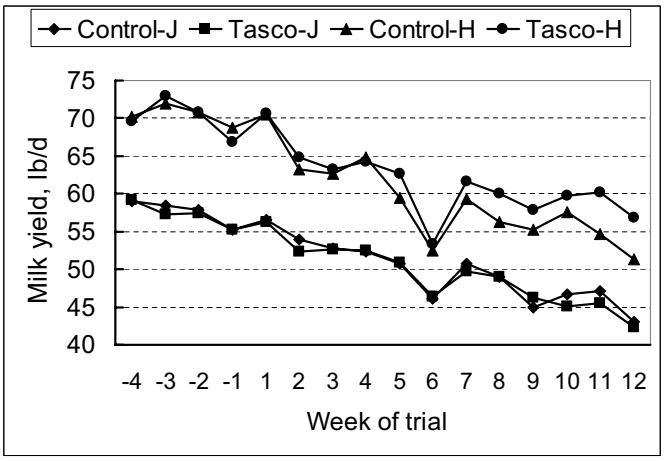

Fig. 1. Weekly means of milk yield of cows at Rose Ark Dairy Farm during the summer months of 2005. Treatments were Control-J (Small cows, mostly Jersey, not fed Tasco); Tasco-J (Small cows fed Tasco); Control-H (Large cows, mostly Holstein, not fed Tasco); and Tasco-H (Large cows,fed Tasco). Tasco is Brown seaweed meal, Acadian Agritech, Dartmouth, Nova Scotia, Canada.

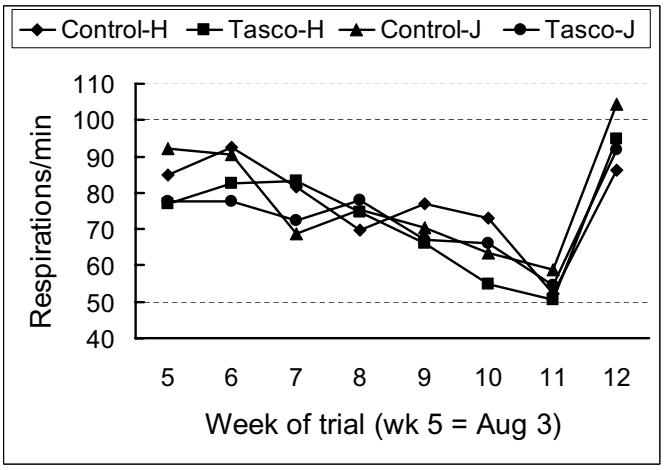

Fig. 2. Weekly means of respirations per minute of cows at Rose Ark Dairy Farm during August and September of 2005. Treatments were Control-J (Small cows, mostly Jersey, not fed Tasco); Tasco-J (Small cows fed Tasco); Control-H (Large cows, mostly Holstein, not fed Tasco); and Tasco-H (Large cows fed Tasco). Tasco is Brown seaweed meal, Acadian Agritech, Dartmouth, Nova Scotia, Canada.

Feeding Mannan Oligosaccharides to Sows During Gestation and Lactation Alters Immune Cells in Milk

J.W. Frank[1], C.L. Bradley[1], M.E. Davis[1], D.C. Brown[1], Z.B. Johnson[1], R. Musser[2], and C.V. Maxwell[1]

Story in Brief

Thirty sows were used to determine the effects of feeding mannan oligosaccharides (Bio-Mos) during gestation and lactation on immune cell populations and cytokine concentrations in colostrums and milk. The treatments were a common gestation diet (control) or the common diet supplemented with Bio-Mos. Samples (40 to 50 mL) of colostrum (d 0) and mature milk (d 14) were obtained from each sow during lactation. Concentrations of immunoglobulins, cytokines, and the proportion of specific leukocytes were determined in the samples. Sows supplemented with Bio-Mos had fewer mummies at farrowing than control sows ($P < 0.04$); however, Bio-Mos supplemented sows had greater weight loss during lactation than control sows ($P < 0.01$). The concentration of immunoglobulins ($P < 0.001$) and all leukocytes ($P < 0.02$) in mature milk was lower than in colostrum. No effect of Bio-Mos supplementation was detected in milk IFN-γ, IL-2, IL-10, or TGF-β concentrations. The proportion of macrophages (CD14+ leukocytes) decreased in mature milk compared to colostrum of control sows (31.0 vs. 5.2%), while the proportion of this cell type remained elevated in Bio-Mos supplemented sows (25.5 vs. 20.6%) (treatment x stage of lactation interaction, $P < 0.04$). Supplementing the sow's diet with Bio-Mos during gestation and lactation increased the proportion of macrophages in mature milk. Further research will reveal if this change in mature milk is beneficial to the development of the nursing piglet's innate immunity.

Introduction

Intake of colostrum by the newborn piglet is important both for its immediate survival and its ability to thrive after weaning (Rooke and Bland, 2002). Furthermore, the immunological components of colostrum (i.e., leukocytes, cytokines, growth factors, etc.) contribute to the development of the piglet's immune system (Le Jan, 1996). However, the effects of the diet on the populations of immune cells and cytokines within the sow's colostrum and milk have not been extensively studied. The potential changes in the concentration of the immune components in colostrum and milk may impact pig performance during the lactation period and subsequent performance to market weight.

Bio-Mos (Alltech, Inc., Nicholasville, Ky.) has been reported to alter microbial populations in the gastrointestinal tract, by its ability to attach to type-1 fimbriae on the cell surface of specific bacteria, interfering with the ability of the bacteria to colonize the intestinal tract (Spring et al., 2000). By supplementing the sow's diet with Bio-Mos, to alter pathogen exposure, it may be possible to positively alter immune cell components of the sow's milk. Therefore, the aim of this study was to evaluate if there are any benefits on the immune variables of colostrum and milk from supplementing the sow's diet with Bio-Mos.

Experimental Procedures

Animals and diets. Thirty sows from one farrowing group were randomly assigned to one of two treatments. The treatments were a common gestation diet or the common diet supplemented with Bio-Mos. Treatments began 3 weeks prior to lactation, and continued through weaning. The control diet was supplemented with Bio-Mos (2 kg/ton of feed) at the expense of corn and administered as the treatment diet. The gestation diets were limit-fed, in which the amount provided was based on sow condition. Sows continued on their respective treatment during the lactation phase (1 kg Bio-Mos/ton of feed), where sows were provided feed ad libitum until weaning.

Performance and immunological measurements. Initial body weight of sows was determined when sows began receiving dietary treatments during gestation (approximately d 86 of gestation). Sow body weight was determined again when the sows were moved into the farrowing facility and at weaning. Feed intake of individual sows was determined during gestation and lactation. The number of pigs born, pigs born alive, stillborns, and mummies was determined at farrowing, as well as live pig birth weight and weaning weight. The number of days for sows to return to estrus following weaning was also determined.

Samples (40 to 50 mL) of colostrum (d 0) and mature milk (d 14) were obtained from each sow. Sub-samples were centrifuged, the fat layer discarded, and the supernatant collected for the determination of IgM, IgG, and IgA immunoglobulin concentrations, and the concentration of specific cytokines (INF-γ, IL-2, IL-10, and TGF-β). Leukocytes were isolated from each milk sample, and the leukocyte population was defined by single stain flow cytometry. Monoclonal antibodies were used to determine the populations of T cell subpopulations (CD3, CD4, CD8), macrophages (CD14), IL-2 receptor on T cells (CD25), gamma/delta T cells (TCRγδ), and the presence of major histocompatability complex-II (MHC-II) on leukocytes.

Statistical analysis. The data were analyzed as a completely randomized design using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). The experimental model used for the analysis of the immune variables consisted of dietary treatment (control and Bio-Mos), stage of lactation (colostrum and mature milk), and the interaction.

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Results and Discussion

Supplementing sows with Bio-Mos during gestation and lactation reduced ($P < 0.04$) the number of mummies and increased sow weight loss during lactation ($P < 0.01$; Table 1). The greater lactation weight loss of Bio-Mos supplemented sows did not translate into statistically heavier piglets at weaning, although weaning weight was 7 lb heavier per litter.

The concentration of the immunoglobulins, essential for passive immune protection throughout lactation, was not affected by dietary treatment (Table 2). There have been reports of Bio-Mos supplementation increasing the concentration of immunoglobulins in colostrum (Newman and Newman, 2001; Quinn et al., 2001). Consistent with previously published work (Klobasa et al., 1987), immunoglobulin concentrations decreased dramatically in mature milk compared to colostrum ($P < 0.001$). Bio-Mos supplementation during gestation and lactation did not impact IFN-γ, IL-2, IL-4, or TGF-β concentrations within the colostrum or milk (Table 2).

As expected, the proportion of all measured cell types decreased in the mature milk compared to colostrum ($P < 0.02$; Table 3). However, there was no treatment effect on CD8+ (cytotoxic T cells), CD3+ (T cells), CD4+ (T helper cells), CD25+ (activated lymphocytes), TCRγδ (T cells with γδ receptor), or MHCII+ (antigen presenting cells) proportions in the colostrum or milk (Table 3). Interestingly, the proportion of macrophages (CD14+ leukocytes) decreased in mature milk compared to colostrum of control sows (31.0 vs. 5.2%), while the proportion of this cell type remained elevated in Bio-Mos supplemented sows (25.5 vs. 20.6%) (treatment x stage of lactation interaction, $P < 0.04$). At birth the piglet's helper T-cell (Th) population is predominantly differentiated into a Th2 subset. During mid- to late-lactation, as the animal is exposed to environmental pathogens, the cell population is directed towards a Th1 subset. Each of these cell types has specific immunological functions directed against certain types of immune challenges. The principal function of Th2 cells is to stimulate cell-mediated (humoral) immune responses against allergens, helminths, and arthropods; while the principal function of Th1 cells is to stimulate phagocyte-mediated (cytotoxic T cells and macrophages) defense against bacterial and viral challenges (Abbas et al., 2000). In a swine production environment, bacterial and viral challenges cause significant economical losses from reduced animal performance. By altering the macrophage proportions in the mature milk with the supplementation of the sow's diet with Bio-Mos, we may have directed the development of a Th1 subset of cells, allowing the piglet to become more immunologically mature at an earlier age.

Implications

Supplementing the sow's diet with Bio-Mos during gestation and lactation increased the proportion of macrophages in mature milk. Further research in this area will reveal how this change may alter the development of the innate immune system in neonatal pigs.

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Table 1. Sow and litter performance of sows fed a control or Bio-Mos supplemented diet during gestation and lactation.

Trait	Sow treatment		*P*–value
	Control	Bio-Mos	
Sow performance			
Initial gestation weight, lb	541.6 ± 13.9	555.0 ± 12.1	0.47
Final gestation weight, lb	566.7 ± 13.8	584.2 ± 12.1	0.35
Gestation weight gain, lb	25.2 ± 2.6	29.2 ± 2.3	0.25
Sow weaning weight, lb	493.4 ± 14.7	475.8 ± 12.9	0.38
Lactation weight loss, lb	-73.4 ± 9.4	-109.3 ± 8.2	0.01
Sow ADFI, lb/d	9.95 ± 0.73	8.93 ± 0.64	0.30
Return to Estrus, d	5.34 ± 0.16	5.08 ± 0.14	0.23
Sow litter performance			
Number born alive	12.19 ± 0.77	12.38 ± 0.67	0.86
Number stillborn	1.81 ± 0.52	1.31 ± 0.46	0.48
Number of mummies	0.71 ± 0.20	0.13 ± 0.18	0.04
Litter weight, lb	38.66 ± 2.33	40.03 ± 2.04	0.66
Piglet weight, lb	3.21 ± 0.17	3.30 ± 0.15	0.71
Number weaned	9.23 ± 0.47	9.56 ± 0.41	0.59
Age of pig at weaning, d	21.05 ± 0.51	21.13 ± 0.45	0.91
Litter weaning weight*, lb	126.0 ± 9.0	133.0 ± 7.9	0.57
Pig weaning weight*, lb	13.60 ± 0.57	13.86 ± 0.50	0.60

*Analyses have both age at weaning and pigs born alive included as covariates.

Table 2. Immunoglobulin and cytokine concentrations from the colostrum and mature milk of sows fed a control or Bio-Mos supplemented diet during gestation and lactation.

	Sow treatment			Stage of lactation		
Trait	Control	Bio-Mos	P-value	Colostrum	Mature milk	*P*-value
Immunoglobulins, ng/mL						
IgG	3252.4 ± 375	3208.1 ± 325	0.93	6430.3 ± 308	30.2 ± 389	0.0001
IgM	309.2 ± 34	343.8 ± 30	0.45	480.8 ± 28	172.2 ± 36	0.0001
IgA	986.4 ± 66	967.8 ± 58	0.83	1610.5 ± 55	343.7 ± 69	0.0001
Cytokines, pg/mL						
INF-γ	1057 ± 311	901 ± 270	0.71	1081 ± 256	866 ± 323	0.59
IL-2*	25.5 ± 1.6	35.5 ± 1.5	0.76	18.2 ± 1.5	57.5 ± 1.6	0.07
IL-10[a]	17.2 ± 2.6	5.6 ± 2.3	0.37	7.5 ± 2.2	12.8 ± 2.7	0.86
TGF-β	109 ± 28	135 ± 24	0.49	115 ± 23	130 ± 29	0.67

[a] Data were transformed [log (x + 1)] for statistical analysis due to heterogeneity of variance.

Table 3. Phenotypic expression of cell surface markers (as indicated by single-stain flow cytometric analysis) on leukocytes from the colostrum and mature milk of sows fed a control or Bio-Mos supplemented diet during gestation and lactation.

	Sow treatment			Stage of lactation		
Trait, %[a]	Control	Bio-Mos	P-value	Colostrum	Mature milk	*P*-value
CD3	4.3 ± 1.17	5.0 ± 1.19	0.70	6.6 ± 1.10	2.7 ± 1.26	0.02
CD4	7.7 ± 1.70	8.4 ± 1.69	0.79	11.9 ± 1.56	4.1 ± 1.82	0.01
CD8	14.1 ± 2.37	11.5 ± 2.34	0.45	20.4 ± 2.18	5.2 ± 2.53	0.01
CD14[b]	18.1 ± 3.57	23.0 ± 3.51	0.33	28.2 ± 3.27	12.9 ± 3.80	0.01
CD25	12.8 ± 2.18	10.5 ± 2.15	0.47	20.3 ± 2.00	3.0 ± 2.32	0.01
TCRγδ	11.3 ± 2.32	10.8 ± 2.29	0.88	19.4 ± 2.13	2.8 ± 2.47	0.01
MHC II	14.2 ± 2.33	13.2 ± 2.30	0.77	24.1 ± 2.13	3.3 ± 2.48	0.01

[a] Populations of T cell subpopulations (CD3, CD4, CD8), macrophages (CD14), IL-2 receptor on T cells (CD25), gamma/delta T cells (TCR1), and the presence of major histocompatability complex-II (MHC-II) on leukocytes.
[b] Treatment x stage of lactation interaction (P = 0.04) discussed in text.

Evaluation of *Bacillus* Cultures (88/18) and Antibiotic Supplementation Administered in the Diets of Nursery Pigs on Growth Performance and Potential Immunological Mode of Action

D.C. Brown[1], M.E. Davis[2], C.V. Maxwell[1], T. Rehberger[2], and Z.B. Johnson[1]

Story in Brief

A total of 288 pigs were weaned to a wean-to-finish facility and blocked by BW to determine the effect of a *Bacillus*-based direct-fed microbial (DFM) and antibiotic (AGP) supplementation on the blood cytokine profiles. Treatments were arranged as a 2 x 2 factorial with 2 levels of AGP and 2 levels of DFM. Peripheral blood mononuclear cells (PBMC) were isolated from 4 pigs/treatment on d 20 and d 42 postweaning (PW) and cytokine production was elaborated by stimulating with lipopolysaccharide (LPS) for tumor necrosis factor-α (TNF-α) and interleukin-1β (IL-1β) concentrations and with concanavalin A for interleukin-4 (IL-4) concentrations. Plasma samples were obtained to measure circulating concentrations of TNF-α. Monocyte IL-1β concentrations from pigs fed DFM were decreased ($P < 0.05$) from d 20 to d 42 PW, whereas IL-1β concentrations from pigs not fed DFM were similar across the 2 days (DFM x day interaction, $P < 0.05$). Interleukin-4 concentrations from PBMC from pigs fed DFM were similar across the 2 days PW, whereas PBMC IL-4 concentrations from pigs not fed DFM decreased ($P = 0.05$) from d 20 to d 42 (DFM x day interaction, $P < 0.05$). Plasma TNF-α concentrations decreased ($P < 0.05$) from d 20 to d 42 PW in pigs fed AGP, but remained similar across the 2 days in pigs not fed AGP (AGP x day interaction, $P = 0.10$). No differences were detected in unstimulated PBMC TNF-α concentrations on d 20 PW amongst treatments; however, PBMC TNF-α concentrations from pigs fed AGP were lower ($P < 0.05$) on d 42 than from pigs fed the control diet, whereas TNF-α concentrations from pigs fed DFM or DFM+AGP did not differ from control or AGP supplemented pigs (DFM x AGP x day interaction, $P = 0.09$). These data indicate that both DFM and AGP supplementation alters the cytokine profile of nursery pigs by decreasing the production of proinflammatory cytokines (IL-1β and TNF-α) at the end of the nursery phase.

Introduction

The mechanisms by which growth-promoting levels of antibiotics improve pig performance have not been completely elucidated. One hypothesis is that alterations in the intestinal microbial population may decrease the production of negative growth factors such as the inflammatory cytokines, which have been documented to decrease feed intake and negatively alter metabolic growth processes (Spurlock, 1997). The gastrointestinal tract of animals is the site of complex interactions between the host immune system and various dietary factors and their breakdown products, as well as microorganisms, parasites, and exogenous toxins (Gaskins, 2001). Studies on colonization of the intestinal tract of gnotobiotic animals with either defined enteric bacteria or incompletely defined normal gut microflora revealed that the microbial population drives gut immune system development (Cebra, 1999). A direct-fed microbial containing *Bacillus* strains having inhibitory effects against *E. coli* serotypes F18 and K88 was developed by Agtech Products, Inc. following the screening of isolates native to infected swine herds. Previous experiments determined that this direct-fed microbial had immunomodulatory effects on innate and adaptive immunity and improved feed efficiency when supplemented to nursery pigs (Dirain et al., 2004; Davis et al., 2005). The objective of the study was to evaluate cytokine profiles of pigs elicited by a *Bacillus*-based direct-fed microbial and antibiotic supplementation in diets of nursery pigs.

Experimental Procedures

Animals and Housing. Approximately 288 pigs from 32 litters were weaned and transported to the University of Arkansas Wean-to-Finish Facility (~ 2 miles). Pigs were blocked by initial body weight, penned in groups of 7 to 8 pigs/pen, and housed in 36 slatted pens (1.5 m x 3.0 m) equipped with a radiant heater, 2-hole feeder, and wean-to-finish cup waterers.

Treatment Allocation. One of four dietary treatments was randomly assigned to each pen within block and administered during Phase 1 (d 0 to 8 post-weaning), Phase 2 (d 8 to 21 post-weaning), and Phase 3 (d 21 to 43 post-weaning) of the nursery period. Treatments were arranged in a 2 x 2 factorial design, with 2 levels of antibiotic supplementation (0 g and 50 g Carbadox/ton of feed during Phase 1 and Phase 2; 0 g and 400 g oxytetracycline/ton of feed during Phase 3) and 2 levels of supplementation with a *Bacillus*-based direct-fed microbial (0% and 0.25% MicroSource 88/18 to provide 7.5 x 105 cfu/g of feed). Pigs allotted to treatments containing *Bacillus* cultures were separated from those fed diets devoid of *Bacillus* to eliminate any exposure of the pigs to the feces that might cross-contaminate pens not administered Bacillus.

Sampling. A 15 mL blood sample was collected and mixed with EDTA(ethylenediaminetetracetic acid) for the isolation of peripheral blood mononuclear cells (PBMC) on d 20 and d 42 post-weaning. Cytokine elaboration of lymphocytes was induced by the addition of concanavalin A (ConA) to determine interleukin (IL-4) concentrations. Monocyte-derived macrophages were enriched from PBMC by adhesion to glass surfaces. Monocyte-derived

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macrophages were then primed with interferon-γ and stimulated with lipopolysacharide (LPS) to determine tumor necrosis factor (TNF-α) and IL-1β production. A 5 mL blood sample was collected and mixed with EDTA for the determination of plasma TNF-α concentrations.

Statistical Analysis. Data were analyzed as a randomized complete block design with pen as the experimental unit. Analysis of variance was performed using the GLM procedure of SAS (SAS Institute, Inc., Cary, N.C.). The model included the effects of antibiotic addition, *Bacillus* supplementation, day, and appropriate interactions.

Results and Discussion

Bacillus supplementation to pigs during the nursery phase of production did not influence ($P > 0.18$) production of TNF-α, IL-1β, or IL-4 from unstimulated PBMC (Table 1). Plasma TNF-α concentrations were also unaffected ($P = 0.67$) by *Bacillus* supplementation to pigs during the nursery period (Table 1). However, pigs fed *Bacillus* cultures had a higher ($P < 0.05$) production of IL-1β from LPS stimulated PBMC on d 20 after weaning when compared to d 42 after weaning, while IL-1β production was similar ($P > 0.10$) on d 20 and d 42 after weaning in pigs fed diets devoid of *Bacillus* cultures (*Bacillus* x day interaction, $P = 0.05$; Fig. 1). Furthermore, the production of IL-4 from ConA stimulated PBMC of pigs supplemented with *Bacillus* cultures was similar ($P > 0.10$) on d 20 and 42 after weaning, but pigs fed diets devoid of *Bacillus* cultures had a higher ($P < 0.05$) production of IL-4 from ConA stimulated PBMC on d 20 after weaning compared to production on d 42 after weaning (*Bacillus* x day interaction, $P = 0.05$; Fig. 2). Pigs fed antibiotics had lower ($P < 0.05$) plasma TNF-α concentrations on d 42 after weaning when compared to d 20 after weaning and compared to pigs fed diets devoid of antibiotics on d 20 and 42 after weaning (Antibiotic x day interaction, $P = 0.10$; Fig. 3). Moreover, pigs fed diets containing *Bacillus* cultures and antibiotics in combination on d 20 after weaning had a lower ($P < 0.05$) production of TNF-α from unstimulated PBMC when compared to d 42 after weaning and compared to pigs fed the negative control or antibiotics-only diets on d 42 after weaning (*Bacillus* x Antibiotic x day interaction, $P = 0.09$; Fig. 4).

The improvements in growth performance due to antibiotic supplementation observed in the current study and others (Gustafson and Bowen, 1997) may be due to decreased concentrations of plasma TNF-α by the end of the nursery period. Tumor necrosis factor-α is a pro-inflammatory cytokine that is released by macrophages during inflammation to activate cellular and humoral components of the immune system. This pro-inflammatory cytokine and others such as IL-1β and IL-6 are responsible for redistributing the body's nutrients from tissue growth to support immune function (Wan et al., 1989). Therefore, the reduction in plasma TNF-α due to antibiotic supplementation may allow the piglet to utilization energy for growth rather than for immune system development/activation.

Supplementation of *Bacillus* cultures has been reported to improve growth performance in weanling pigs (Yang et al., 2003); however, results have been variable. Administration of *Bacillus* cultures has resulted in improved feed intake in swine when evaluated in field trials on commercial swine farms and in university research experiments. At d 42 after weaning, pigs fed the diet with *Bacillus* cultures and antibiotics in combination had a higher concentration of TNF-α from unstimulated PBMC than at d 20 after weaning. The negative effects seen in feed efficiency and increased production of TNF-α from unstimulated PBMC due to *Bacillus* and antibiotic supplementation to pigs during Phase 3 may be due to the use oxytetracycline during this phase of production. A study conducted by Agtech Products, Inc. reported that oxytetracycline inhibits the growth of *Bacillus* spores in vitro. Therefore, the use of oxytetracycline during Phase 3 may have inhibited the growth or killed the *Bacillus* organisms, thereby eliciting an inflammatory immune response and negatively affecting the pig's growth response.

The results of this study indicate that care should be taken when combining direct-fed microbial products with antibiotics that may either mask their effect or be a detriment to performance due to the inflammatory responses that may be generated from the killing of the organisms by antibiotics. Although the concentrations of inflammatory cytokines measured earlier in the nursery phase in response to *Bacillus* supplementation were higher, at the end of the nursery period pigs supplemented with *Bacillus* cultures had reduced TNF-α and IL-1β concentrations from stimulated PBMC when compared to pigs fed diets devoid of *Bacillus*. These anti-inflammatory responses may be a result of the immune system responding to an initial inflammatory response from feeding Bacillus, such that the cytokine profile of these pigs develops toward a more anti-inflammatory profile as a feedback control response to inflammation. In this respect, the initial inflammation from *Bacillus* supplementation that may result in decreased performance guides the immune system development toward anti-inflammatory responses that promote growth and efficiency.

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Table 1. Effects of pigs fed diets with two levels of antibiotic supplementation (0 g and 50 g Carbadox/ton of feed during Phase 1 and Phase 2; 0 g and 400 g oxytetracycline/ton of feed during Phase 3), and two levels of *Bacillus* supplementation (0% and 0.25% 88/18) during Phase 1, Phase 2, and Phase 3 on cytokine elaboration responses from peripheral blood mononuclear cells cultures on days 20 and 42 after weaning.

	Bacillus at d 42 after weaning				Antibiotics at 42 d after weaning				Days Post-weaning			
Trait	-	+	SE	P-value	-	+	SE	P-value	20	42	SE	P-value
TNF-α (pg/mL)												
Plasma*	20.4	24.6	6.8	0.67	24.33	20.7	6-7	0.71	32.0	13.0	7	**0.06**
TNF-α (pg/mL)												
Unstimulated	1,102	1,032	195-203	0.81	1,202	931	195-203	0.34	815	1,319	195-203	**0.09**
Stimulated [1,**]	4,835	3,735	1095-1140	0.49	3,508	5,061	1095-1140	0.34	4,338	4,231	1095-1140	0.95
IL-1 β (pg/mL)												
Unstimulated	272	416	127	0.43	321	368	127	0.79	590	99	127	**0.012**
Stimulated [1,**, ***]	509	680	170	0.49	468	722	170	0.30	962	227	170	**< 0.01**
IL-4 (pg/mL)												
Unstimulated	11	0	5	0.18	4	7	6	0.78	0	11	6	0.18
Stimulated [2,**]	328	267	60	0.48	339	257	60	0.34	359	237	60	0.16

[1] Values represent the concentration of tumor necrosis factor-α (TNF-α) or interleukin-1 (IL-1β) in wells stimulated with lipopolysaccharide (LPS) minus the concentration of TNF-α or IL-1β in the unstimulated wells.

[2] Values represent the cytokine concentration in wells stimulated with concanavalin A minus the cytokine concentration in the unstimulated wells.

* Antibiotic × day interaction, P = 0.10 (see Fig. 3).

** *Bacillus* × day interaction, P ≤ 0.05 (see Fig. 1 & 2).

*** Antibiotic × *Bacillus* × day interaction, P = 0.09 (see Fig. 4).

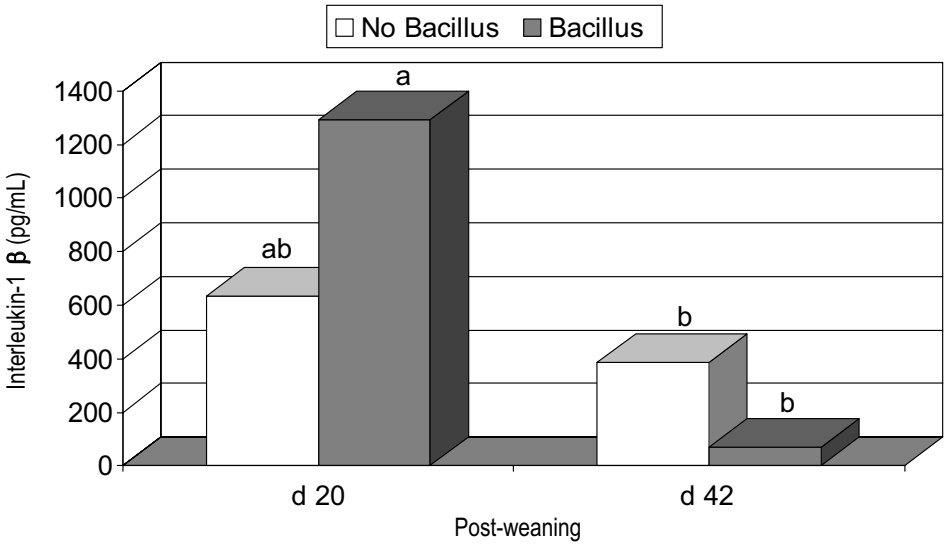

Fig. 1. Monocyte IL-1β elaboration responses from LPS stimulated cell cultures of peripheral blood mononuclear cells isolated from pigs fed diets with or without *Bacillus* cultures during the nursery phase of production (*Bacillus* x day interaction, P = 0.05). a,b Bars with differing letters represent means that differ (P < 0.05).

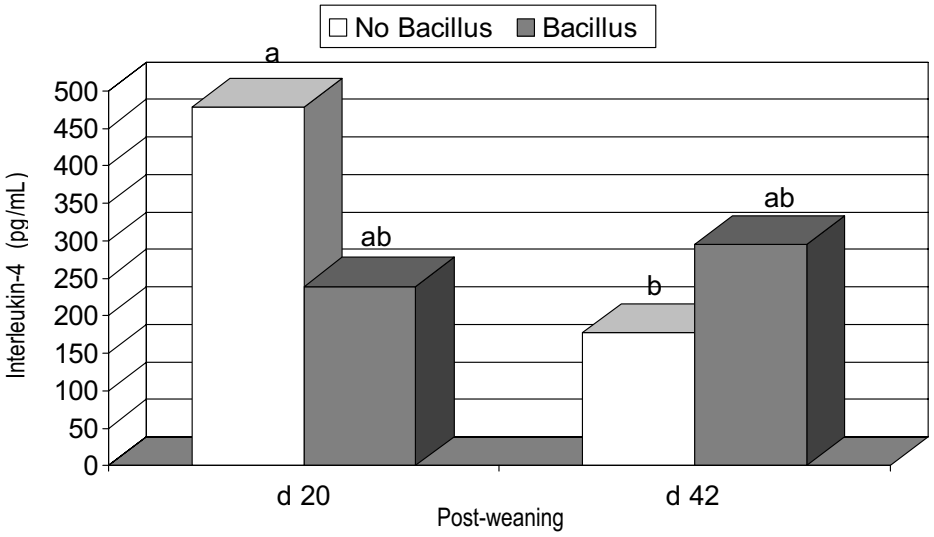

Fig. 2. Lymphocyte IL-4 elaboration responses from Con A stimulated cell cultures of peripheral blood mononuclear cells isolated from pigs fed diets with or without *Bacillus* cultures during the nursery phase of production (*Bacillus* x day interaction, P = 0.05). a,b,c Bars with differing letters represent means that differ (P < 0.05).

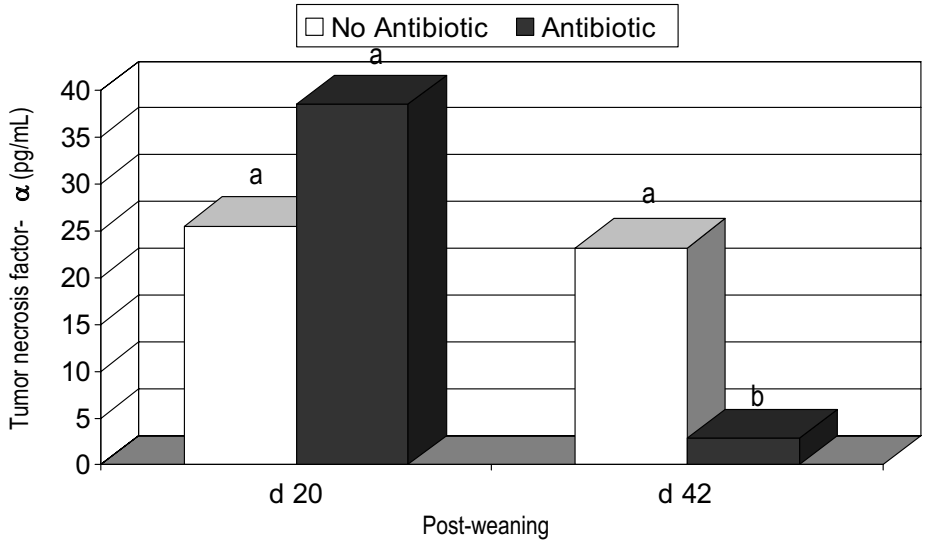

Fig. 3. Plasma TNF-α concentrations from pigs fed diets with or without antibiotics during the nursery phase of production (Antibiotic x day interaction, P = 0.10).
[a,b]Bars with differing letters represent means that differ (P < 0.05).

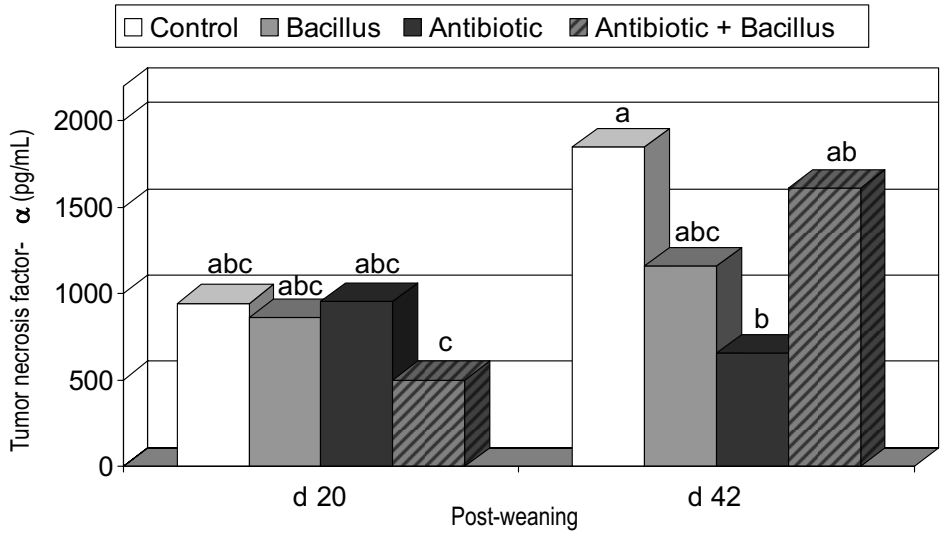

Fig 4. Monocyte TNF-α elaboration responses from unstimulated cell cultures of peripheral blood mononuclear cells isolated from pigs fed diets containing *Bacillus* cultures and/or antibiotics during the nursery phase of production (*Bacillus* x Antibiotic x day interaction, P = 0.09).
[a,b,c]Bars with differing letters represent means that are differ (P < 0.05).

Prediction of Number Born Alive and Weaning Weight of Litter in First Parity Sows Using Performance Test 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 reproductive performance in first parity females 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 (WT100) 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 was calculated. Backfat (BF), loin eye area (LEA), and body length (LEN) were measured. Number of live born pigs (NBA) and weight of litter at weaning (WWL) were recorded. Regression analyses were used to determine if NBA and WWL could be predicted using previous performance test records of the dam. Regression models included effects for contemporary group of the dam, maternal grandsire, and sire of the litter, as well as WT100, ADG, LEA, BF, and LEN as covariates. In Landrace, ADG was a significant covariate ($P = 0.02$) for NBA. For Yorkshire, LEN was a significant ($P < 0.01$) covariate for NBA, and ADG ($P = 0.06$) and LEA ($P < 0.01$) were significant covariates for WWL. In Duroc, WT100 ($P < 0.01$) and LEN ($P = 0.02$) were both significant covariates for NBA, whereas LEN ($P = 0.03$) was a significant covariate for WWL. In Hampshire, ADG was a significant ($P = 0.05$) covariate for NBA, and WT100 ($P < 0.01$), ADG ($P = 0.01$), and BF ($P = 0.03$) were significant covariates for WWL. Regression models accounted for 37 to 59% of the variation in NBA and WWL; however, the majority of this variation was due to contemporary group, maternal grandsire, and sire of the litter. No covariate alone contributed more than 1% to the total variation in NBA or WWL, so would probably not be useful in predicting these traits.

Introduction

Litter size (number born and number weaned) is an important economic component of sow productivity. Noguera et al. (2002a,b) reported that long-term selection experiments for directly increasing litter size by means of conventional selection have not, in general, been successful. This may be due to low heritability or the difficulty of achieving high selection intensity in practice. It is important to know how selection for other traits may affect this trait. The objective of this study, therefore, was to determine if performance test traits would be useful in predicting subsequent reproductive performance of first parity females in Landrace, Yorkshire, Duroc, and Hampshire breeds of swine.

Experimental Procedures

Data for this study consisted of performance test records of Landrace, Yorkshire, Duroc, and Hampshire pigs collected in a commercial swine operation (The Pork Group, A Division of Tyson Foods, Inc., Rogers, 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 2 indexes were combined into an overall ranking depending on the breed. Equal emphasis was given to both indexes for Landrace; more emphasis was given to the maternal index for Yorkshire; more emphasis was given to the Grow-Fin index for Duroc; and the emphasis was totally on the Grow-Fin index for Hampshire.

Gilts were fed for ad libitum consumption a pelleted corn-soybean meal diet that was 1.14% lysine, 19% protein, and 3,344 mcal/kg ME in groups of 8 to 10 pigs in a pen, with each pig having an area of 1.2 m^2. Exact composition of the diet varied due to ingredient cost. Different size pens were available in different facilities, so pens in some barns held 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), loin eye area (LEA), and body length (LEN) were measured. Backfat and LEA were measured at approximately the 12th rib using B-mode ultrasound equipment. Body length was measured from the top of the tail to the point of the shoulder when the head is down.

Gilts were ranked on an overall index at the end of the test. Those ranking highest were examined for acceptable phenotype (leg structure, vulva, etc.), and then retained for great-grandparent replacements if of acceptable phenotype; the next tier was used for grandparent replacements. Approximately 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 num-

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ber of pigs born alive (NBA), and total weaning weight of the litter (at an average of approximately 17 d of age, WWL) were recorded.

Linear regression was used to adjust WT100 to 100 d of age. Other performance test traits were adjusted to 177 d of age, and weaning weight of the litter was adjusted to 17 d of age. Regression coefficients used to adjust these traits are shown in Table 1.

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 maternal grandsires, is shown in Table 2. Regression analyses using PROC GLM of SAS (SAS Inst., Inc., Cary, N.C.) were performed for NBA and WWL. Models included terms for CG, maternal grandsire, and sire of the litter, as well as the performance test traits WT100, ADG, LEA, BF and LEN as covariates.

Results and Discussion

Means and standard deviations for all traits are given in Table 3. There were 805 Landrace, 2,970 Yorkshire, 624 Duroc, and 376 Hampshire females weighed at 100 d of age that were kept long enough to produce a first parity litter.

Results of regression analyses are presented in Table 4. Contemporary group was an important source of variation for both NBA and WWL for all breeds. Maternal grandsire was important ($P < 0.01$) for NBA in the Yorkshire breed and approached significance ($P = 0.07$) for NBA in the Duroc breed, but did not contribute to variation in this trait above that accounted for by CG for Landrace or Hampshire. Sire of the litter was also an important source of variation ($P < 0.01$) for NBA in Yorkshire and approached significance for NBA in Duroc ($P = 0.07$) and Hampshire ($P = 0.12$). Variation due to maternal grandsire was not significant ($P > 0.05$) for WWL in any breed; however, the P-value was < 0.20 in all breeds. Variation due to sire of the litter approached significance ($P = 0.11$) only in the Yorkshire breed.

In Landrace, ADG was the only covariate ($P = 0.02$) for NBA, whereas for WWL, no performance test trait showed a significant regression. For Yorkshire, LEN was a ($P < 0.01$) covariate for NBA; ADG ($P = 0.06$) and LEA ($P < 0.01$) were covariates for WWL. In Duroc, WT100 ($P < 0.01$) and LEN ($P = 0.02$) were both covariates for NBA, whereas LEN ($P = 0.03$) was a covariate for WWL. In Hampshire, ADG was a ($P = 0.05$) covariate for NBA, and WT100 ($P < 0.01$), ADG ($P = 0.01$) and BF ($P = 0.03$) were covariates for WWL.

Regression coefficients for covariates with P-values < 0.10 are shown in Table 5. For NBA, these may be interpreted as follows: 1) for a 1 lb increase in ADG, litter size should increase by 1.72 pigs in Landrace and by 1.91 pigs in Hampshire; 2) for a 1 lb increase in WT100, NBA should increase by 0.02 in Duroc; and 3) an increase in body length of 1 inch should increase NBA by 0.11 in Yorkshire and 0.20 in Duroc. For WWL in Yorkshire, an increase in ADG or LEA would decrease weaning weight of the litter. Small, negative genetic correlations between WWL and ADG (-0.04) and between WWL and LEA (-0.05) were found in the Yorshire breed (Johnson and Nugent, 2004). In contrast, an increase in WT100, ADG or BF would increase WWL in Hampshire, whereas a 1 inch increase in body length would increase WWL by 4.55 lb in Duroc.

Regression models accounted for 38 to 59% of the variation in NBA and for 37 to 53% of the variation in WWL (Table 4); however, the majority of this variation was due to contemporary group, maternal grandsire and sire of the litter. Although some covariates were significant sources of variation for NBA and WWL, none contributed more than 1% to the variation in these traits above that accounted for by CG, maternal grandsire, and sire of litter. An exception was that WT100, ADG, and BF contributed 2.3, 1.6, and 1.1%, respectively, of the 53% of the variation in WWL for Hampshire. These results implied that performance test traits would probably not be useful in predicting the reproductive traits of NBA and WWL.

Implications

Regression analyses indicated that relationships do exist between performance test traits and subsequent reproductive performance, although the amount of variation accounted for above that accounted for by contemporary group and sire effects is small. These relationships vary by breed and population.

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Table 1. Regression coefficients used to adjust data.

	Breed			
Trait[a]	Landrace	Yorkshire	Duroc	Hampshire
WT100, lb	1.634232	1.796254	1.603868	1.712756
WT177, lb	1.522738	1.933629	1.550914	2.140678
LEA, in^2	0.017444	0.033095	0.008587	0.024875
Backfat, in	0.002377	0.002819	0.003603	0.004339
Body length, in	0.087661	0.044705	0.059315	0.060399
Weaning wt of litter, lb	15.752126	15.747428	11.600902	12.766232

[a]WT100 is weight at approximately 100 d of age and was adjusted to 100 d of age; WT177, loin eye area, backfat, and body length were measured at the end of the 77-d performance test and were adjusted to 177 d of age. Weaning weight of litter was adjusted to 17 d.

Table 2. Descriptive statistics for data sets.

Item	Breed			
	Landrace	Yorkshire	Duroc	Hampshire
Number of contemporary groups	46	79	48	41
Number of maternal grandsires	110	301	107	58
Number of sires	151	361	111	69

Table 3. Mean and standard deviation for performance test traits and subsequent reproductive performance in the first parity for Landrace, Yorkshire, Duroc and Hampshire females.

Trait[a]	n	Mean	SD
Landrace			
AGE100, d	805	98.87	3.11
WT100, lb	805	111.49	12.25
ADG, lb	795	1.84	0.19
AGE177, d	795	175.51	4.01
WT177, lb	795	253.20	19.35
Body length, in	795	38.84	1.89
Backfat, in	795	0.64	0.14
Loin eye area, in^2	795	6.50	0.85
Litter size	805	7.63	2.53
Total weaning weight of litter, lb	740	193.74	63.91
Age at weaning, d	740	16.66	4.99
Yorkshire			
AGE100, d	2,970	99.66	2.87
WT100, lb	2,970	107.19	12.63
ADG, lb	2,950	1.99	0.23
AGE177, d	2,950	176.26	3.79
WT177, lb	2,950	260.63	21.71
Body length, in	2,950	38.50	1.92
Backfat, in	2,949	0.64	0.14
Loin eye area, in^2	2,949	6.76	0.85
Litter size	2,970	8.44	2.82
Total weaning weight of litter, lb	2,741	188.74	61.94
Age at weaning, d	2,741	16.98	4.47
Duroc			
AGE100, d	624	99.20	2.81
WT100, lb	624	103.76	12.45
ADG, lb	619	1.95	0.21
AGE177, d	619	175.89	3.88
WT177, lb	619	253.74	19.03
Body length, in	619	37.28	1.66
Backfat, in	618	0.69	0.13
Loin eye area, in^2	618	6.43	0.70
Litter size	624	7.95	2.29
Total weaning weight of litter, lb	624	149.97	48.03
Age at weaning, d	624	16.54	5.00
Hampshire			
AGE100, d	376	100.52	2.33
WT100, lb	376	97.03	10.41
ADG, lb	372	1.83	0.19
AGE177, d	372	177.25	3.41
WT177, lb	372	237.49	18.46
Body length, in	372	36.85	1.77
Backfat, in	372	0.58	0.11
Loin eye area, in^2	372	6.89	0.78
Litter size	376	7.66	2.13
Total weaning weight of litter, lb	375	156.69	57.25
Age at weaning, d	375	16.70	4.70

[a] AGE100 and WT100 are age and weight at 100 d of age; ADG is average daily gain on the 77-d performance test; and AGE177 is age at the end of the 77-d performance test. WT177, body length, backfat thickness and loin eye area were measured at the end of the 77-d performance test and were adjusted to 177 days of age by linear regression. WT100 was adjusted to 100 d of age by linear regression and total weaning weight of litter was adjusted to an average weaning age of 17 d. Average weaning weight is adjusted total weaning weight of litter divided by number of pigs in litter at weaning. Values for ages (AGE100, AGE177, and age at weaning) are unadjusted.

Table 4. Results of regression analysis (P-values[1] from type I SS) for number born alive, total weaning weight and average weaning weight for litters of Landrace, Yorkshire, Duroc, and Hampshire first parity females.

	Breed			
Source of variation[2]	Landrace	Yorkshire	Duroc	Hampshire
		Number born alive		
CG	< 0.01	< 0.01	< 0.01	< 0.01
Maternal grandsire		< 0.01	0.07	
Sire of litter		< 0.01	0.07	0.12
WT100			< 0.01	
ADG	0.02			0.05
Loin eye area				
Backfat	0.16			
Body length	0.13	< 0.01	0.02	
R^2	0.42	0.38	0.59	0.53
		Weaning weight of litter		
CG	< 0.01	< 0.01	< 0.01	0.05
Maternal grandsire	0.11	0.13	0.16	0.11
Sire of litter		0.11		
WT100				< 0.01
ADG		0.06		0.01
LEA		< 0.01		
Backfat				0.03
Body length			0.03	
R^2	0.45	0.37	0.50	0.53

[1]P-values not shown are > 0.20.
[2]CG = contemporary group of the dam, and WT100 = 100-d weight.

Table 5. Regression coefficients for covariates having P-values < 0.10.

	Breed			
Source of variation[1]	Landrace	Yorkshire	Duroc	Hampshire
		Number born alive		
WT100, lb			0.02146	
ADG, lb	1.72484			1.90608
Body length, in		0.11472	0.20344	
		Weaning weight of litter		
WT100, lb				0.98078
ADG, lb		-7.79598		35.69416
LEA, in^2		-5.41447		
Backfat, in				84.79456
Body length, in			4.55406	

[1]WT100 = 100-d weight.

Forage Availability and Nutritive Composition of Bahiagrass and Bermudagrass Grazed by Steers With or Without Steroid Implants[1]

M.L. Looper[2], R. Flores[3], G.E. Aiken[4], C.F. Rosenkrans, Jr.[3], and D.K. Brauer[2]

Story in Brief

Bermudagrass (*Cynodon dactylon*) is the predominant warm-season perennial grass used for cattle production in Arkansas. Bahiagrass (*Paspalum notatum*), also a warm-season perennial, is grown along the Gulf Coast but not utilized extensively in Arkansas because it does not persist in this colder environment. Objectives were to compare forage availability and nutritive composition of a more cold-tolerant bahiagrass variety, 'Sand Mountain' (n = 4 pastures) or 'Common' bermudagrass (n = 4 pastures) grown in west-central Arkansas, and to determine performance of crossbred steers (initially n = 48; last 54 days n = 32) with or without steroid implants grazing bahiagrass and bermudagrass pastures for 97 days. Forage availability during the entire grazing period was lower ($P < 0.001$) for Sand Mountain bahiagrass (1,043 lb dry matter (DM)/acre) than Common bermudagrass (2,042 lb DM/acre), and forage availability declined ($P < 0.001$) for both forages with time during the experiment. A forage x date interaction was present ($P < 0.05$) for acid detergent fiber (ADF) and crude protein (CP) content, and tended ($P = 0.08$) to influence neutral detergent fiber concentration. Percentages of CP were greater and ADF was lower in bermudagrass compared with bahiagrass in August following July fertilization. Forage type, steroid implant, and the interaction did not influence ($P > 0.10$) average daily gain (mean = 1.9 lb/day per steer) during the grazing period. Sand Mountain bahiagrass may be suitable as a warm-season grass in northern portions of the Southeast; however, several years of data are needed to determine the persistence of Sand Mountain bahiagrass in west-central Arkansas.

Introduction

Bermudagrass and bahiagrass are the predominant perennial warm-season grasses utilized for cattle grazing in the southeastern U.S. Winterkill is problematic for specific varieties of both forages and limits their use to adapted areas of the southeastern U.S. Bermudagrass is used extensively throughout the Southeast, usually at latitudes below 36° N (Taliaferro, 2005) while bahiagrass is widely used along the Gulf Coast up to southern Arkansas. Sand Mountain bahiagrass, a naturally selected bahiagrass developed by E. van Santen and Auburn University, is more cold-tolerant than other bahiagrass varieties and may be a suitable warm season grass for northern portions of the Southeast. To our knowledge, performance data of steers grazing bahiagrass as far north as west-central Arkansas are non-existent. Objectives of the current experiment were to 1) compare forage availability and nutritive composition of 'Sand Mountain' bahiagrass with 'Common' bermudagrass grown in west-central Arkansas, and 2) determine performance of steers with or without steroid implants grazing bahiagrass and bermudagrass pastures.

Experimental Procedures

This experiment was conducted near Booneville (35° 5' N; 94° 0' W) in west-central Arkansas. Crossbred steers (n = 48; initial body weight = 610 ± 57 lb) with (n = 24 steers) or without (n = 24 steers) steroid implants (Synovex S™) were randomly assigned to 2.5-acre pastures of Sand Mountain bahiagrass (n = 4 pastures) or Common bermudagrass (n = 4 pastures) for 97 days. Due to drought conditions, the initial stocking rate of 6 steers/pasture (2.4 steers/acre) was reduced to 4 steers/pasture (1.6 steers/acre) on July 21 until termination of the experiment (September 13). Body weights were recorded at the initiation (June 8), day 56 (August 3), 84 (August 31), and at termination of grazing (September 13). Implanted steers were reimplanted at day 56 of grazing. Pastures were fertilized prior to initiation of grazing on May 5 (65 lb N/acre), and again on July 7 (51 lb N/acre) and August 22 (91 lb N/acre). Forage availability was evaluated every 2 weeks using a disk meter, and compressed forage height was recorded at 50 locations within pastures. To calibrate disk meter measurements, forage was clipped to ground level beneath the disk meter at 5 locations across each pasture monthly. Samples were dried (140°F) in a forced-air oven for 72 h and weighed for calculation of regression equations relating lb dry matter (DM)/acre with disk meter height. Random grab samples (10-12 samples/pasture) for nutritive analyses were collected monthly, ground to pass through a 0.04-inch screen, and analyzed for crude protein (CP; Leco® Nitrogen Determinator, St. Joseph, Mich.), acid detergent fiber (ADF), and neutral detergent fiber (NDF) using Goering and Van Soest (1970) procedures.

Forage availability and nutritive composition were analyzed as repeated measures using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.) with a compound symmetry covariance structure. The model included forage type, date, and the interaction. Least squares means were compared using the PDIFF option in PROC MIXED of SAS when protected by a significant ($P < 0.05$) treatment effect. Effects of forage type, implantation, and the interaction on ADG of steers on day 56 and 84, and on overall ADG on day 97 was determined by the MIXED procedure of SAS using pasture as the experimental unit.

[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, Ark.

[3] Department of Animal Science, Fayetteville

[4] USDA-ARS, Forage-Animal Production Research Unit, Lexington, Ky.

Results and Discussion

Forage availability during the entire 97-day grazing period was lower ($P < 0.001$) for Sand Mountain bahiagrass (1,043 lb DM/acre) than Common bermudagrass (2,042 lb DM/acre). Overall, forage availability of both forages declined during the experiment from a mean initial availability of 2,556 lb DM/acre to 1,045 lb DM/acre at termination of grazing (Fig. 1) and was partially due to extremely dry conditions in the Booneville area. Rainfall during the experiment (5.4 in) was approximately 30% of the 30-yr norm (18 in; National Oceanic and Atmospheric Administration-National Weather Service, 2005). Nitrogen is frequently the most limiting factor for bahiagrass production but sufficient rainfall also is necessary for growth. A forage x date interaction was present ($P < 0.05$) for CP and ADF content, and tended ($P = 0.08$) to influence NDF concentration (Table 1). Crude protein was greatest ($P < 0.05$) for bahiagrass on the initial collection date (June 15) while CP was greatest for bermudagrass in June and August (Table 1). Arthington and Brown (2005) reported CP decreased approximately 38% from week 4 to week 10 of maturity in both 'Pensacola' bahiagrass and 'Tifton 85' bermudagrass. Fertilization of pastures on July 7 with 51 lb N/acre during the current experiment increased CP of bermudagrass on August 10 compared with CP on July 12 (Table 1). However, CP for bahiagrass was similar ($P > 0.10$) before and after the July fertilization (Table 1). Percentage of ADF was greatest for bermudagrass on September 6; however, ADF was increased on August 10 and remained higher on September 6 (Table 1). Increased ADF is negatively correlated with digestibility (Van Soest et al., 1978). Averaged across all dates, bahiagrass contained 6.6% more ADF than bermudagrass which was similar to results reported by Johnson et al. (2001). Percentages of NDF were greatest for the August and September dates for both forages (Table 1).

Forage type, steroid implant, or the interaction did not influence ($P > 0.10$) cumulative ADG at days 56, 84, or total ADG during the entire 97-day grazing experiment. Total ADG was 1.9 lb/day (pooled standard error = 0.1) per steer for both bahiagrass and bermudagrass. Typically, steroid implants improve ADG in cattle by 9% to almost 18% in grazing cattle, and DM intake is increased in implanted animals (Rumsey et al., 1992). Consequently, sufficient available forage is necessary to achieve additional weight gain with steroid implants (Rumsey and Hammond, 1990). Rayburn (1986) reported forage intake was maximized when forage availability was approximately 2,000 lb of DM/acre. Due to less than normal rainfall, forage availability for both forages may have been limited from the end of July until the termination of the experiment in September (Fig. 1), and may partially explain why ADG was not different ($P > 0.10$) between steers with or without steroid implants. Differences in forage quality between bahiagrass and bermudagrass at various times during the experiment, drought conditions, light stocking rates, cattle weighing schedule, and/or a limited number of animals also may have affected these results.

Forage availability of bahiagrass was lower than bermudagrass during the entire grazing period. Further, CP was greater and ADF was lower in bermudagrass compared with bahiagrass in August following July fertilization. However, steers grazing either bahiagrass or bermudagrass had similar ADG (1.9 lb/day per steer) during the experiment. Bahiagrass may be suitable as a warm-season grass in northern portions of the Southeast. Several years of data are needed to determine the persistence of bahiagrass in west-central Arkansas.

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Table 1. Percentages of crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) of 'Sand Mountain' bahiagrass and 'Common' bermudagrass harvested on four dates during the summer and early fall.

	CP	ADF	NDF
Bahiagrass			
June 15	12.9^{ab}	26.6^{de}	53.7^{f}
July 12	6.1^{d}	29.5^{bc}	57.1^{de}
August 10	8.4^{cd}	32.4^{a}	60.8^{a}
September 6	8.5^{cd}	31.0^{ab}	58.8^{bcd}
Bermudagrass			
June 15	10.2^{abc}	25.3^{e}	55.5^{ef}
July 12	6.8^{cd}	27.4^{cd}	57.7^{cd}
August 10	13.5^{a}	27.9^{cd}	59.4^{abc}
September 6	9.7^{bcd}	31.6^{ab}	59.5^{ab}
Pooled standard error	1.4	0.7	0.6

^{a,b,c,d,e,f}Means within a column without a common superscript differ; forage x date interaction (CP and ADF, $P < 0.05$; NDF, $P = 0.08$).

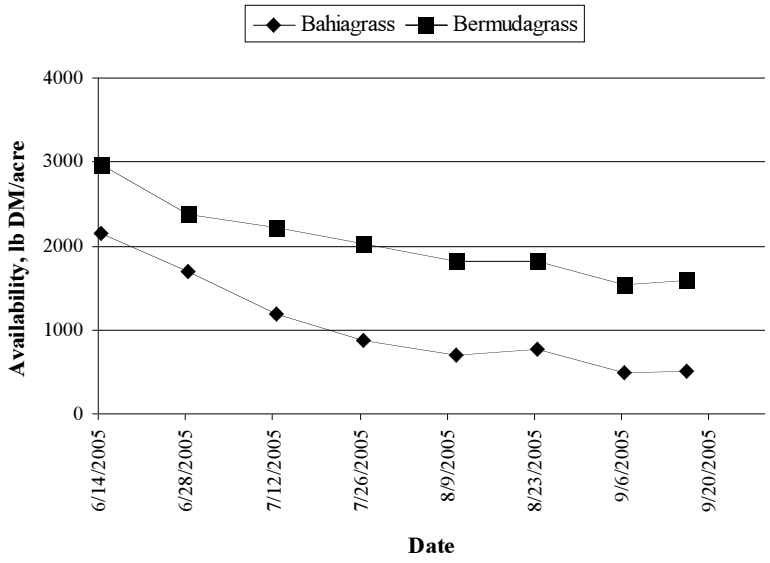

Fig. 1. Forage availability of 'Sand Mountain' bahiagrass and 'Common' bermudagrass during summer and early fall (forage effect, $P < 0.05$; date effect, $P < 0.05$).

Effects of Grain By-products as Supplements for Stocker Cattle Grazing Bermudagrass[1]

T.E. Davis, B. Kegley, K. Coffey, W. Coblentz, R. Ogden, and P. Hornsby[2]

Story in Brief

Two experiments were conducted to compare corn, dried distillers' grains (DDG), and pelleted soybean hulls (SH) as supplements for cattle grazing bermudagrass. In Exp. 1, 66 crossbred steers (675 ± 7.1 lb) were stratified by weight and allotted randomly to six 6-acre bermudagrass pastures for a 107-d study. One of three supplement treatments (corn, DDG, or SH) was assigned randomly to each pasture group and was offered at 0.5% (as fed) of BW. Calves were weighed at 28-d intervals and supplement was adjusted after each weigh day. In Exp. 2, five ruminally-cannulated steers grazed bermudagrass pasture and were individually fed supplements (corn, DDG, or SH) at 0.5% as fed of BW in a 3 x 3 replicated incomplete Latin-square design with a 14-d adaptation and a 5-d sampling period. In Exp. 1, supplementation with DDG and corn increased ($P < 0.04$) ADG compared to supplementation with SH (1.96, 1.92, and 1.63 lb for DDG, corn, and SH, respectively). In Exp. 2, ruminal DM degradation measures of bermudagrass were not affected by type of supplementation. The potential extent of digestion for DDG (93%) was lower than for corn (97%, $P = 0.01$) and SH (96%, $P = 0.06$). Supplementation with corn or DDG at 0.5% of BW improved gain of stocker cattle grazing bermudagrass compared to supplementation with SH, but these differences were not explained by differences in bermudagrass ruminal DM degradation measurements.

Introduction

Arkansas has approximately 420,000 stocker cattle and the number is increasing. The type of feed and its cost affect the profitability of the enterprise; therefore, new sources of low-cost nutritious supplements are constantly being sought. With the increasing number of ethanol plants in the US, there will be an increasing amount of by-product feeds available. Distillers' grains are by-products that remain following the removal of starch and soluble sugars from corn, with the remaining protein and non-soluble carbohydrates adding valuable nutrients to cattle diets; however, P concentrations are above cattle requirements and could cause health problems (possible formation of urinary calculi). Distillers' grains have been an economical feed for feedlot and dairy cattle for years; with increasing supply, they may become economical as supplements for grazing animals.

Limited research has investigated using distillers' grains as supplements for calves grazing bermudagrass, which is a common forage in Arkansas. Although soil fertility, rainfall, and maturity affect the nutritive value of bermudagrass, its high fiber content limits calf growth. Calves grazing bermudagrass generally respond positively to supplemental energy from grains. Yet, high levels of starch-containing grains, such as corn, decrease forage intake and digestion of forage-based diets. Soybean hulls are a locally-available milling by-product that are low in starch and thus provide energy without the potential negative impacts on fiber digestion. A comparison of distillers' grains, soybean hulls, and corn in stocker cattle would provide information for Arkansas producers and allow them to make more informed and economical supplementation choices.

Experimental Procedures

Experiment 1. Sixty-six crossbred steers (initial BW averaged 675 ± 7.1 lb) were stratified by BW and allotted randomly to grazing six 6-acre pastures at the University of Arkansas Stocker-Receiving Unit near Savoy, Ark., on May 11, 2005. Calves had ad libitum access to fresh water and were monitored daily for morbidity. One of three supplement treatments (corn, DDG, or SH) was assigned randomly to each pasture group and steers were offered these supplements at 0800 h daily at a rate of 0.5% of BW (as fed). Pastures were predominately common bermudagrass (14.7% CP, 68% neutral detergent fiber [NDF], 32% acid detergent fiber [ADF], 0.39% P) and averaged 5,692 lb/acre of available forage over the 107-d study. Calves were weighed at 28-d intervals and the amount of supplement offered was adjusted after each weigh day such that calves were offered 0.5% of BW. Any supplement refused was recorded. Supplement samples were collected every 28 d and were analyzed for CP, NDF, ADF, and P.

Cattle were weighed at the beginning and end of the trial on two consecutive days. Blood samples were collected on d 0, 28, 56, 84, and 107 via jugular venipuncture with vacuum tubes. These samples were stored on ice after collection until centrifuged at 1,200 x g for 20 min for separation of serum or plasma; then serum or plasma samples were stored frozen (-4°F) until analyzed. Samples for serum urea nitrogen concentrations were collected into glass tubes containing a clot activator (BD Vacutainer®, Franklin Lakes, N.J.) and analyzed with a colorimetric assay (L-Type UN kit, Wako Chemicals USA, Inc., Richmond, Va.). Samples for plasma nonesterified fatty acid (NEFA) concentrations were taken in tubes with EDTA (BD Vacutainer®). Plasma was analyzed with a commercial colorimetric assay (NEFA-C kit, Wako Chemicals USA, Inc.).

[1] Financial support for this project was provided by the Arkansas Department of Higher Education Student Undergraduate research Fellowship (SURF) and a Dale Bumpers College of Agricultural, Food and Life Sciences Honors College Research Grant.

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Fecal grab samples were taken from four calves per pasture on d 84 and 107 and stored frozen to examine fecal P concentrations. Fecal material was later thawed, dried in a forced-air oven at 122°F, ground to pass through a 1-mm screen of a Wiley Mill, subsampled, wet ashed with nitric acid, and P determined with a colorimetric assay. Additionally, forage availability was measured every 28 d with a calibrated rising disk meter, and grab samples were taken and composited to determine CP, NDF, ADF, and P.

Steer BW, ADG, blood metabolites, and fecal P concentrations were statistically analyzed using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). The experimental unit was pasture. The model included the effect of supplement. A repeated statement was used for blood data.

Experiment 2. Five ruminally-cannulated crossbred (Gelbvieh x Angus x Brangus) steers (initial BW averaged 1,750 lb) grazed a bermudagrass pasture (3.6 acres) for three 19-d periods and had ad libitum access to fresh water. Steers were weighed at the beginning and end of each period. Each period consisted of 14 d of supplement adaptation followed by 5 d of ruminal digestion measurements. The experiment was designed such that each steer was offered each supplement for one period during the study, and so that each supplement was offered to two steers during two periods and one steer during one period. By using this design, five animal observations were provided for each supplement. Period 1 began on June 28, 2005. Steers were caught daily at 0800 h and individually fed the supplements described in Exp. 1 (Table 1) at 0.5% of BW (as fed).

Bermudagrass forage was collected from the same pasture the steers were grazing immediately before the ruminal measurement phase of Period 1. In situ incubations of the forage and supplements were conducted as described by Vanzant et al. (1998). Dacron bags (10 x 20 cm; 53 ± 10-µm pore size; Ankom Co., Fairport, N.Y.) were filled with 5 g (as-fed) of dried (122°F), ground (to pass through a 2-mm screen in a Wiley Mill) bermudagrass, or the appropriate supplement, and then heat sealed to determine ruminal DM digestibility. All Dacron bags for each time period were placed in mesh laundry bags (35 x 50-cm), preincubated in tepid (102°F) water for 20 min to decrease the lag time associated with microbial attachment, and then inserted (except for 0 h) into the ventral rumen before the morning feeding. Bags containing the appropriate supplement were removed at 0, 3, 6, 9, 12, 18, 24, 36, 48, and 72 h after insertion. Bags containing dried bermudagrass were removed at 0, 6, 9, 12, 18, 24, 48, 72, 96, and 120 h after insertion. All bags were rinsed five times with tap water, then five times with deionized water, in a top-loading washing machine with a 1 min agitation and a 2 min spin per rinse to remove particles adhering to the outside of bags. Bags were dried under forced air for at least 48 h at 122°F and then weighed after equilibration to atmospheric moisture. The percentage of forage or supplement DM remaining at each incubation time was fitted to the nonlinear regression model of Mertens and Loften (1980). Fraction A represented the portion that was immediately soluble in water, Fraction B was defined as the portion of DM that disappeared at a measurable rate, and Fraction U represented the portion that was undegradable in the rumen. Potential extent of digestion was calculated as 100 - U. Kinetic parameters (B, U, digestion lag time [L], and rate of disappearance [k_d]) were estimated using PROC NLIN of SAS (SAS Inst., Cary, N.C.). After parameters were estimated, treatment comparisons were made using PROC MIXED of SAS where the model included animal, period, and treatment.

Results and Discussion

Experiment 1. Steer BW (Fig. 1) were not different ($P > 0.05$) from d 0 to 84; BW did differ ($P < 0.05$) on d 107, when steers supplemented with corn and DDG weighed more than steers supplemented with SH ($P < 0.04$). Average daily gains of steers supplemented with corn (1.92 lb) and DDG (1.96 lb) were greater than for steers supplemented with SH (1.63 lb; $P < 0.04$) for the entire 107 d. The lower ADG for steers supplemented with SH differ from the results of Anderson et al. (1988) and Garces-Yepez et al. (1997). These researchers reported similar ADG for cattle supplemented with corn versus SH. In our study, supplement type did not affect forage availability in the pastures, and forage availability was never limiting (minimum observed was 2,749 lb DM/acre).

There was a main effect ($P < 0.01$) of supplement type on serum urea-N (Fig. 2). Steers supplemented with DDG had the greatest ($P < 0.01$) serum urea-N concentrations, steers supplemented with SH had intermediate ($P < 0.05$) concentrations, and steers supplemented with corn had the lowest ($P < 0.05$) concentrations of serum urea-N. This difference was probably because of the greater amount of CP that the DDG and SH contained as compared to corn (Table 1). This excess protein was degraded in the rumen and the ammonia was absorbed across the rumen wall and converted to urea in the liver. Because of the moderate to high level of CP in the bermudagrass, none of these steers, even those supplemented with corn, should have been deficient in protein. All of these serum urea-N concentrations are considered high for cattle, and the concentrations for the steers supplemented with DDG were approaching levels that may cause decreased fertility for heifers of breeding age (Elrod and Butler, 1993).

Concentrations of plasma nonesterified fatty acid (NEFA; Fig. 3) were not different ($P = 0.69$) among supplemental treatments. Plasma NEFA concentrations increase when fat stores are being metabolized for energy utilization. The concentrations of NEFA were greatest ($P < 0.01$) on d 0, before supplementation started, and were lower for the remainder of the experiment, indicating that energy was not acutely limiting for these growing steers.

There was a main effect of supplement source and day on fecal-P concentrations ($P < 0.003$). Steers supplemented with DDG had the greatest ($P < 0.01$) fecal-P concentrations (0.84%), corn supplemented steers were intermediate (0.70%) and did not differ ($P = 0.25$) from that of steers supplemented with SH who had the lowest concentrations of fecal-P (0.66%). These results were expected because of DDG having a greater concentration of P, corn being intermediate, and SH containing the lowest P concentration. Fecal-P concentrations also varied by day, with concentrations on d 84 (0.70%) being lower than concentrations on d 107 (0.84%). This difference probably reflects an increased concentration of P in the bermudagrass during this last period.

Experiment 2. There were no effects ($P > 0.28$) of supplement type on ruminal DM disappearance of bermudagrass (Table 2). These results agree with the results of Garces-Yepez et al. (1997) where sheep were fed a corn-based supplement or SH at a similar rate as in this study and no suppression of ruminal organic matter digestibility was observed. However, Galloway et al. (1993) showed a decrease in bermudagrass hay intake and NDF digestion when cattle were supplemented with corn at 0.5% of BW.

Ruminal DM disappearances of supplements (Table 2) were different among sources, with DDG having the greatest water soluble fraction, corn intermediate, and SH having the smallest ($P < 0.01$). Soybean hulls had the greatest ($P < 0.01$) fraction that was

degradable at a measurable rate; corn was intermediate, and DDG the smallest. Rate of disappearance (k_d) did not differ (P = 0.26) between DDG and SH, yet both rates were lower than that of corn (P < 0.01). Lag times were greatest (P < 0.01) from SH, intermediate from DDG, and smallest from corn. The potential extent of ruminal DM disappearance was greater for corn (P < 0.03) than for DDG with SH being intermediate and not different from either corn or DDG. However, all potential extents of ruminal DM disappearance were greater than 92%.

In conclusion, supplementation with corn or DDG at 0.5% of BW improved ADG of stocker cattle grazing bermudagrass compared to supplementation with SH. However, ruminal DM disappearance of bermudagrass was not different when these supplements were fed at 0.5% of BW daily. All these supplement types produced desirable rates of gain for stocker cattle grazing bermudagrass in Arkansas.

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Table 1. Nutrient composition of supplements fed to steers grazing bermudagrass pasture.

	CP	NDF	ADF	P
	----------% of DM----------			
Corn	9.0	13.3	3.0	0.14
Distillers' grains	29.0	45.3	17.6	0.72
Soybean hulls	12.1	65.3	47.4	0.11

Table 2. Ruminal disappearance kinetics of bermudagrass forage and supplements for steers grazing bermudagrass pasture in Exp. 2.

	Fraction A[1]	Fraction B[1]	Fraction U[1]	Lag time	K_d[2]	Potential extent[3]
	----------% of DM----------			h	/h	%
Bermudagrass						
Corn	18.6	52.3	29.1	0.75	0.032	70.9
DDG[4]	17.2	52.2	30.6	1.15	0.038	69.4
SH[5]	17.3	52.2	30.5	1.33	0.038	69.5
P-value	0.32	0.99	0.29	0.67	0.38	0.29
SE	0.64	1.08	0.65	0.46	0.0033	0.65
Supplement						
Corn	32.7[b]	64.3[b]	3.0	0.4[f]	0.108[a]	97.0[d]
DDG[4]	37.2[a]	55.6[c]	7.2	1.4[e]	0.043[b]	92.9[e]
SH[5]	14.4[c]	81.1[a]	4.5	4.5[d]	0.055[b]	95.6[de]
P-value	<0.0001	<0.0001	0.034	0.0111	0.0011	0.034
SE	0.77	0.97	0.84	0.65	0.007	0.84

[1]Fraction A = immediately soluble fraction, B = fraction disappearing at a measurable rate, and U = undegraded fraction
[2]K_d = ruminal disappearance rate
[3]Calculated as (100-U)
[4]Dried distillers' grains
[5]Soybean hulls
[abc]Within a feed type and column, means with different superscripts differ (P < 0.01).
[def]Within a feed type and column, means with different superscripts differ (P < 0.05).

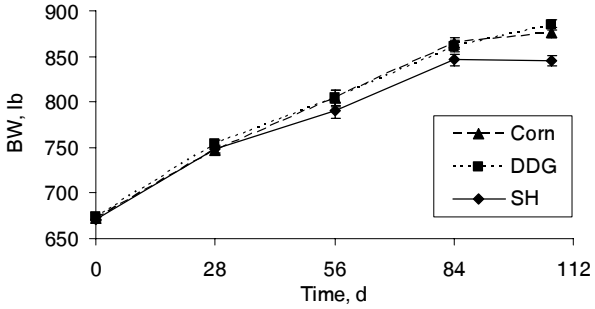

Fig. 1. Effect of supplement source on performance of steers grazing bermudagrass pastures throughout a 107-d trial (Exp. 1).

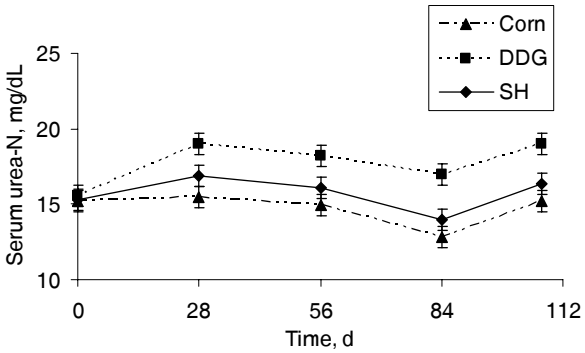

Fig. 2. Effect of supplement source on serum urea-N concentrations from steers grazing bermudagrass pastures in Exp. 1.

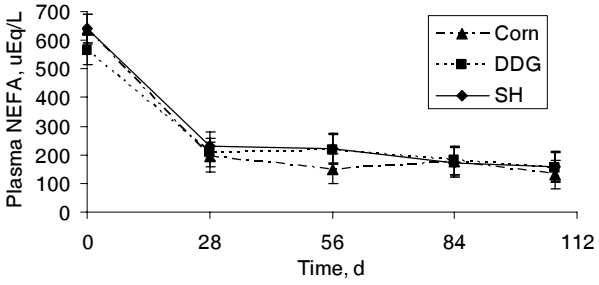

Fig. 3. Effect of supplement source on plasma nonesterified fatty acid (NEFA) concentrations in steers grazing bermudagrass pastures in Exp. 1.

Effects of Planting Date and Glyphosate Application on Performance of Stocker Cattle Grazing Cool-Season Annual Grasses Interseeded into Warm-Season Grass Sod

P. Beck, S. Gunter, M. Phillips, and B. Stewart[1]

Story in Brief

Normally, in southern Arkansas, interseeding of cool-season grasses is delayed until early to mid-October to reduce competition between warm-season grasses and cool-season annual grasses, which delays the initiation of grazing of these pastures. Sod-suppression using glyphosate has been suggested as a way to have an earlier sod-seeding date, thus improving fall forage production and animal performance. This research was conducted to determine the impact of an application of a low rate of glyphosate herbicide and planting date on performance of growing beef calves grazing interseeded cool-season annual pastures. Twenty, 2-acre bermudagrass/crabgrass pastures were planted to soft-red winter wheat (cv Roane, 120 lb/acre) and annual ryegrass (cv Marshall, 20 lb/acre) in mid-September or mid-October of 2005 using a no-till drill, with or without an application of 1 pint of glyphosate at planting. Planting date did not affect ($P \geq 0.07$) overall ADG, but ADG of calves grazing pastures planted in September was 0.62 lb/day greater ($P = 0.03$) from April to May than ADG of calves grazing pastures planted in October. Glyphosate application at planting increased ($P \leq 0.05$) overall ADG and ADG from mid- February to mid-March. Planting in September with an application of glyphosate increased ($P \leq 0.01$) grazing d/acre by 43 d compared to planting in September without glyphosate application or planting in October with or without glyphosate. Gain per acre was 146 lb greater ($P < 0.01$) for pastures planted in September with glyphosate application compared to planting in September without glyphosate application or planting in October with or without glyphosate.

Introduction

In the fall and early spring, grazing stocker calves on small grain pasture has been extensively used to improve net-farm income in the High Plains, this forage system is not as wide-spread in the Southeast. The improved net income comes from the availability of high-quality forage at a time of year when it is usually scarce and the availability of weaned calves at a seasonally low price. This fact suggests that BW gain during the fall and early winter is more valuable than gain during the spring. There are approximately 11.8 million acres of bermudagrass (*Cynodon dactylon* [L.] Pers.) grown in the southern United States. Because much of the land is not suited for cultivation, interseeding of small grains and annual ryegrass into warm-season grass sod, which has a low machinery requirement, is common throughout the southeastern United States. Normally in southern Arkansas interseeding is delayed until early to mid-October to reduce competition between warm-season grasses and cool-season annual grass seedlings. This delays the initiation of grazing of these pastures. Sod-suppression using glyphosate has been suggested as a way to have an earlier sod-seeding date, thus improving fall forage production and animal performance. This research was conducted to determine the impact of an application of a low rate of glyphosate herbicide and planting date on performance of growing beef calves grazing interseeded cool-season annual pastures.

Experimental Procedures

Twenty, 2-acre bermudagrass/crabgrass pastures were interseeded with soft red winter wheat (cv Roane, 120 lb/acre) and annual ryegrass (cv Marshall, 20 lb/acre) in mid-September or mid-October of 2005 using a no-till drill, with or without an application of 1 pint of glyphosate (Roundup, Monsanto Co., St. Louis, Mo.). In the fall before seeding, the pastures were grazed to reduce standing herbage mass in order to increase seed to soil contact and reduce shading of cool-season grass seedlings. Glyphosate was applied the day prior to planting. Approximately 1 month after seeding (on October 11 and November 11 for pastures planted in September and October, respectively), 200 lb/acre of 30-0-30 fertilizer was applied. Ammonium nitrate (150 lb/acre) was applied to all pastures on February 9.

Grazing was initiated when adequate forage was visually estimated to have accumulated to support 3 calves/pasture (2 heifers and 1 steer; average BW = 601 ± 11.8 lb) on January 18 or February 15 for pastures planted in September or October, respectively. Grazing was managed using the put-and-take method, where the 3 initial calves were used to measure performance and additional calves were added as necessary in order to equalize grazing pressure among pastures. The calves were fed 1 lb of corn-based supplement daily designed to supply required minerals, prorated for feeding 3 d/week. Forage DM yield was estimated during the trial using a rising-plate meter calibrated by clipping to ground level and regression equations were developed to estimate DM yield. Beginning, ending, and interim (28-d) BW were recorded unshrunk at 0800 h.

Calf ADG and total BW gain were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.) and animal grazing day/acre, and gain/acre were analyzed by analysis of variance using the GLM procedure of SAS as a completely randomized design using a 2 x 2 factorial arrangement of treatments. Pasture was used as the experimental unit, and the random term for ADG and total BW gain was pasture within treatment. Because grazing day/acre and gain/acre were determined on a pasture basis, residual error was used as the error term. In the presence of a significant planting date by glyphosate application interaction ($P < 0.05$), least-squares means of the interactive effects were separated using predicted differences.

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Results and Discussion

There was no significant planting date by glyphosate application interaction (P > 0.22) for calf BW, ADG, or total BW gain during the grazing period, so the main effects of planting date and glyphosate application are shown in Tables 1 and 2, respectively. In February, March, April, and May, BW was greater (P ≤ 0.04) for calves grazing pastures planted in September than calves grazing pastures planted in October, because the calves began grazing 28-d earlier (Table 1). The initial grazing BW of all calves did not differ (P = 0.92) by planting date, averaging 600 lb. Planting date did not affect (P ≥ 0.07) overall ADG or ADG during the February to March or March to April grazing periods, but ADG of calves grazing pastures planted in September were 0.62 lb/day greater (P = 0.03) from April to May than ADG of calves grazing pastures planted in October. Total BW gain per calf was 75 lb greater (P < 0.01)for pastures planted in September than for pastures planted in October.

Application of glyphosate did not affect (P ≥ 0.18) BW of calves at anytime during the grazing study (Table 2). Glyphosate application at planting increased (P ≤ 0.05) overall ADG and ADG from mid-February to mid-March, but did not affect (P ≥ 0.22) ADG from January to February, March to April, or April to May. Total BW gain per calf was increased (P = 0.04) 28 lb by applying glyphosate at planting.

Because of significant planting date by glyphosate application interactions (P ≤ 0.04) grazing d/acre and BW gain/acre are shown in Figures 1 and 2, respectively, by planting date and glyphosate treatment. Planting in September with an application of glyphosate increased (P ≤ 0.01) grazing d/acre by 43 d compared to planting in September without glyphosate application or planting in October with or without glyphosate (Fig. 1). Body weight gain/acre was also increased (P < 0.01) 146 lb by planting in September with glyphosate application compared to planting in September without glyphosate application or planting in October with or without glyphosate (Fig. 2).

Following the September 19 planting, rains associated with hurricane Katrina caused the emergence of interseeded wheat and ryegrass, but warm weather following these rains also initiated regrowth of warm-season grasses in pastures that did not receive glyphosate treatment. The resultant competition for sunlight, water, and soil nutrients reduced the growth and winter-annual grass stand cover of these pastures, explaining the reduced number of grazing day/acre and less BW gain/acre produced. When planting was delayed until mid-October competition by warm-season grasses was reduced so glyphosate had little effect on stand development, although the glyphosate application increased ADG of calves grazing pastures planted in September by 0.21 lb/d, and by 0.42 lb/day for calves grazing pastures planted in October.

Implications

At a current cost of around $3.70/pint, it appears that planting date of interseeded cool-season grasses can be moved back to mid-September if warm-season grasses are sprayed with a low rate of glyphosate. By including this management practice, the initial stocking date can be earlier allowing more grazing days, increased ADG, and greater BW gain per acre.

Table 1. Main effect of planting date of wheat and ryegrass interseeded into warm-season grass sod on the performance of calves during the 2005-2006 grazing season.

	Planting Date[a]			
	September 19	October 19	SE[b]	P-value
Body Weight, lb				
January 18	601	-	8.33	-
February 15	669	599	17.00	0.01
March 15	720	653	17.48	0.02
April 12	799	744	17.57	0.04
May 10	851	779	17.10	< 0.01
On test BW	601	599	16.03	0.92
Average Daily Gain, lb				
Jan 18 to Feb 15	2.61	-	0.19	-
Feb 15 to Mar 15	1.80	1.93	0.18	0.61
Mar 15 to Apr 12	2.85	3.26	0.14	0.07
Apr 12 to May 10	1.86	1.24	0.18	0.03
Overall	2.28	2.14	0.09	0.32
Total BW gain per calf, lb	255	180	9.10	< 0.01

[a] Wheat and ryegrass were interseeded into bermudagrass/crabgrass sod on September 19 or October 19 with or without application of 1 pt/acre glyphosate.
[b] Standard error of the mean, n = 20.

Table 2. Main effect of glyphosate application prior to interseeding wheat and ryegrass into warm-season grass sod on the performance of calves during the 2005-2006 grazing season.

	Glyposate Application[a]			
	No	Yes	SE[b]	P-value
Body Weight, lb				
January 18	600	602	11.79	0.91
February 15	628	640	17.00	0.62
March 15	673	700	17.48	0.29
April 12	757	787	17.57	0.24
May 10	798	832	17.07	0.18
Average Daily Gain, lb				
Jan 18 to Feb 15	2.37	2.85	0.27	0.25
Feb 15 to Mar 15	1.60	2.13	0.18	0.05
Mar 15 to Apr 12	2.99	3.11	0.15	0.56
Apr 12 to May 10	1.49	1.61	0.18	0.66
Overall	2.06	2.36	0.09	0.04
Total BW gain per calf, lb	204	232	9.11	0.04

[a] Wheat and ryegrass were interseeded into bermudagrass/crabrass sod on September 19 or October 19 with or without application of 1 pt/acre glyphosate.
[b] Standard error of the mean, n = 20.

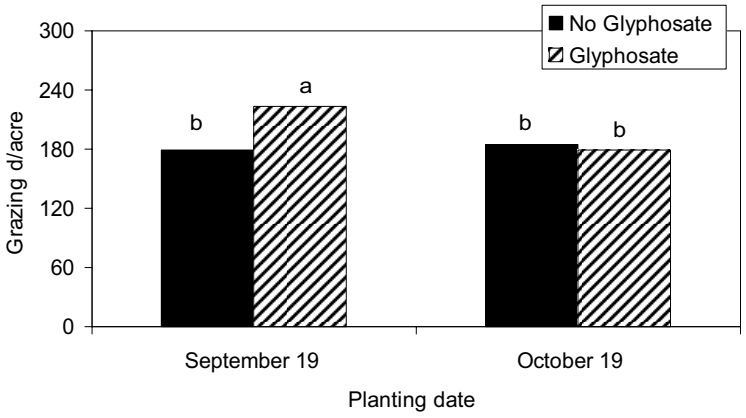

Fig. 1. Effect of planting date and glyphosate application at establishment of cool-season annual grasses interseeded into bermudagrass/crabgrass pasture on grazing days per acre of growing beef calves.
[a,b]Columns with differing letters differ (P < 0.01).

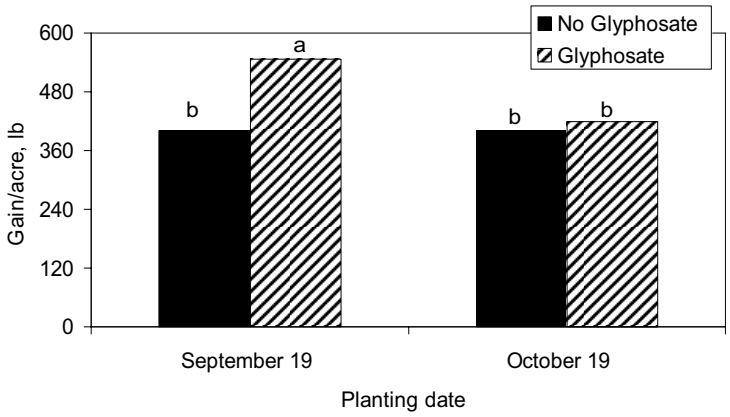

Fig. 2. Effect of planting date and glyphosate application at establishment of cool-season annual grasses interseeded into bermudagrass/crabgrass pasture on BW gain of growing beef calves per acre.
[a,b]Columns with differing letters differ (P < 0.01).

Quality Characteristics and In Situ Dry Matter Disappearance Kinetics of Bahiagrass and Three Varieties of Bermudagrass Harvested During the Summer and Early Fall in West-Central Arkansas[1]

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Story in Brief

Limited data are available that describe the DM disappearance kinetics of bahiagrass (*Paspalum notatum*) during summer and early fall. Five ruminally-cannulated steers were used to determine ruminal in situ disappearance kinetics of DM for 'Sand Mountain' bahiagrass compared with 3 varieties of bermudagrass (*Cynodon dactylon*; 'Common', 'Midland', and 'Tifton 44') harvested on 3 dates (June 9, August 6, and October 5, 2004) in west-central Arkansas. For fractions A, B, and C, the potential extent of disappearance, rate of disappearance (K_d), and effective degradability, a forage type x harvest date interaction ($P < 0.05$) was observed. Fraction B was greater ($P < 0.05$) for bahiagrass on June 9 (60.6%), August 6 (54.7%), and October 5 (56.4%) compared to Common (49.4, 43.3, and 42.5%), Midland (50.6, 49.8, and 42.6%), and Tifton 44 (53.3, 46.3, and 41.0%). Potential extent of disappearance was greater ($P < 0.05$) for bahiagrass on June 9 (81.0%) and October 5 (69.4%) compared to all 3 varieties of bermudagrass, and the K_d was slower ($P < 0.05$) for Tifton 44 (0.034/hr) and bahiagrass (0.040/hr) compared to Common (0.048/hr) and Midland (0.049/hr) on August 6. Effective degradability was greater ($P < 0.05$) for bahiagrass (58.3%) on June 9 compared to all 3 varieties of bermudagrass. On August 6, effective degradability was greater ($P < 0.05$) for Midland (48.0%) compared to bahiagrass (45.8%); however, effective degradability of bahiagrass was greater ($P < 0.05$) than that observed for Common (41.6%) and Tifton 44 (37.0%). 'Sand Mountain' bahiagrass offers a greater effective degradability of DM than bermudagrass during early summer and a greater potential extent of disappearance of DM than bermudagrass during summer and early fall.

Introduction

In the southeastern U.S., cow-calf production systems are the primary beef production enterprises due to the availability of forages throughout the year. Bahiagrass and bermudagrass are two primary warm-season forages utilized in the southeastern U.S. for hay production and grazing. Bahiagrass is grown on more than 4.9 million acres of land (Beaty and Powell, 1978; Gates et al., 1999), is adapted to a wide range of soil conditions, and is persistent under low fertility, drought, intermittent flooding, and heavy continuous grazing (Gates et al., 1999; Williams and Hammond, 1999). However, the disappearance kinetics of DM for bahiagrass is unclear. Therefore, the objective of the current study was to compare the nutritive values and ruminal in situ disappearance kinetics of DM for bahiagrass compared with 3 varieties of bermudagrass harvested on 3 dates in west-central Arkansas.

Experimental Procedures

This experiment was conducted near Booneville (35° 5' N; 94° 0' W) in west-central Arkansas. All forage within 2 quadrants (20 in x 20 in) of replicate 2.5-acre pastures of 'Sand Mountain' bahiagrass, 'Common', 'Midland', and 'Tifton 44' bermudagrass was clipped on June 9, August 6, and October 5, 2004. Forage samples were dried to a constant weight at 122°F and ground to pass through a 0.039- or 0.079-in screen in a Wiley mill. Samples ground to pass through a 0.039-in screen were analyzed for crude protein (CP; Leco® Nitrogen Determinator, St. Joseph, Mich.), acid detergent fiber (ADF), neutral detergent fiber (NDF) as described by Goering and Van Soest (1970), and in vitro DM digestibility (IVDMD) using the Ankom Daisy II In Vitro Digester® (Ankom Technology Corp., Fairport, N.Y.). Subsamples ground to pass a 0.079-in screen were stored at room temperature before subsequent in situ analysis.

Five ruminally-cannulated crossbred steers (1,397 ± 38 lb) were utilized to evaluate the in situ disappearance kinetics. Steers were maintained individually in 11.1- x 16.1-ft pens and were offered a basal diet of bermudagrass hay (14.3% CP, 71.4% NDF, and 27.0% ADF; DM basis) and a corn-based supplement (95.3% cracked corn, 3.0% molasses, and 1.7% trace mineral salt; as-fed basis). On an as-fed basis, the basal diet contained 85% bermudagrass hay and 15% supplement, and was offered at 0700 h and 1700 h in equal portions at a cumulative daily rate of 2% of BW. Steers had ad-libitum access to fresh water and were adapted to the basal diet for 10 d prior to the initiation of the trial.

Samples (0.2 oz) of each forage were weighed into Dacron (3.9 in x 7.9 in; 50 ± 10-µm pore size; Ankom Technology™, Macedon, N.Y.) bags. Dacron bags for each time period were placed in 14.2 x 19.7 in mesh laundry bags and incubated in tepid (102.2°F) water for 20 min. Mesh bags were placed in the ventral rumen prior to the 0700 h feeding and incubated for 3, 6, 9, 12, 24, 36, 48, 72, and 96 h. Following removal from the rumen, bags were rinsed in a top load washing machine. The 0-h bags were rinsed immediately following incubation in tepid water for 20 min. Samples were dried at 122°F to a constant weight following rinsing.

Disappearance kinetics were calculated by nonlinear regression of the percentage of DM remaining on incubation time using the PROC NLIN procedure of SAS (SAS Inst., Inc., Cary, N.C.).

[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.

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Fraction A was defined as the immediately soluble fraction. Fraction B represented that portion of DM that disappeared at a measurable rate, and fraction C was defined as the portion that was undegraded in the rumen. Fraction B and C, lag time, and rate of disappearance (K_d) were determined directly from the nonlinear model. Fraction A was calculated as 100 – (B + C); similarly, the potential extent of disappearance was calculated as 100 – C. The effective ruminal degradability of DM was calculated as A + B x $[K_d/(K_d + K_p)]$, where K_p = particulate passage rate (0.035 ± 0.007/hr) for steers consuming a similar bermudagrass-based basal diet (Scarbrough et al., 2001). Indices of nutritive value were analyzed using the SAS system for mixed models with repeated measurements. In situ disappearance kinetics were analyzed as a randomized complete block design with a 4 x 3 factorial arrangement of treatments using the MIXED procedure of SAS with steers representing the blocking term. Least squares means were separated using the PDIFF option of MIXED when protected by a significant ($P < 0.05$) treatment effect.

Results and Discussion

Nutritive values for each forage type and harvest date are presented in Table 1. For fractions A, B, C, potential extent of disappearance, K_d, and effective degradability, a forage type x harvest date interaction ($P < 0.05$) was observed. Fraction B was greater ($P < 0.05$) for bahiagrass than for all 3 varieties of bermudagrass across all harvest dates (Table 2). Fraction B for bahiagrass on June 9 (60.6%), August 6 (54.7%), and October 5 (56.4%) was higher than reported values for bermudagrass harvested over a range of maturities (Mandebvu et al., 1999) and stockpiled bermudagrass (Scarbrough et al., 2001). Fraction B for bahiagrass harvested on June 9 was 7.0, 7.0, and 12.5 percentage units higher than that for eastern gamagrass at the boot, anthesis, and mature stages of growth, respectively (Coblentz et al., 1998). The potential extent of disappearance was greater ($P < 0.05$) for bahiagrass than for all 3 varieties of bermudagrass on June 9 and October 5 (Table 2). Extent of disappearance did not differ ($P > 0.05$) between bahiagrass (71.3%) and Midland (68.9%) on August 6; however, the potential extent of disappearance for bahiagrass was 11.5 and 10.4 percentage units greater ($P < 0.05$) than Common and Tifton 44, respectively. The potential extent observed for bahiagrass on June 9 is comparable to that of eastern gamagrass at the boot stage but higher than gamagrass at the anthesis and mature stages of growth (Coblentz et al., 1998) and bermudagrass at various maturities (Mandebvu et al., 1999; Scarbrough et al., 2001).

No differences ($P > 0.10$) among forages were observed for K_d for June 9, and K_d averaged 0.055/hr. The K_d was slower ($P < 0.05$) for Tifton 44 (0.034/hr) and bahiagrass (0.040/hr) compared to Common (0.048/hr) and Midland (0.049/hr) on August 6. On October 5, K_d was slower ($P < 0.05$) for bahiagrass (0.028/hr) compared to Common (0.043/hr), Midland (0.040/hr), and Tifton 44 (0.044/hr). The K_d for bahiagrass on June 9 and August 6 was higher than for bermudagrass harvested over a range of maturities (Mandebvu et al., 1999). Although ADF was greater ($P < 0.05$) for bahiagrass compared to the 3 varieties of bermudagrass (Table 1), effective degradability was greater for bahiagrass (58.3%) on June 9 compared to all 3 varieties of bermudagrass. Effective degradability was increased ($P < 0.05$) for Midland (48.0%) than for bahiagrass (45.8%) on August 6; however, effective degradability of bahiagrass was greater ($P < 0.05$) than that observed for Common (41.6%) and Tifton 44 (37.0%). The effective degradability of bahiagrass for all 3 harvest dates is higher than for stockpiled bermudagrass (Scarbrough et al., 2001).

Implications

'Sand Mountain' bahiagrass provides beef cattle producers in west-central Arkansas an alternative mid-summer and early fall grazing forage. Although bahiagrass offers adequate DM degradability, further research is warranted to determine animal performance of beef cows grazing bahiagrass in west-central Arkansas.

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Table 1. Least squares means for concentrations of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and *in vitro* dry matter digestibility (IVDMD) for 'Sand Mountain' bahiagrass, 'Common', 'Midland', and 'Tifton 44' bermudagrass harvested on three dates near Booneville, AR.

	Forage type				Harvest date		
Item	Bahiagrass	Common	Midland	Tifton 44	Jun 9	Aug 6	Oct 5
	% of DM				% of DM		
CP	8.1^{b}	16.4^{a}	14.3^{a}	13.3^{ab}	17.4^{a}	12.8^{b}	8.9^{c}
NDF	75.0^{a}	69.7^{b}	68.6^{b}	73.7^{a}	68.2^{c}	72.3^{b}	74.2^{a}
ADF	42.6^{a}	32.5^{b}	34.3^{b}	36.5^{b}	33.4^{b}	37.1^{a}	38.9^{a}
IVDMD	64.4	61.7	63.5	60.7	71.5^{a}	61.5^{b}	54.7^{b}

^{a,b,c}Means, within a row and main effect of forage type or harvest date, without common superscripts differ ($P < 0.05$).

Table 2. In situ dry matter (DM) disappearance kinetics for 'Sand Mountain' bahiagrass, 'Common', 'Midland', and 'Tifton 44' bermudagrass harvested on three dates near Booneville, AR.

Harvest date/ Forage	A[1]	B	C	Extent[2]	Lag time, h[3]	K_d/hr	Effective Degradability[4]
	% of DM						% of DM
June 9							
Bahiagrass	20.6[b]	60.6[a]	19.0[b]	81.0[a]	4.16	0.059[a]	58.3[a]
Common	24.9[a]	49.4[c]	25.7[a]	74.3[b]	3.38	0.056[a]	54.9[b]
Midland	23.7[a]	50.6[b,c]	25.7[a]	74.3[b]	2.35	0.052[a]	53.6[b,c]
Tifton 44	20.6[b]	53.3[b]	26.3[a]	73.7[b]	2.82	0.051[a]	52.3[c]
August 6							
Bahiagrass	16.6[b]	54.7[a]	28.7[b]	71.3[a]	4.21	0.040[b,c]	45.8[b]
Common	16.5[b]	43.3[c]	40.2[a]	59.8[b]	1.21	0.048[a]	41.6[c]
Midland	19.1[a]	49.8[b]	31.1[b]	68.9[a]	1.87	0.049[a]	48.0[a]
Tifton 44	14.6[c]	46.3[c]	39.1[a]	60.9[b]	1.59	0.034[c]	37.0[d]
October 5							
Bahiagrass	13.0[c]	56.4[a]	30.6[c]	69.4[a]	5.55	0.028[b]	37.7[b]
Common	18.6[a]	42.5[b]	38.9[b]	61.1[b]	1.39	0.043[a]	41.9[a]
Midland	18.4[a]	42.6[b]	39.1[b]	60.9[b]	2.84	0.040[a]	40.9[a]
Tifton 44	16.3[b]	41.0[b]	42.7[a]	57.3[c]	2.58	0.044[a]	39.0[b]
PSE[5]	0.7	1.1	1.0	1.0	0.84	0.003	0.7

[a,b,c]Means, in a column and within a given harvest date, without common superscripts differ ($P < 0.05$).
[1]Abbreviations: A = Immediately soluble fraction; B = fraction disappearing at a measurable rate; C = undegraded fraction; and K_d = rate of disappearance.
[2]Potential extent of disappearance in the rumen and calculated as 100 - C.
[3]Main effect of forage type was the only significant ($P < 0.001$) treatment effect.
[4]Calculated as $A + B \times [K_d/(K_d + \text{particulate passage rate})]$, where mean passage rate for five steers was 0.035 ± 0.007/hr.
[5]Pooled standard error of forage type x harvest date interaction means (n = 5 steers).

Effect of Herbage Depletion on the Grazing Dynamics and Short-Term Intake Rate of Steers Grazing Wheat Pastures

P. Gregorini[1], J. Caldwell[2], M. Bowman[2], C. Masino[1], W. Coblentz2, P.A. Beck[1], and S.A. Gunter[1]

Story in brief

Reduction of herbage mass may not accurately predict herbage intake rate, as it does not incorporate aspects of availability and accessibility of preferred plant parts. There is little research attempting to understand cattle foraging strategies during pasture depletion. This study aimed to assess grazing dynamics and herbage intake rate under pasture depletion grades, analyzing other components than herbage mass. Three steers were assigned to grazing scenarios that simulated 3 levels of pasture depletion (Treatments: Undisturbed sward, CNTL; high level of depletion, HD, and medium level of depletion, MD). Grazing scenarios were characterized by the amount of green leaf and stem, and their ratio. Intake rate was determined by a rumen evacuation technique. Grazing dynamic was determined through bite and eating step rate, bite depth, eating distance and grazed area, and bites and intake per feeding station. From the CNTL to the HD; green leaf mass, stem mass, and accessibility decreased, but green leaf availability increased. Steers showed a decrease of fresh herbage intake rate (P = 0.04), and dry (P = 0.06) and fresh (P = 0.04) herbage intake per feeding station, as well as a tendency (P = 0.1) to increase bite rate with increasing level of depletion. Depletion led steers to increase foraging velocity (eating steps per min) and grazed area. It seems that concepts other than herbage mass need to be taken into account when changes in herbage intake, grazing dynamics and grazing management are analyzed.

Introduction

Under winter-annuals grazing environments, a linear relation between herbage mass and intake is blindly accepted. However, several works clearly show that the reduction of herbage mass itself may not accurately predict herbage intake rate (Iason et al., 2002), as it does not comprise differences in plant parts, nor incorporate aspects of the accessibility of leaves, the preferred plant parts (Drescher, 2003). Consequently, linearity between herbage depletion and intake reductions remains doubtful.

It is recognized that green leaf is the "pasture component" that promotes intake and is better correlated with bite mass than herbage mass (Wade and Carvalho, 2001). At the pasture/animal interface, availability and accessibility of leaves constrain the herbage consumed in each bite (Drescher, 2003). While practically the accessibility of leaves is measured and expressed as sward surface height, what might be determinants for intake rate are the mass and accessibility of green leaves at the bite horizon. Despite these considerations, there are few and sporadic research reports attempting to understand and use cattle foraging strategies during a progressive downward defoliation. The objective of this study was to assess grazing dynamics and herbage intake rate under 3 levels of pasture depletion, analyzing other components than herbage mass.

Experimental Procedures

This study took place at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, in April 2005. Six wheat (*Triticum aestivum* L.) pastures established using 3 tillage methods were used; tillage method was used as a block. Treatments were a high level of depletion (HD; sward surface height 2.75 inches), low level of depletion (LD; sward surface height 5.5 inches) and undisturbed sward (CNTL, sward surface height 8.25 inches). Treatments were generated through different residence times by dairy heifers on each pasture. Three grazing scenarios (0.4 acre, polywire fenced) were set up in each pasture the day before measurements. Grazing scenarios were grazed (grazing session) by 2 of 3 Angus steers (BW = 1,296 ± 62.3 lb), randomly chosen and allocated to treatments and replicates. The night before measurements, steers were shrunk. Three hours before every grazing session, they were fed 4.4 lb of ground corn to reduce differences in appetite. Two hours before grazing sessions, ruminal contents of steers were removed. A grazing session consisted in taking the steers to the allocated grazing scenario, and letting them freely graze for 15 min. During this period, 2 trained observers counted the bites and eating steps during a continuous minute every 5 minutes while steers had their head down and were completely engaged in their eating activity (biting, chewing). After the grazing sessions, ruminal contents were removed, and sampled for DM.

Based on the herbage eaten during grazing sessions, fresh and dry intake rates were calculated. To calculate eating distance, the mean eating step measured by Gregorini et al. (2006) was multiplied by the eating step rate. Each eating step was considered as a feeding station. The area of feeding station was calculated according to Rook et al. (2004) and number of feeding stations multiplied by the area of a feeding to calculate area grazed. Fifty undisturbed sward surface height measurements were taken within each grazing scenario in bitten areas, and an additional 50 were taken immediately adjacent to the bitten area to determine apparent bite depth. Grazing scenarios were sampled for undisturbed sward surface height (pre-grazing) using a sward height ruler. This was measured at 30 random points in each grazing scenario. Herbage mass was collected at ground level by hand clipping nine, 76 x 76 inch quadrants in each grazing scenario. This mass was separated into green leaf and stem mass and oven dried for DM calculation. All dependent variables were analyzed under a completely randomized block design by ANOVA utilizing the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). Least-squares means were separated using linear and quadratic contrasts.

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Results and Discussion

The sward surface heights obtained by the differential grazing time applied to each grazing scenario match the sward surface height target (Table 1). In both sward features and grazing behavior variables, the block effect was not significant ($P > 0.05$). Herbage depletion reduced green leaf and stem mass, but increased the green leaf/stem ratio as depletion level increased. In other words, when generating the treatments, steers on the depleting pastures might be induced to eat more stems as well, since most of the upper strata leaves were being eaten, and the remaining leaves were mainly located among stems (less accessible). This might have generated a higher availability at the high depletion rate. The availability of determined herbage mass is the proportion of preferred parts of herbage (leaves) in this total mass of herbage. Accessibility is defined as the ease of ingestion of preferred parts of herbage (Drescher, 2003). As a result, steers on the 3 treatments had to cope with a reduction of green leaf mass, an increased availability but reduced accessibility.

The reduction of green leaf mass (and accessibility, theoretical) with higher depletion level may explain the marked ($P < 0.04$) reduction of fresh herbage (19% DM) intake rate. These results are in accordance with the works of Chacon and Stobbs (1973) and Forbes and Coleman (1993). The latter suggested that green leaf appears to be the single most important component of herbage whether measured as mass, proportion, density or ratio. Dry herbage intake rate tended to differ ($P = 0.14$) among treatments. The changes in grazing dynamics shown by the steers when green leaf density and accessibility decreased through herbage depletion (Table 1) may indicate a positive selection for green leaf. Redmon et al. (1995) argued that reductions in herbage intake are related to decreases in digestibility rather than ingestive issues. If animals positively seek green leaf, and green leaf is the more digestible component of herbage, it is evident that a reduction of herbage mass leads to reductions in herbage digestibility. However, from a behavioral viewpoint, an explanation of a dynamic decrease of herbage intake would be the following: intake rate would decrease during pasture depletion, since preferred profitable bites (leafy bites) are diluted (less clustered). At this point, selectivity would increase. While the selection process occurs, animals look for more profitable bites, trying to maintain a constant energy intake rate. Such a process is time consuming and would be what makes intake rate decrease. In addition, a decrease in accessibility generates bites with less mass and more jaw movements. At the same herbage mass, but different availability and accessibility, Gregorini et al. (2006) showed how steers changed their grazing dynamic. Basically, reductions in accessibility increase the eating step rate and residence time per feeding station.

Cattle graze down vegetative temperate pastures in layers when a plot area and time in it are restricted (Wade and Carvalho, 2001). This phenomenon might ensure a high proportion of leaf in the diet (Wade and Carvalho, 2001). Availability under the high depletion treatment was higher, but accessibility was markedly reduced. A reduced accessibility and green leaf density may have led steers to find feeding stations less profitable as depletion increased. This is supported by the increments of the eating step rate and the reduction of bites per feeding station. The marked difference on fresh and dry intake per feeding station reinforces this concept. Because of a reduction (dilution) of profitable feeding stations, depletion made steers walk and cover more area (Table 1). Clearly, they were seeking leaves. The cost of walking is negligible in relation to the energy requirement of the entire grazing process (Di Marco and Aello, 1998). The present results indicate that, from an energetic point of view, it makes sense for cattle depleting a pasture to keep walking, taking fewer and less deep bites (Table 1) per eating step. Cropping and processing are the most expensive components of the grazing process (Wright and Illius, 1995). Bite rate, used as a mechanism of compensation to maintain intake rate, increased with pasture depletion, which is energetically expensive. However, bite depth decreased ($P < 0.01$). This means that bites had less mass; therefore, bites may have taken less processing effort. It seems that cattle do not graze blindly. Certainly, they may energetically adjust their foraging strategy while depleting pastures to maintain a constant energy intake rate. At this point, to think about a simple amount of herbage as a threshold determining intake rate, a result of a complex process like grazing, seems incomplete.

Implications

At small scales, like paddocks, changes in herbage availability and accessibility determine changes in grazing behavior, intake rate, and consequently, performance. The understanding of grazing dynamics may help us to design grazing management, leading cattle to harvest as much green leaf as possible with the least effort. Therefore, grazing cattle in short grazing sessions, with small leafy areas (pastures) may be an alternative to be considered.

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Table 1. Effect of herbage depletion on pasture features and grazing behavior of steers grazing wheat pastures.

	Level of depletion				P- value	
Trait	**High**	**Low**	**Control**	**SE**	**Linear**	**Quadratic**
Sward features						
Green leaf mass (lb/ft^2)	0.009	0.017	0.035	0.006	0.33	0.01
Stem mass (lb/ft^2)	0.003	0.015	0.027	0.003	0.02	< 0.001
Green leaf/Stem ratio	3.09	1.32	0.89	0.25	< 0.001	< 0.001
Sward surface height (inches)	3.43	5.74	9.23	0.91	0.006	< 0.001
Grazing behavior						
Bite rate (bites/ min)	42.8	32.54	26.55	5.20	0.18	0.10
Bites per feeding station	3.21	5.69	6.33	1.09	0.22	0.13
Eating step rate (steps/ min)	15.16	10.91	6.08	1.54	0.07	0.02
Fresh herbage intake rate (lb/ min)	0.617	0.793	1.058	0.11	0.34	0.04
Dry herbage intake rate (lb/ min)	0.074	0.103	0.125	0.176	0.29	0.14
Fresh intake per feeding station (lb)	0.04	0.130	0.178	0.026	0.04	0.01
Dry intake per feeding station (lb)	0.004	0.017	0.022	0.002	0.06	0.061
Eating distance (ft)	290.91	207.9	116.60	29.42	0.06	0.002
Area grazed (ft^2)	125.93	88.87	50.48	12.70	0.067	0.002
Bite depth (% of SSH)[a]	6.5	39	51	0.03	< 0.001	< 0.001

[a] SSH = Sward Surface Height.

Animal Performance and Economics of Novel Endophyte Tall Fescues for Stocker Cattle

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Story in Brief

Pastures planted to the novel endophyte (NE) tall fescues Jesup infected with the endophyte AR542 and HiMag infected with Number 11 endophyte (HM11) were compared to Kentucky 31 (KY-31) tall fescue infected with native endophyte, and soft red winter wheat and cereal rye (WR) or ryegrass (RG). Pastures (n = 4/treatment in 2003-04 and 6/treatment in 2004-05 and 2005-06) were stocked with 1.5 calves per acre in the fall and 2.5 calves per acre in the spring. Throughout the study, ADG of calves grazing NE were 0.51 lb/d and 1.18lb/d greater ($P < 0.01$) than KY-31, during the fall and spring, respectively. During the fall of 2003-04, gains by calves grazing WR were 0.65 lb/d greater ($P < 0.01$) than NE. In the fall of 2004-05, ADG of WR and RG were less than KY-31 and NE tall fescues. The poor fall grazing performance of the steers grazing cool-season annuals is due to the short grazing period (35 days) and poor forage growth of the annual pastures. In the spring of 2004-05, RG produced the greatest ADG, and WR was not different than NE. Grazing days/acre and gain/acre were lower for WR than NE, but were similar for RG and NE tall fescues. During the 2005-06 grazing study, ADG of the steers grazing WR and RG in the fall were greater ($P < 0.01$) than ADG of steers grazing Jesup AR542 and HM11. During the spring, ADG of calves grazing RG was greatest ($P < 0.01$) and ADG of WR was greater ($P = 0.02$) than Jesup AR542 and tended ($P = 0.06$) to be greater than HM11, which did not differ ($P = 0.65$). During the 2005-06 grazing season, gain/acre was greatest ($P < 0.01$) for RG, intermediate for Jesup AR542, HM11, and WR, which did not differ ($P > 0.14$) and least ($P < 0.01$) for KY-31. Across the 3-yr study, the average profit per acre for NE pastures was $80. At this level of profitability it would require 4 years to pay for the new stand of NE fescue and return a profit, assuming a 6% discount rate on future returns.

Introduction

For stocker cattle producers to remain profitable, forage programs must be developed that promote economical high rates of gain. Kentucky-31 tall fescue, the most widely grown introduced forage in the United States, does produce high-quality pasture in spring and fall but calves exhibit reduced growth rates and elevated body temperatures, which are signs of fescue toxicosis caused by ergot alkaloids produced by fungal endophytes in the forage. The fungal endophytes enable the tall fescue to be persistent in harsh conditions. Endophyte strains have been discovered that do not produce or produce very little ergot alkaloids. These 'novel' endophytes have been promoted to combine the advantages of plant persistence with the increased animal performance of fescues not containing the endophytes. The development and use of stress tolerant tall fescue infected with novel endophytes have been suggested as the next major advance for livestock production. The following study has been designed to compare performance and economics of stocker cattle grazing winter annual pasture or Kentucky-31 tall fescue to two tall fescue varieties infected with novel endophytes.

Experimental Methods

In September of each year, bull and steer (body weight = 450 to 500 lb) calves were received at the University of Arkansas Livestock & Forestry Research Center located northwest of Batesville, Ark. Pastures were planted at 20 lb/acre in 2002 to the NE tall fescues. The NE tall fescue varieties planted were Jesup infected with AR 542 endophyte (Jesup AR542; MaxQ; Pennington Seed Inc.), and HiMag infected with Number 11 endophyte (HM11; University of Arkansas, Fayetteville) for comparison to Kentucky 31 (KY-31) tall fescue infected with native endophyte, a blend of soft red winter wheat (Delta King 9027) and cereal rye (Wintergrazer70; Pennington Seed Inc.) planted at a rate of 60 lb of each /acre into a clean-tilled seed bed in early September of 2003, 2004, and 2005 (WR), and annual ryegrass (RG; Marshall; Wax Seed Co., Amory, Miss.) seeded at 40 lb/acre into a clean-tilled seedbed in early September of 2004 and 2005. In the fall before planting, seedbeds were clean-tilled and fertilized according to soil test to meet N, P, and K requirements using ammonium nitrate, diammonium phosphate, and potash. Tillage operations included offset disking and chisel plowing, followed by use of a finishing disk, cultipacker, and finally a grain-drill for seeding. The pastures were topdressed with 130 lb urea/acre in mid-February to deliver 60 lb N/acre.

In the fall of each year, pastures were stocked at a set stocking rate of 1.5 steers/acre (3 calves per pasture). In the fall of 2003, the calves were assigned to tall fescue pasture and began grazing on September 16, while calves assigned to small grain pastures began grazing on November 11. In the fall of 2004, the tall fescues were grazed beginning on November 4, and the WR and RG were grazed beginning on December 2. In the fall of 2005, calves were assigned to pastures on November 8. In the 2003-04 grazing season, calves were removed from tall fescue pastures on December 23 and WR pastures on January 23 when forage allowance became limiting to calf growth. Grazing was terminated on January 6 for all pastures in

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the fall 2004-05 grazing season. Fall grazing for the 2005-06 grazing season, was terminated for each pasture when forage allowance became limiting to calf growth on an average date of January 23 for RG, January 24 for WR, January 28 for HM, January 31 for Jesup AR542, and February 3 for KY-31.

In January of each year, calves (n = 80 in 2004 and n = 150 in 2005 and 2006) were received and randomly assigned to pasture as described above. Five calves per pasture (2.5 calves per acre) began grazing on March 17, 2004 and March 18, 2005. Calves were removed from pastures when forage allowance and quality began limiting growth on May 12, 2004 and 2005 for cattle grazing WR, July 8 for calves grazing tall fescue in 2003-04 and on June 6, 2005 for calves grazing tall fescue and RG pastures. During the spring grazing season of 2006, calves began grazing WR pastures on March 1, RG pastures on March 1 or March 8, and tall fescue pastures on March 17. Two calves were removed from a HM11 pasture because of limited forage availability on April 4. The calves were removed from KY-31 pastures on April 20, because heat stress associated with clinical signs of fescue toxicosis caused 2 mortalities. Grazing was terminated for the pastures in other treatments when forage allowance and or forage quality became limiting to calf growth on an average date of May 11 for WR, May 26 for RG, June 17 for HM, and June 22 for Jesup AR542. While grazing, the cattle were weighed every 28 days after a 16 hr removal of feed and water.

The cost of establishing the WR, RG, and NE pastures for this study (Table 1) were based on enterprise budgets compiled by the Mississippi State Budget Generator (Agricultural Economics Department, Mississippi State University, Starkville). The seed costs included: wheat at $0.12/lb, rye at $0.19/lb, ryegrass at $0.43/lb, and novel endophyte fescue at $4.00/lb. Fertilizer costs included: 17-17-17 at $0.14/lb, urea at $0.15/lb, diammonium phosphate at $0.14/lb, and potash at $0.14/lb. The custom rate for fertilizer application was $2.50/acre. Enterprise budgets were generated using input and field operations data from the research site. Direct and fixed tractor costs were $6.81 and 6.38/acre, respectively. Direct and fixed equipment costs were $2.32 and 4.93/acre, respectively. Expenses also included 1.0 h of labor/acre at $8.50/hr. An opportunity cost of establishing novel endophyte tall fescue was also added because cattle did not graze these pastures for one year after establishment. This $79.78/acre charge was based on the profitability of small grain pastures during a grazing study at the research site (Beck et al., 2005). Net returns of the stocker cattle enterprise were analyzed using the average profit potential based on the livestock markets for the 10-yr period from 1991 to 2000. Value per lb BW gain was calculated using Arkansas purchase prices from 1991 to 2000 (Cheney and Troxel, 2004) of 450 lb medium frame number 1 steers in September for fall grazing and February for spring grazing. Sales prices were based on Arkansas prices from 1991 to 2000 of 650 lb medium frame number 1 steers in January and May for the fall and spring grazing period, respectively. The value of gain use in these calculations was $63.31/cwt for the fall grazing period and 23.62/cwt for the spring grazing period. Expenses incurred by steers during the receiving and grazing periods are shown in Table 2 and were based on actual costs. Dependent variables were analyzed by analysis of variance for a completely random design with pasture serving as the experimental unit using the mixed procedure of SAS (SAS Inst., Inc., Cary, N.C.). In the presence of a significant treatment effect ($P < 0.05$), least-squares means were separated using least-significant differences.

Results and Discussion

Profitability of a stocker enterprise is determined by both high animal performance and production per acre. In this study, NE tall fescues produced higher animal performance than native endophyte tall fescue, and higher gain per acre than either small grains or native endophyte tall fescue (Table 3). These NE tall fescues offer potential benefits related to decreased risk of stand establishment of annual forage crops and high animal performance. During the fall of the 2003-04 grazing study, gains by calves grazing WR were 0.65 lb/d greater than NE, which were 0.51 lb/d greater than KY-31. During the spring of 2004, ADG of NE and WR were not different, and were greater than KY-31. Tall fescue pastures produced 190.5 more grazing days/acre than WR during the 2003-04 grazing study, because grazing was started 56 days earlier in the fall and continued 66 days later in the summer. Gain/acre for NE was 172% greater than KY-31 or WR, reflecting the high quality of the forage and length of the grazing season.

In the fall and winter of the 2004-05 grazing study, ADG of steers grazing NE was 0.57 lb/day greater than KY-31, which was 0.42 lb/day greater than WR and RG. The poor fall grazing performance of the steers grazing cool-season annuals was due to the short grazing period (35 days) and poor forage growth of the annual pastures. During the spring, steers grazing RG had the greatest ADG, NE and WR were intermediate, and ADG of steers grazing KY-31 was least. Grazing-days per acre were least for WR because of the earlier maturity of the pastures, while KY-31, NE, and RG did not differ. Gain/acre was greatest for NE and RG, intermediate for WR, and least for KY-31.

In the fall and winter of the 2005-06 grazing study, ADG of the steers grazing WR and RG were greater ($P < 0.01$) than ADG of steers grazing Jesup AR542 and HM11. The ADG of steers grazing Jesup AR542 was greater ($P < 0.01$) than ADG of steers grazing KY-31. During the spring, calves grazing RG gained more ($P < 0.01$) daily than the calves in the other treatments. Average daily gains of calves grazing WR was greater ($P = 0.02$) than calves grazing Jesup AR542 and tended ($P = 0.06$) to be greater than calves grazing HM11. The ADG of calves grazing Jesup AR 542 and HM11 did not differ ($P = 0.65$).

Jesup AR542 pastures produced more ($P < 0.03$) grazing-days/acre during the 2005-06 grazing season than all other treatments. The HM11 variety produced more ($P < 0.01$) grazing-d/acre than RG which was greater ($P = 0.03$) than WR. Because of the early grazing termination date of the KY-31 pastures because of animal mortalities associated with endophyte toxicity the animal grazing-d/acre was least ($P < 0.01$) for KY-31. Total gain/acre during the 2005-06 grazing season was greatest ($P < 0.01$) for RG and least ($P < 0.01$) for KY-31. Gain/acre was intermediate for Jesup AR542, HM11, and WR, which did not differ ($P > 0.14$).

The performance differences during the fall of 2005 between the calves grazing HM11 and Jesup AR542 and the reduced carrying capacity of HM11 compared to Jesup AR542 can be explained by the poor survival of HM11 during the 2005 drought. When stands were evaluated during the fall of 2005, HM11 had an average stand of 64% (range of 43 to 81%) compared to 90% stand count for KY-31 and 86% stand count for Jesup AR542. Analysis of the endophyte infection level in each of the fescue varieties indicates there may be differences in infection rate in these varieties. The endophyte infection rates were not different ($P = 0.84$) for the Kentucky-31 and Jesup AR542 varieties (93 and 92%, respectively),

which were greater than ($P < 0.01$) the endophyte infection analyzed for the HM11 (60%). The lower infection rate of HM11 tillers may explain the lack of drought persistence of this variety.

In 2003-04, profit/acre of NE averaged $157/acre, which was $175 greater ($P < 0.01$) than KY-31 and WR. While in 2004-05, profit/acre of NE averaged $34 per acre, which was $131/acre greater than KY-31 and WR. Profitability/acre of Jesup AR542 ($29) and RG ($3.61) did not differ ($P = 0.13$). In 2005-06, profitability of Jesup AR542 and RG did not differ ($P = 0.31$) and generated greater ($P < 0.01$) profits per acre than WR and KY-31. The HM11 tall fescue variety was intermediate and did not differ ($P > 0.15$) from Jesup AR542 or WR. Across the 3-yr study, profitability of Jesup AR542 ($83/acre), HM11 ($77/acre), and RG ($55/acre) did not differ ($P > 0.20$), but were more ($P < 0.01$) profitable than WR (-$29/acre) and KY-31 (-$75/acre). If the profit stream over time of the NE tall fescues is converted to current dollars using a 6% discount rate, this level of profitability would require 4 years for a new planting of NE tall fescue to break even and begin producing positive returns. Profit/acre would be $334/acre for HM11 and $379/acre for Jesup AR542 over the first 10-yr after planting a new NE fescue stand.

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Table 1. Estimated costs associated with establishing cool-season annuals or novel endophyte infected tall fescue.

	Forage type[a]		
Item	NE	WR	RG
Agronomic costs, $/acre			
Fertilizer	66.50	66.50	66.50
Tall fescue seed	80.00	-	-
Winter annual seed	-	18.60	17.20
Tillage operations	29.39	29.39	29.39
Hay crop harvest[b]	81.45	-	-
Establishment costs	257.34	114.49	113.09
Return from hay[b]	(105.00)	-	-
Opportunity cost[c]	79.78	-	-
Net Cost, $/acre	232.12	114.49	113.09

[a] NE = Jesup tall fescue infected with the AR542 endophyte and HiMag tall fescue infected with the Number 11 endophyte, WR= soft red winter wheat and cereal rye and RG=annual ryegrass (Marshall, Wax Seed Co.).
[b] Newly established tall fescue was harvested for hay during the first year after establishment, with estimated yield of 6,000 lb tall fescue produced/acre valued at $35/ton.
[c] Opportunity costs is the profit potential (estimated from Beck et al., 2005) from stocker cattle grazing small grain pasture not realized because of removal cattle from NE tall fescue pastures during the establishment year.

Table 2. Non-pasture cattle ownership costs for receiving and grazing periods.

Item	Cost
Interest, $/d	0.11
Death loss, $/steer	8.22
Mineral, $/d	0.07
Veterinary supplies, $/steer	14.27
Transportation, $/steer	4.00
Receiving hay and feed, $/steer	10.64

Table 3. Effects of forage type on steer BW and performance during the 2003-04, 2004-05, and 2005-06 grazing seasons.

	Forage[a]					
Item	KY-31	Jesup AR542	HM11	WR	RG	SE
			2003-04			
ADG, lb						
Fall	1.21^{x}	1.72^{y}	1.72^{y}	2.37^{z}	-	0.11
Spring	1.00^{x}	2.03^{y}	2.02^{y}	1.86^{y}	-	0.10
Grazing-d/ac	429.5^{y}	429.5^{y}	429.5^{y}	239.0^{x}	-	4.5
Gain/acre, lb	461^{x}	827^{y}	822^{y}	493^{x}	-	32.3
Profit, $/ac	-19.40^{y}	158.39^{z}	156.02^{z}	-17.56^{y}	-	15.5^{y}
			2004-05			
ADG, lb						
Fall	1.38^{y}	1.91^{z}	1.99^{z}	0.98^{x}	0.94^{x}	0.13
Spring	0.75^{x}	1.89^{y}	1.95^{y}	1.97^{y}	2.46^{z}	0.10
Grazing-d/ac	256^{z}	263^{z}	263^{z}	178^{y}	257^{z}	3.2
Gain/acre, lb	125^{x}	499^{z}	517^{z}	297^{y}	496^{z}	53.1
Profit, $/ac	-91.85^{x}	29.33^{yz}	37.82^{z}	-101.81^{x}	3.61^{y}	11.7
			2005-06			
ADG, lb						
Fall	1.53^{x}	2.05^{y}	1.86^{xy}	2.65^{z}	2.76^{z}	0.13
Spring	0.32^{w}	1.62^{x}	1.69^{xy}	1.98^{y}	2.42^{z}	0.11
Grazing-d/ac	215^{v}	373^{z}	346^{y}	278^{w}	304^{x}	7.9
Gain/acre, lb	225^{x}	660^{y}	600^{y}	620^{y}	769^{z}	27.4
Profit, $/ac	-95.40^{w}	87.34^{y}	63.30^{xy}	36.95^{x}	106.12^{z}	12.8

[a] KY-31 = Kentucky 31 infected with the endemic (or native) endophyte, Jesup R542 = Jesup tall fescue infected with the AR542 endophyte, and HM11 = HiMag tall fescue infected with the Number 11 endophyte, and WR=Wheat-Rye, and RG=annual ryegrass.

[w-z] Least-squares means within a row with no superscripts in common differ ($P \leq 0.05$).

Cow and Calf Performance While Grazing Tall Fescue Pastures with Either the Wild-Type Toxic Endophyte or a Non-Toxic Novel Endophyte

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Story in Brief

Fescue (*Festuca arundinacea*, Schreb.) pastures are common in Northwest Arkansas but cattle performance has declined due to the toxicity caused by the wild-type endophyte *Neotyphodium coenophialum* in the fescue plant. Gelbvieh x Angus crossbred cows (n = 52; 1,023 lb initial BW) were allocated randomly by weight and age to one of four 25-acre pastures of tall fescue containing either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (HM4; 2 replicates each). Cows confirmed as pregnant began grazing the experimental pastures on October 15, 2004. Extremely dry summer conditions resulted in depleted forage reserves. Cows were then moved to a bermudagrass pasture and fed bermudagrass hay. Pastures with HM4 were removed before those with E+ and were offered 1,808 lb more hay ($P = 0.20$) than those on E+. Cow weight and BCS changes during the year were not different ($P > 0.20$) between HM4 and E+, but a greater percentage ($P < 0.01$) of cows grazing HM4 were pregnant at the time of weaning. Calf birth date and birth weight were not different ($P > 0.37$) between forages, but actual and adjusted weaning weights, and calf gain from birth to weaning tended to be greater ($P < 0.06$) by 41, 44, and 38 lb, respectively, from HM4 compared with E+ pastures. Therefore, Arkansas producers could improve performance of their cows and calves by using new novel endophyte technology, but should weigh the cost against the benefits before renovating large acreages of existing E+ pastures.

Introduction

Fescue (*Festuca arundinacea*, Schreb.) 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*). Although this fungus is beneficial to the plant, it produces toxins that cause fescue toxicity, a disorder characterized by reduced DM intake, decreased weight gains, decreased pregnancy rates, vasoconstriction, fescue foot, increased body temperature, and rough hair coats (Realini et al., 2005). Although research has been performed to rid the endophyte from the tall fescue plant, it was not beneficial to producers because plant persistence declined (Parish, 2003). Fescue plants infected artificially with a non-toxic endophyte maintained their vigor but did not have detrimental effects on cattle (Bouton et al., 2003; Parish et al., 2003; Nihsen et al., 2004). The objectives of this study were to observe animal production and forage availability from a tall fescue, friendly endophyte association (HM4) compared with tall fescue with the toxic wild-type endophyte (E+).

Experimental Procedures

This study was conducted at the Livestock and Forestry Branch Station located near Batesville, Ark. Gelbvieh x Angus crossbred cows (n = 52; 1,023 ± 22.5 lb initial BW) were stratified by weight and age and allocated randomly to one of four 25-acre pastures of tall fescue containing either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (HM4; 2 replicates each). Cows began grazing the experimental pastures October 15, approximately 2 wk following weaning of their calves and were confirmed pregnant via rectal palpation prior to allocation.

Cow weight and BCS were evaluated at the beginning of the trial, at calving, and at weaning, and cow pregnancy rates were determined by rectal palpitation at weaning. Calf weights were obtained at birth, then monthly from mid-May until weaning in early October. Calves were weaned using a low-stress weaning program where they were gathered, vaccinated, and placed directly across an electric fence from their dams for 14 d. After this time, calves were moved to a new location.

Forage availability was measured once a month using disk meters, and forage samples were gathered at that time. Hay was harvested during the spring from approximately one third of each pasture for subsequent feeding. Extremely dry summer conditions forced feeding of the winter hay supply during the summer. Once the hay from a particular pasture was depleted, cows were moved to a bermudagrass pasture and fed bermudagrass hay. Early fall rainfall allowed resumed forage growth and all cows were returned to their respective pastures 7 d prior to weaning.

Cow weight and BCS, calf weights, and forage availability were analyzed using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). Cow pregnancy rates were analyzed by Chi-square using the PROC FREQ of SAS.

Results and Discussion

Average available forage and the amount of hay offered to the different groups of cows are shown in Table 1. The available forage did not differ ($P = 0.73$) between forages when averaged across the sampling dates. As mentioned previously, dry summer conditions

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necessitated feeding of hay harvested from those pastures during the spring. Cows on HM4 depleted their hay supplies earlier than those on E+ and were removed from their pastures earlier (one pasture removed July 29, the other removed September 3), resulting in those cows being offered 1,808 lb more hay (P = 0.20) than those on E+. The reason for lower available forage on HM4 pastures may be due to an increase in forage intake, lower forage production, or a combination of these two factors Crude protein concentrations did not differ (P = 0.92) for these two forage types (data not shown). Crude protein concentrations did vary across harvest dates with highest levels occurring in November of 2004 and October of 2005 and the lowest levels occurring in June and August of 2005.

Cow weight and BCS during the year were not different (P > 0.20) between HM4 and E+ forages, although HM4 cows were numerically heavier (P = 0.20) at weaning (Table 2). A greater percentage (P < 0.01) of cows grazing HM4 was pregnant at the time of weaning. Body condition scores at calving and breeding were at approximately 6. At a BCS of 6, cows should have been cycling and reproductive rates should have been high, based on previous research. Therefore, differences in pregnancy rates observed in this study are likely due to tall fescue toxins independent of BCS.

Calf birth date (data not shown) and birth weight (Table 3) were not different (P = 0.37) between forages, but actual and adjusted weaning weights, and calf gain from birth to weaning were greater (P ≤ 0.05) from HM4 compared with E+ forage. The daily gain differences between HM4 and E+ for calves in our study were similar to those reported by Parish (2003) for another 'friendly endophyte' - tall fescue association (Max Q) compared with E+.

Implications

In the first year of a 2-year study, cows grazing fescue pastures with a novel endophyte had higher pregnancy rates and their calves had heavier weaning weights than cows grazing the wild-type fescue pastures. Therefore, novel endophyte technology could prove to be beneficial for producers in Northern Arkansas. However, further evaluations are needed to determine plant vigor and persistence and potential economic benefits of novel endophyte – tall fescue associations compared with wild-type fescue pastures.

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Table 1. Forage availability and hay offered to cows grazing pastures of tall fescue containing either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (HM4; 2 replicates each).

	Forage			
Item	E+	HM4	P-value	SE
Available forage, lb/acre	3,118	2,940	0.73	452.9
Hay offered[a]	2,192	4,000	0.20	12.7

[a]Hay offered represents the hay fed to cows after the hay harvested from a specific pasture was fed.

Table 2. Cow performance while grazing tall fescue pastures with either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (HM4).

	Forage			
Item	E+	HM4	P-value	SE
Cow weight, lb				
Initial	1,033	1,015	0.75	48.2
At calving	1,201	1,183	0.73	46.2
At breeding	1,130	1,080	0.59	80.5
At weaning	950	1,021	0.20	38.1
Body condition score[a]				
Initial	6.2	6.2	0.85	0.15
At calving	6.2	6.2	0.98	0.15
At breeding	6.1	5.9	0.21	0.11
At weaning	5.4	5.4	0.81	0.17
Pregnancy, %	42	81	0.01	

[a] Body condition scores were estimated on a 9-point scale where a BCS of 6 is described as having no distinct visible bone structure, the transverse processes can be felt with firm pressure, the hindquarters appear plump and full, and there is sponginess over foreribs and around tail head representing fat deposits.

Table 3. Calf performance while grazing tall fescue pastures containing either the wild-type toxic endophyte (E+) or a non-toxic novel endophyte (HM4).

	Forage			
	E+	HM4	P-value	SE
Birth weight, lb	80	82	0.37	3.6
Weaning weight, lb	423	464	0.05	20.0
Adjusted weaning weight, lb[a]	396	440	0.05	16.1
Daily gain, lb	1.54	1.75	0.04	0.07

[a] Weaning weights adjusted to 205 days of age.

Growth Performance by Fall-Calving Cow-Calf Pairs Grazing Tall Fescue Pastures with Different Proportions Stockpiled Until Late Fall

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Story in Brief

Stockpiling tall fescue (*Festuca arundinacea* Schreb.) is a viable but variable management practice used to reduce winter feed costs for cattle. The objective of this 2-yr study was to determine the impact of stockpiling different proportions of total fescue acreage on growth performance of fall-calving cows and their calves. One hundred fifty-six fall-calving cows (1,213 ± 15 lb) were assigned to 1 of 8 predominantly tall fescue pastures (subdivided into six 4-acre paddocks) at a stocking rate of one cow/2.4 acres on August 19 of both years. The pastures were assigned to treatments consisting of: 1) no stockpiled area (S0); 2) 33% of area stockpiled (S33); or 3) 50% of area stockpiled (S50). Stockpiling was initiated on September 10 of both years. Cows grazing S0 had lower (P = 0.05) weight loss from August 19 (precalving) to the end of the breeding season compared with the mean of cows grazing S33 and S50. Cow BCS loss from precalving to November 20 (beginning of breeding season and of grazing stockpiled cells) was greater (P < 0.05) for S33 vs. S50 cows. Calf daily gains were greater (P = 0.05) from S0 than from S33 and S50 calves. Available forage was greater (P < 0.05) from S50 than S33 pastures, but total hay consumed did not differ among treatments. Therefore, although stockpiling total tall fescue is a viable option for spring-calving cows, stockpiling as much as 33% of the total acreage may limit performance by fall-calving cows.

Introduction

Reducing the amount of harvested forage required during the winter to maintain cow performance could reduce feeding cost for cow/calf producers (Adams et al., 1994). Cattle producers in the southeastern United States including Arkansas have many hardships to overcome, including the maintenance of cows during the non-traditional grazing season (Scarbrough et al., 2004). Stockpiling forages is one way to help with this problem, by either increasing the amount of, or improving utilization of, the available forage produced during late summer and early fall, and grazing the surplus during late fall and early winter (Riesterer et al., 2000). Kallenbach et al. (2003) suggested that stockpiled tall fescue could reduce or eliminate supplemental feeds for cattle during this grazing period. Tall fescue is ideal for stockpiling because its upright growth pattern and high biomass availability reduce the potential for winter rot, and leave a more consumable forage (Riesterer et al., 2000). These factors combine to allow moderate rates of gain for cows and stocker calves grazing stockpiled tall fescue (Poore et al., 2000). Currently, there is little or no information available that describes what portion of the total tall fescue acreage should be set aside for stockpiling, or the value of stockpiled tall fescue for fall-calving cows. The objective of this study was to determine the optimum proportion of acres to stockpile in order to optimize fall-calving cow performance.

Experimental Procedures

The study site is located at the Livestock and Forestry Branch Station located near Batesville, Ark., on a Clarksville very cherty silt loam with 20 to 40 percent slopes. The soil type is described as being deep, somewhat excessively drained, and moderately rapidly permeable, and is typical of the soil in many pasture sites in the Ozark Highlands.

One hundred fifty-six fall-calving cows (1,213 ± 15 lb) were assigned randomly by weight and age on August 19 of both years to 1 of 8 pastures that were predominantly tall fescue. Pastures were stocked at a stocking rate of one cow/2.4 acres. The pastures were subdivided into six 4-acre paddocks. The pastures were assigned randomly to treatments consisting of: 1) no stockpiled area (S0); 2) 33% of area stockpiled (S33); or 3) 50% of area stockpiled (S50). Cows assigned to S0 were rotated through all 6 experimental paddocks using 5 to 6-d grazing intervals followed by 25 to 30-d rest periods. Those assigned to S33 and S50 pastures were rotated through only 2 or 3 paddocks, respectively, until September 10. This removed available forage on those paddocks to prepare them for subsequent stockpiling. On September 10, cows on the S33 and S50 treatments were grazed rotationally on the 4 or 3 remaining paddocks, respectively, to allow the 2 (S33) or 3 (S50) early-grazed paddocks to stockpile until late November. Hay was offered during adverse weather conditions or when estimated available forage dropped below approximately 1,000 lb/acre.

Corn gluten feed was offered during the breeding season with a goal of maintaining the cows at their present body condition score. These supplements were offered at 2 lb/head daily while the cows were grazing fescue, but at 5 lb/head daily when cows were consuming tall fescue hay. These differences were based on estimated forage quality differences and estimated forage intake by the cows on hay vs. stockpiled fescue.

The entire pasture area was fertilized with 60 lb N/ac and with P and K to meet soil test recommendations in mid-September. Available forage was measured monthly and clipped forage samples were gathered at that time. Cow weights and body condition scores were estimated immediately precalving (August 19 and August 17, for yr 1 and 2, respectively) and at the start (November 16 and 29 for yr 1 and 2, respectively) and end of the breeding season

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(January 20 and February 1 for yr 1 and yr 2, respectively).

Statistical analyses were performed by using the PROC MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C..) with pasture considered the experimental unit. Planned orthogonal contrasts were used to compare 1) the average from the stockpiled pastures with S0, and 2) S33 with S50.

Results and Discussion

Cow BW, BCS, and changes in BW and BCS during the study did not differ ($P \geq 0.15$) among stockpiling treatments (Table 1). All cows generally lost BW and BCS from the beginning of the study (late pregnancy) to immediately prior to the beginning of the breeding season. Although, no treatment differences were detected for cow BW and BCS change, cows grazing S33 had a greater BCS loss numerically ($P = 0.16$) than those grazing S50. The resulting difference in BCS may be of significance biologically, since the BCS of cows on S33 were below 6.0, but those on S0 and S50 were maintained close to or above a BCS of 6 at the start of the breeding season. A lower percentage of cows having a BCS below 6 conceived compared with cows maintained at or above a BCS of 6 (Morrison et al., 1999). However, conception rates are not available on the current study at the present time.

Total hay offered tended ($P = 0.06$) to be lower for cows grazing stockpiled pastures (avg. of S33 and S50) compared with those grazing S0. Also, cows grazing S50 were offered less hay numerically ($P = 0.11$), than cows grazing S33. These differences represent a substantial savings in the amount of hay offered by grazing stockpiled fescue pastures.

Calf BW at the end of the breeding season was greater ($P = 0.04$), and calf ADG during the breeding season tended ($P = 0.08$) to be greater from those grazing S33 compared with those grazing S50. This is likely because cows on S33 lost more body condition numerically than those on S50 and were less able to maintain milk production for their calves.

The stockpiling treatment by sampling date interaction was not detected ($P = 0.99$), for available forage, indicating that treatment responses were consistent across sampling dates. Available forage did not differ ($P > 0.10$) between S0 and average of the stockpiled treatments (Fig. 1), but available forage from S33 was lower ($P < 0.05$) than that of S50, possibly helping to explain the slight differences ($P = 0.16$) observed in cow BCS change between S33 and S50 prior to breeding. Higher available forage on S50 is likely due to improved utilization of the available forage through stockpiling and was the likely reason for the numerically reduced hay offered to cows grazing the S50 pastures.

Therefore, after 2 yr of the study, performance measurements from fall-calving cows did not favor stockpiling tall fescue. The site the study was conducted on is a very drought-prone site, and rainfall was limiting for extended periods in both years. Also, available forage measurements within a particular pasture were averaged across both stockpiled and non-stockpiled areas. Although total available forage on the whole pasture area may have been adequate, available forage on the specific area the cows were grazing on a given day may have been limiting at times. This could have limited milk production, resulting in reduced calf gains, but also conserved hay, and thereby likely reduced production costs for wintering fall-calving cow calf pairs.

Implications

In our study, stockpiling tall fescue was not advantageous for fall-calving cow or calf growth performance for a number of likely reasons including higher nutrient demands of lactation for the fall-calving cows, poor soil water holding capacity, drought conditions during both years, etc. The major advantage of stockpiling was likely improved forage utilization when 50% of the total acreage was stockpiled. This resulted in a substantial reduction in the amount of hay offered; thereby reducing overall winter feed costs.

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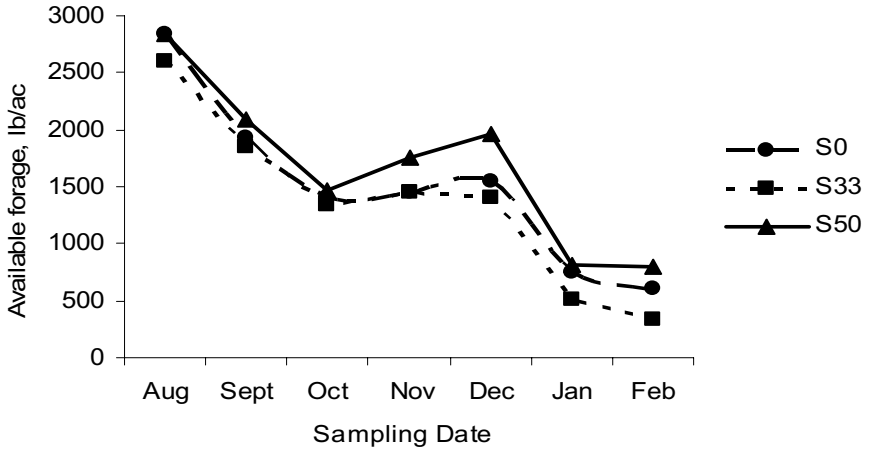

Fig. 1. Forage availability (lb/acre) across sampling dates. Treatments S0, S33, and S50 represent 0, 33, or 50% of the total acreage stockpiled, respectively. A sampling date x treatment interaction was not detected (P = 0.99) and overall available forage from S50 was greater (P < 0.05) than that from S33.

Table 1. Performance of cow/calf pairs grazing tall fescue pastures with different proportions of the pasture acreage stockpiled.

Item	Percent of acres stockpiled [a]			SEM	S0 vs. S33 + S50[b]	S33 vs. S50
	S0	S33	S50			
Cow weights, lb[cd]						
Precalving	1317	1317	1324	22.6	0.88	0.99
Start of breeding	1181	1169	1167			
End of breeding	1252	1254	1241			
Cow weight change, lb						
Precalving to breeding	-129	-155	-149	19.0	0.58	0.61
During breeding season	73	86	75	14.1	0.64	0.62
Precalving to end breeding	-56	-49	-74	13.1	0.72	0.21
Body condition score[e]						
Precalving	6.5	6.6	6.6	0.19	0.45	0.15
Start breeding	6.0	5.7	6.1			
End breeding	6.2	6.1	6.3			
Body condition score change						
Precalving to breeding	-0.5	-0.9	-0.5	0.18	0.40	0.16
During breeding season	0.2	0.5	0.2	0.17	0.45	0.31
Precalving to end breeding	-0.3	-0.4	-0.3	0.09	0.79	0.40
Hay offered, lb/cow	1865	1567	935	339.2	0.06	0.11
Calf weights, lb						
Birth weight	81	81	79	1.9	0.62	0.50
End of breeding	378	392	351	12.3	0.67	0.04
Average daily gain, lb						
During breeding season	2.25	2.36	2.14	0.077	0.99	0.08
Birth to end of breeding	2.26	2.31	2.16	0.173	0.72	0.16

[a] S0, S33, and S50 represent pastures in which 0, 33, or 50% of the total acres were stockpiled from September 10 to late November.

[b] P-values for orthogonal contrasts comparing S0 with the mean of S33 and S50, or S33 with S50.

[c] Weights precalving, at the beginning of breeding season, and at the end of breeding season, corresponds to August 19 yr 1, August 17 yr 2; November 16 yr 1, November 29 yr 2; and January 20 yr 1, February 1 yr 2, respectively.

[d] Cow weight and BCS were analyzed using a repeated measures analysis of variance. No date × treatment interactions were detected.

[e] Based on a scale of 1 to 9 where 1 is very thin and 9 is very obese.

Interaction of Fescue Toxin with Liver Enzyme P450 3A

A.S. Moubarak, Hehai Wang, Z.B. Johnson, and C.F. Rosenkrans, Jr.[1]

Story in Brief

This study was conducted to investigate the effect of the ergot alkaloid, ergotamine (ET), on the induction of cytochrome P450 3A. Sprague-Dawley rats were treated by injecting intraperitoneally as follows: control (0.5 ml of only corn oil for 4 days); dexamethasone treatment (100 mg/kg of BW of dexamethasone in corn oil for 1, 2, 3 or 4 days); and ergotamine treatment (100 mg/kg of BW of ergotamine in corn oil for 4 days). Liver tissues were collected from each group (n = 5/treatment, total of 30) and liver microsomes prepared. Cytochrome P450 3A activity was evaluated using ET and its isomer as substrates in medium containing liver microsomes and NADPH (nicotinamide adenine dinucleotide) at 37°C for 30 min. The disappearance of substrate and the appearance of metabolites were measured using high pressure liquid chromotagraphy (HPLC). Microsomes from rats treated with dexamethasone were 5 times more ($P < 0.01$) active than microsomes from control animals in the biotransformation of ET (32.1 and 7.0 nM/min/mg protein, respectively; SE = 4.83) or ET isomer (21.6 and 4.7 nM/min/mg protein, respectively SE = 1.71) into corresponding metabolites. The amount of substrate (ET or ET isomer) remaining after incubation with cytochrome P450 3A did not differ ($P > 0.05$) between ergotamine-treated and control rats (5.2 vs. 7.0 nM ET/min/mg protein; SE = 4.83, or 1.5 vs. 4.7 nM ET isomer/min/mg protein; SE = 1.70). When ketoconazole was used as a specific inhibitor of cytochrome P450 3A, ergotamine metabolisms were inhibited in a dose dependent fashion. Data presented in this study suggest that although ET and its isomer are ideal substrates for the isozyme cytochrome P450 3A, they have no effect on the induction of cytochrome P430 3A after 4 days of treatment.

Introduction

When the subject is fescue toxicity, nothing is more important than the ability of the liver to detoxify those toxins. Cytochrome P450 (CYP) is an inducible enzyme system that plays a key role in the detoxification and clearance of many compounds including both toxins and drugs (Pollock, 1994). The CYP 1-3 families are active in the metabolism of xenobiotics with CYP 3A subfamilies being the most important in drug metabolism (Wright and Paine, 1994). The metabolism of ergot alkaloids, such as bromocriptine, ergotamine, and other structurally similar ergot derivatives, is mediated mainly by CYP 3A4. Moochhala et al. (1989) reported that bromocriptine interferes with P450-dependent oxidative metabolism of xenobiotics. Later it was demonstrated that CYP 3A exhibits a particularly high affinity for ergopeptides. Activation or inhibition of the induction process of such enzyme systems can have severe consequences. Witkamp et al. (1995) reported that tiamulin, a semi-synthetic antibiotic frequently used in agricultural animals, strongly inhibited the hydroxylation rate of testosterone at the 6 beta position via the formation of a CYP 3A4 metabolic intermediate complex in both microsomes and hepatocytes. This report was designed to study the effects of administering ergotamine (ET) in vivo on the induction of the CYP 3A family using dexamethasone as a specific inducer for similarity and to evaluate the in vitro interaction of ET with CYP 3A using ketoconazole as a specific inhibitor.

Experimental Procedures

All the chemicals and reagents used in these experiments were of the highest quality available and were purchased from Sigma Chemical Co. (St. Louis, Mo.) unless stated otherwise. Sprague-Dawley rats (n = 30; BW ~250 g) were allowed ab libitum access to water and chow. Rats were randomly assigned to treatment and treated intraperitoneally with one of the following treatments: 1) Control treatment (n = 5 rats, injections of 0.5 ml of corn oil for 4 consecutive days), 2) dexamethasone (DXM) treatment (n = 20 rats, injections of 100 mg/kg of BW of dexamethasone in 0.5 ml of corn oil for 1, 2, 3 or 4 consecutive days) and 3) ET treatment (n =5 rats, injections of 100 mg/kg of BW of ergotamine in 0.5 ml of corn oil for 4 consecutive days). Approximately 24 h after the last injection, each rat was anesthetized with chloroform, decapitated, and the liver was harvested. Livers were stored at –20°C until microsomes were prepared.

Michaelis-Menten kinetics were used to evaluate the interaction of CYP 3A with ET, and the linearity of the Lineweaver-Burk plot of 1/V (velocity) versus 1/S (substrate) was further examined by measuring enzyme activity at various concentrations (2.0 to 20.0 μM) of the enzyme substrate, ET, in the presence and absence of kentoconazole (3.0 and 5.0 μM).

Liver microsomes were prepared as reported by Moubarak and Rosenkrans (2000). Briefly, liver tissues (3 to 5 g) were diced with scissors and then washed with 150 mM sodium chloride buffer. The diced tissue was ground (1 g tissue/10 ml of buffer (250 mM sucrose, 100 mM Tris-HCl, 1 mM EDTA (ethylenediaminetetracetic acid), pH 7.4)) with ice-cold medium using a precooled blender for 10 to 20 sec and further homogenized using a Polter-Elvehjem (5 X). The homogenate was sequentially centrifuged at 800 x g for 10 min, at 13,500 x g for 20 min collecting the supernatant and then at 105,000 x g for 60 min collecting the pellet which contained the microsomal fraction. The pellet (microsomal fraction) was resuspended in buffer containing 100 mM sodium phosphate and 20% volume/volume glycerol. The protein concentration after resuspension was approximately 40 mg/ml. Aliquots of

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microsomal suspensions were stored at –20°C and were used within 20 to 30 days. Protein concentration was determined by the method of Lowry using bovine serum albumin as the standard.

Ergotamine and its isomer (ET-iso) were used as substrates to assay presumptive CYP 3A4 activity in vitro. They were analyzed using a standard assay method in 330 µl of assay medium, 100 µl of cofactor generating system (nicotinamide adenine dinucleotide; NADPH), 20 µl of ET (final concentration was 4 µg/ml of fully isomerized ET), and 50 µl microsomal protein (final concentration was 0.4 mg/ml). The assay medium (pH 7.4) consisted of 100 mM potassium phosphate, 0.1 mM EDTA, and 5.0 mM $MgCl_2$. The NADPH generating system consisted of assay medium with 10 mM NADP+, 10 mM D-glucose-6-phosphate, and 2.0 U/ml of Glucose-6-phosphate dehydrogenase. The reactions were initiated by adding the NADPH generating system and were terminated after 30 min by adding 100 µl of 94% acetonitrile and 6% glacial acetic acid. After the stop solution was added, the mixture was centrifuged at 12,000 x g for 4 min. Supernatant (150 µl) from each reaction was examined for the disappearance of ET and ET-iso and the appearance of their metabolites using the high pressure liquid chromatography (HPLC) method described by Moubarak and Rosenkrans (2000).

Data for the dexamethasone treated rats were analyzed using one-way ANOVA with day as the independent variable and concentration of remaining substrate (ET or ET-iso) as the dependent variables. Induction data for the 3 treatments (Control, DXM, and ET) after 4 days of treatment were analyzed using one-way ANOVA with treatment as the independent variable and concentration of remaining substrate (ET or ET-iso) as the dependent variable. The kinetics data of kentoconazole inhibition were interpreted using the double reciprocal plot method of 1/S versus 1/V.

Results and Discussion

Data in Figure 1 represent the disappearance of ET and its isomer after incubation with liver microsomes from rats that had been treated sequentially for 1, 2, 3, or 4 days with 100 mg/kg of BW of dexamethasone, a specific inducer of cytochrome P450 3A. Dexamethasone induced cytochrome P450 3A activity in rats to a significant ($P < 0.01$) level only after the third and fourth days of treatments. These results indicate that the mechanism of DXM induction of rat liver microsomal cytochrome P450 3A was time dependent, and it took at least 3 to 4 successive days of treatments to reach the maximum level of activity. Liver microsomes from rats treated with dexamethasone were 5 times more ($P < 0.01$) active than microsomes from the control animals in the biotransformation of ET (32.1 vs. 7.0 nM/min/mg protein, respectively; SE = 4.83) or ET-isomer (21.6 vs. 4.7 nM/min/mg protein, respectively SE = 1.71) into their corresponding ET metabolites.

The induction of CYP 3A4 is mainly regulated by the novel orphan receptor or pregnane X receptor (PXR), but other receptors including the constitutively active receptor (CAR) and, indirectly, the glucocorticoid receptor (GR) are involved. Dexamethasone, one of the glucocorticoids, influences several aspects ofcytochrome P450 3A induction. However, most of these effects are not dependent on GR binding to CYP genes, but rather on complex protein-protein interplay between GR and various other receptors (Honkakoski and Negishi, 2000). Information on how or if ET fits into the induction processes of CYP 3A rat is limited or not available.

Ergotamine treatment for 4 consecutive days produced no significant ($P > 0.05$; 5.2 vs. 7.0 nM ET/min/mg protein; SE = 4.83, and1.5 vs. 4.7 nM ET-iso/min/mg protein; SE = 1.70) increase in the cytochrome P450 3A activity over that of the control animals (Fig. 2). Moubarak et al. (2003) showed that treatment of rats with similar ergot alkaloids, dihydroergotamine (DHET) or ergonovine (EN), at a concentration of 100 mM did not produce any significant increase in the cytochrome P450 3A activity over that of control rats. Although it is generally accepted that most compounds that are metabolized by CYP are to some degree inducers of that CYP enzyme system, data from this study and from a previous study in our laboratory have indicated that all of the ergot alkaloids studied (ET, DHET, and EN) have very small or no induction effects on CYP 3A in rats, yet those alkaloids have been shown to be metabolized by rat CYP 3A. Previous studies have demonstrated that both DXM and ET can also inhibit the in vitro metabolism of tacrolimus mediated by the CYP 3A subfamily (Christians et al., 1996). Another study showed that dihydroergocryptine, a dopamine agonist for the treatment of Parkinson's disease, has an inhibitory effect on CYP 3A4-mediated testosterone metabolism and additionally could induce CYP 3A4 and CYP2E1 mRNA when added at 10 µM to cultured human hepatocytes (Althaus, et al., 2000). Moubarak and Rosenkrans (2000) reported that both ergonovine and dihydroergotamine inhibited in vitro CYP 3A4 activity in a dose dependent manner when ET was used as a substrate, producing quadratic inhibition curves. One can ask, is it possible for a group of compounds such as the ergot alkaloid group (ET, DHET, EN, etc.) to play a double role? One role is to be involved at the upstream induction of CYP 3A and another is to directly interact with the structure of the enzyme inhibiting its catalytic activity. Ergot alkaloids have been demonstrated to affect the cytochrome P450 system, especially isoenzyme CYP 3A4, by binding to the isoenzyme as a substrate (Moubarak and Rosenkrans, 2000).

The linearity of the Lineweaver-Burk plot of 1/V (V_{max}), versus 1/S (ET and ET isomer) shows that the interaction between the substrate (ET) and cytochrome P450 3A in both the presence and absence of ketoconazole (Fig. 3) follows Michaelis-Menten kinetics. Furthermore, the fact that the slope did not change with the addition of ketoconazole, and the decrease in the velocity of the reaction (V_{max}), indicated an uncompetitive inhibition. Thus ketoconazole interacts with the enzyme-substrate complex.

In this study we have demonstrated that although both ET and ET-iso are ideal substrates for cytochrome P450 3A, they appear to have no induction effect on rat hepatic cytochrome P450 3A during the 4 days of treatment when compared to the classic dexamethasone induction. The data from the in vitro interaction among ET, cytochrome P450 3A and its specific inhibitor (ketoconazole) showed that the binding site for ET was different from that for ketoconazole in rat hepatic cytochrome P450 3A.

Acknowledgments

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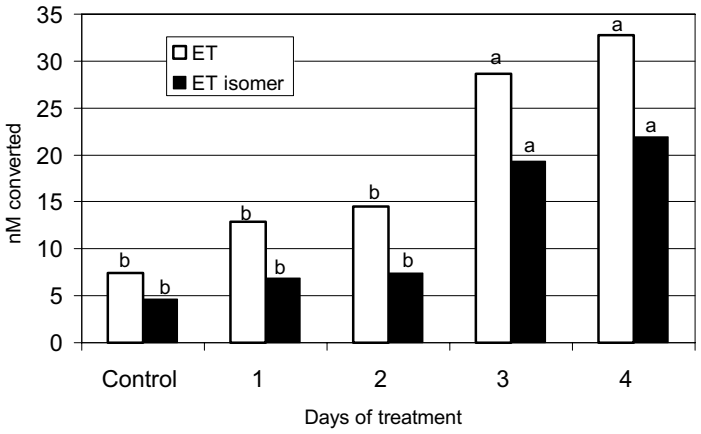

Fig. 1. The effects of intraperitoneal injections of dexamethasone (DXM) on the induction of rat liver cytochrome P450 3A activity over four consecutive days of injection. Means represented by bars containing the same letter (within ET or ET isomer) did not differ (P > 0.05).

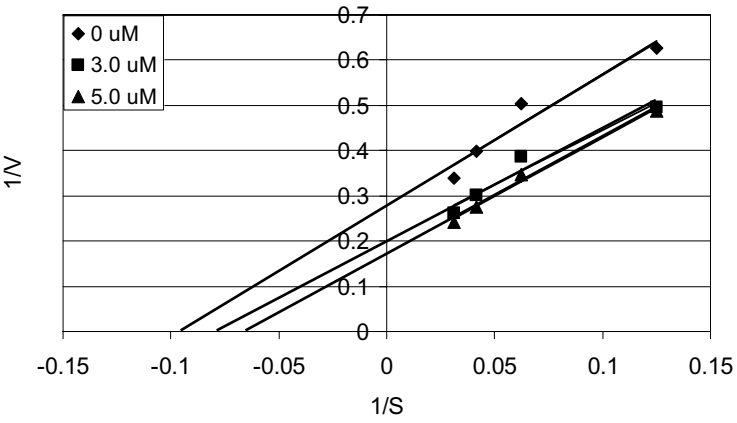

Fig. 3. Lineweaver-Burk plots of rat hepatic cytochrome P450 3A4 activity in 0, 3, and 5 uM of ketoconazole.

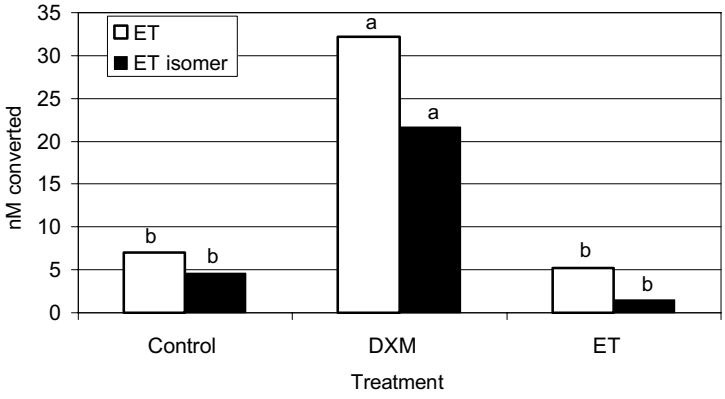

Fig. 2. The amount of substrate (ET or ET isomer) converted after incubation with rat hepatic cytochrome P450 3A preparation from control (CON), dexamethsone (DXM) and ergotamine (ET) treated rats. Means represented by bars containing the same letter (within ET or ET isomer) did not differ (P > 0.05).

Cattle vs. Sheep in Their Responses to Fescue Toxins

A. Moubarak, S.M. Cannon, and C.F. Rosenkrans, Jr.[1]

Story in Brief

Does grazing endophyte-infected fescue have the same effects on sheep as it does on cattle? This study was designed to examine whether metabolism of ergot alkaloid (ergotamine) and the process of detoxification in sheep and cattle are the same when using the liver enzyme cytochrome P450 3A as a marker. Data were collected from livers of 6 steers and 2 sheep to produce preliminary information to design a larger study. Steers used in this study consisted of 3 steers grazing endophyte-infected fescue and 3 steers grazing endophyte-free fescue. The 2 lambs were both fed a grain diet. Livers of both steers and sheep were prepared and examined for the ability to metabolize ergotamine. There were no apparent differences in the metabolism of ergotamine when comparing steers that grazed endophyte-infected fescue to steers that grazed endophyte-free fescue. Therefore, diet of the steers had no effect on the metabolism rate of ergotamine. Liver microsomes from cattle appeared to metabolize a greater amount of ergotamine than did sheep after 30 min (63% vs 20%). This work provides preliminary information on the possible genetic differences between cattle and sheep or between individual animals within the same species which is very helpful in the design of the second phase of this research.

Introduction

Cattle and sheep in the Southern United States routinely graze tall fescue (*Festuca arundinacea*) infected with the endophytic fungus *Neotyphodium coenophialum*. The effects of fescue toxins on cattle have been heavily investigated and debated for a long time. Although, it has been generally accepted that sheep are more tolerant to fescue toxins than cattle, very little information evaluating sheep vs. cattle is available. Fiorito et al. (1991) showed that ewes grazing endophyte-infected fescue had decreased prolactin and lengthened intervals from introduction of the ram until conception. However, mean daily respiration rates, heart rates, rectal temperature, and hematocrit were not affected by the endophyte-infected fescue. Rankins (1996) reported that sheep on diets of endophyte-free and endophyte-infected fescue exhibited no differences and concluded that sheep fed the endophyte-infected fescue did not portray typical fescue toxicosis. Effects of endophyte-infected fescue on cattle have been shown to reduce milk production (Hemken et al., 1979), pregnancy rate of heifers (Schmidt, et al., 1986), and calf weaning weights (Hoveland, 1993). Moubarak and Rosenkrans (2000) reported that the liver enzyme, cytochrome P450 3A, was present and has been shown to metabolize fescue toxins in cattle and is perhaps the major means of detoxification. Cytochrome P450 enzymes catalyze the primary oxidation of a wide variety of natural endogenous substrates. These emzymes also play an important role in the metabolism of exogenous compounds like drugs, procarcinogens, solvents, anesthetics, and ergot alkaloids (Peyronneau et al., 1994). This study was designed to examine whether metabolism of ergot alkaloids (ergotamine, ET) and the process of detoxification in sheep and cattle are different using liver cytochrome P450 3A.

Experimental Procedures

Liver tissues were obtained from steers (900 to 1,300 lb BW) from the University of Arkansas abattoir. Three steers used in this study had grazed endophyte-infected fescue, and 3 steers had grazed endophyte-free fescue. The 2 lambs were both fed a grain diet. Liver tissues (50 to 100 g) were collected and microsomes were prepared according to Kremers et al. (1981). The livers were diced with scissors and then washed with 150 mM sodium chloride buffer. Diced tissue was then ground at 1 g/10 ml in an ice-cold medium (250 mM sucrose, 100 mM Tris-HCl, 1 mM EDTA (ethylenediaminetetracetic acid), pH 7.4) using a precooled blender for 10 to 20 sec followed by homogenization with Potter-Elvehjem (5X). The homogenate was then centrifuged at 800 x g for 10 min, at 13,500 x g for 20 min collecting the supernate, then at 105,000 x g for 60 min collecting the pellet containing the microsomal fraction. The pellet (microsomal fraction) was washed with 100 mM sodium pyrophosphate (pH 7.5) and resuspended in buffer containing 100 mM sodium phosphate and 20% V/V glycerol to give 50 mg protein/ml concentration. Microsome suspensions were aliquoted and stored at -90°C and were used within 20 to 30 days. Protein concentration was determined using bovine serum albumin (BSA) as a standard.

The cytochrome P450 3A activity in all animals was measured using ergotamine as a substrate. The metabolism of ergotamine was assayed (Peyronneau et al., 1994) in medium containing 100 mM Tris-HCl, 10 mM potassium phosphate, 0.1 mM EDTA , pH 7.5, cofactor generating system (nicotinamide adenine dinucleotide; NADPH), 20% glycerol, 1.0 µg/ ml ergotamine that had been fully isomerized, and 0.1 mg/ml microsomal protein in a total volume of 500 µL. The cofactor generating system was: 26 mM NADP+, 66 mM D-glucose-6- phosphate, 66 mM magnesium chloride, and 1 U Glucose-6-Phosphate dehydrogenase in sodium citrate. Bovine liver microsomes were diluted in assay buffer to a working concen-

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tration of 2.5 mg protein/ml and kept on ice. The reactions were started by adding the NADPH generating system and were terminated after 30 min by adding 100 µl of 94% acetonitrile and 6% glacial acetic acid and centrifuged at 12,000 x g for 5 min at pH 7.5. Twenty µl of the supernatant from each enzyme assay were examined for the disappearance of ergotamine and its isomer and also for the appearance of metabolites by using a modification of the high pressure liquid chromatography (HPLC) method described by Moubarak et al. (1993) and Moubarak and Rosenkrans (2000).

Data were analyzed using one-way ANOVA with type of animal as the independent variable and concentration of remaining ET or the appearance of metabolites as the dependent variable. Data were reported as percentage of total ET or total metabolites remaining.

Results and Discussion

Even though this experiment was exploratory in nature and further work to investigate such differences is in progress, the data indicate that there were no apparent differences in the metabolism of ergotamine when comparing cattle that grazed endophyte-infected fescue to cattle that grazed endophyte-free fescue (data not shown). However, when comparing livers of cattle with those of sheep, the metabolism of ergot alkaloids shows differences. Figure 1 is an illustration of an HPLC chromatogram of the products of metabolism of ergotamine by liver microsomes enzyme (cytochrome P450 3A) from cattle and sheep. The enzyme preparation of cattle liver appeared to metabolize ET and its isomer to its respective metabolites. On the other hand, enzyme preparations from sheep liver did not metabolize ET or its isomer to any significant level regardless of the enzyme concentration or the length of the incubation with ET.

The cytochrome P450 3A metabolism of ET and its isomer was time and enzyme concentration dependent. The percentage of ET remaining after incubation with sheep and cattle cytochrome P450 3A after 15, 30 and 45 min is shown in Figure 2. After 30 min of incubation, 63% of ET (100% - 37%) was metabolized by cattle; whereas, only 20% of ET (100% - 80%) was metabolized by sheep during the same time of incubation. The appearance of metabolites is presented in Figure 3. These data demonstrate the ability of enzyme preparation from steers to convert ET to its metabolites in 15 min and leveling off thereafter; whereas, the sheep enzyme preparation produced very little conversion of ET to its metabolites up to 45 min of incubation under our assay conditions.

Implications

Ergot alkaloids (ergotamine) and fescue toxins are generally detoxified in the liver. We have demonstrated in previous work at the University of Arkansas that cytochrome P450 3A is found in cattle and is capable of metabolizing ergotamine. The low level of activity of cytochrome P450 3A in sheep raises several questions. First, is there a different enzyme system in sheep than cytochrome P450 3A that is involved in the detoxification of ergotamine? Second, is it possible that the toxic form of ergot alkaloids is not the parent compound but rather the metabolite itself? Perhaps sheep can tolerate a higher level of toxins because they produce fewer metabolites.

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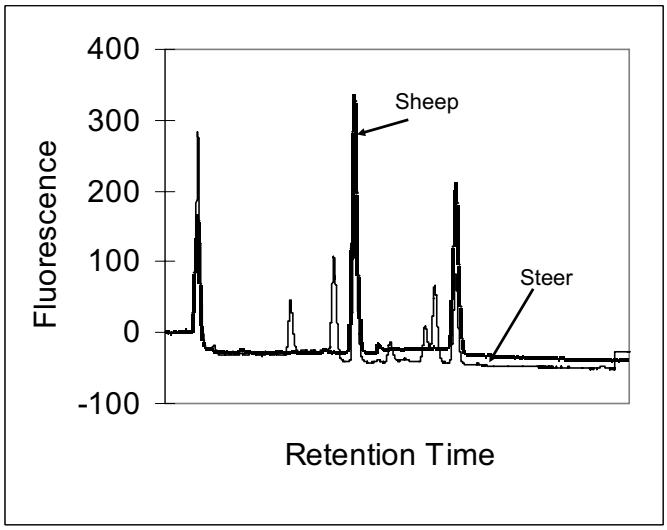

Fig. 1. High pressure liguid (HPLC) chromatogram of products from ergotamine incubation with liver microsomes from steers and sheep.

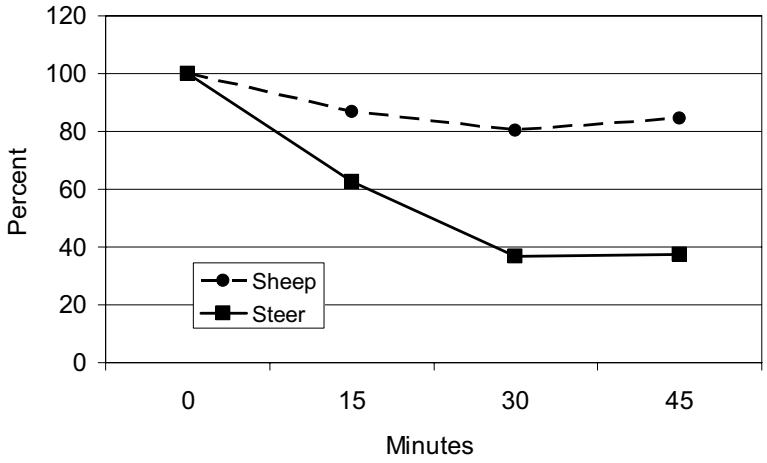

Fig. 2. Time dependent disappearance of ergotamine after incubation with liver microsomes from steers or sheep. Shown is the percentage of ergotamine remaining after incubation. Values differ (P < 0.05) between sheep and steers at 15, 30 and 45 min.

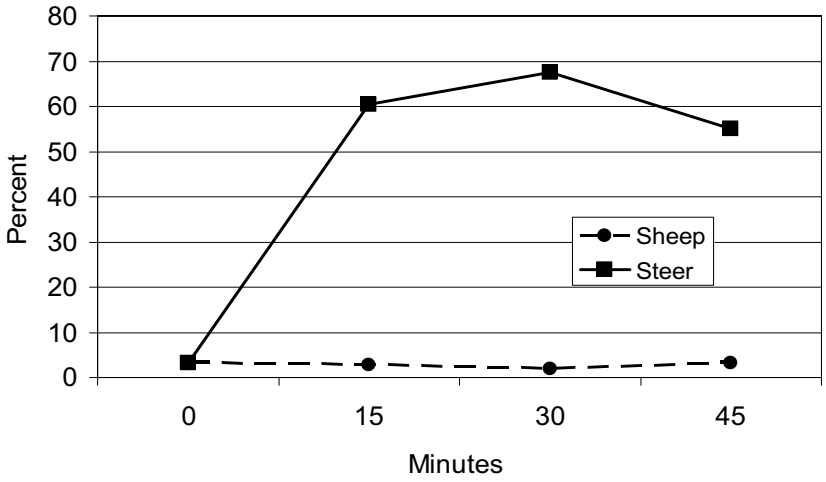

Fig. 3. Time dependent formation of total metabolites when ergotamine was incubated with liver microsomes from steers or sheep. Values differ (P < 0.05) between sheep and steers at 15, 30 and 45 min.

Influence of Endophyte-Infected Tall Fescue Seed on Fecal Shedding of *Escherichia coli* O157:H7 and Blood Metabolites in Experimentally Inoculated Sheep

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Story in Brief

The objectives of this study were to determine effects of short-term feeding of endophyte-infected tall fescue seed on fecal shedding and intestinal concentrations of *E. coli* O157:H7, and concentrations of cortisol and nonesterified fatty acids (NEFA) in experimentally-inoculated sheep. Twelve ewes (mean BW = 101 ± 4 lb) were fed a diet containing either high endophyte-infected (HI-E) or low endophyte-infected (LO-E) tall fescue seed (50%, as-fed basis) for 7 days. Ewes were inoculated with *E. coli* O157:H7 on day 1 of experimental feeding, and fecal shedding of inoculated pathogens was monitored daily. On day 7, ewes were euthanized, and tissues and contents were sampled from the ileum, cecum, and rectum for quantitative enumeration of *E. coli* O157:H7. Fecal shedding of *E. coli* O157:H7 tended (P = 0.06) to be increased in HI-E ewes [5.4 colony forming units (cfu) (log_{10})/gram of feces] compared with LO-E ewes [4.5 cfu (log_{10})/gram of feces]. Populations of *E. coli* O157:H7 in luminal contents from the ileum, cecum, and rectum did not differ (P > 0.36) between treatments. Ileum tissues from HI-E ewes tended (P = 0.12) to have an increased incidence of *E. coli* O157:H7. Mean concentrations of cortisol were similar (P = 0.49) for HI-E and LO-E ewes while mean concentrations of NEFA tended (P = 0.11) to be increased in HI-E ewes over LO-E ewes. We conclude that short-term feeding of HI-E tall fescue seed may increase concentrations of NEFA and fecal shedding of *E. coli* O157:H7 in experimentally inoculated sheep.

Introduction

A majority of the 49 million acres of tall fescue grown in the southeastern United States is infected with an endophyte fungus causing several stressful disorders, collectively characterized as fescue toxicosis. Stress may predispose ruminants to be more susceptible to opportunistic bacteria such as *E. coli* O157:H7.

Consumption of endophyte-infected tall fescue alters metabolic hormones and enzyme activity in ruminants (Nihsen et al., 2004). Cortisol is usually associated with stress in ruminants, and nonesterified fatty acids (NEFA) are increased in nutrient-restricted animals. However, the association between these blood metabolites and *E. coli* O157:H7 shedding in ruminants is lacking.

Effects of grazing endophyte-infected tall fescue on fecal shedding of pathogenic bacteria in naturally-infected ruminants have not been consistent (Looper et al., 2003, 2006). We hypothesized that consumption of endophyte-infected tall fescue seed would induce fescue toxicosis, and consequently increase fecal shedding of *E. coli* O157:H7 from experimentally-inoculated sheep. Therefore, objectives were to determine effects of short-term (7 days) feeding of high endophyte-infected (HI-E) or low endophyte-infected (LO-E) tall fescue seed on fecal shedding and intestinal concentrations of *E. coli* O157:H7, and serum concentrations of cortisol and NEFA in experimentally-inoculated sheep.

Experimental Procedures

The Animal Care and Use Committee of the USDA-ARS, Food and Feed Safety Research Laboratory approved the care, use, and handling of experimental animals (FFSRU IACUC 200502). Twelve non-lactating hair-type sheep (n = 6 each of Katadhin and St. Croix; mean BW = 101 ± 4 lb; mean age 2.6 ± 1.5 yr) were blocked by body weight and breed, and housed indoors in individual pens. Ewes had not been exposed to endophyte-infected tall fescue the 6 months prior to initiation of experiment. Ewes were acclimated to the basal diet (cracked corn substituted for fescue seed) for 7 days prior to the initiation of the experiment. On day 0 of the experiment, ewes were fed a diet containing either high endophyte-infected (HI-E) or low endophyte-infected (LO-E) tall fescue seed for 7 days. Ewes were offered the diet at 3.5% BW, and orts were weighed daily to calculate DMI. Concentrations of ergovaline in fescue seed and in total diets were determined by HPLC (Moubarak et al., 1996). Ewes were experimentally-inoculated with an antibiotic-resistant *E. coli* O157:H7 strain BDMS T4169 (ATCC 700728) on day 1 of feeding treatment, and fecal shedding of the inoculated pathogen was monitored by assay of fecal grab samples daily for 5 days (day 2 through day 6). Sheep were weighed and euthanized (Euthasol®, euthanasia solution, Delmarva Laboratories, Inc., Midlothian, Va.) on day 7, and intestinal contents (10 to 15 grams) and tissues from the ileum, cecum, and rectum were aseptically collected for qualitative enrichment and quantification of the inoculated strain of *E. coli* O157:H7 (described below). Care was taken to ensure that each tissue and lumen content sample was removed from approximately the same location in each animal. Urine was collected from each animal at euthanization (day 7) to determine total ergot alkaloid concentrations via immunoassay.

Blood serum samples were collected on days 1, 2, 4, and 7 from each ewe by venipuncture of the jugular vein, allowed to clot for 24 hours at 40°F, and centrifuged (1,500 x g for 25 min). Serum was frozen and stored until concentrations of cortisol were quantified by radioimmunoassay (Coat-A-Count®, Diagnostic Products, Los Angeles, Calif.). Serum concentrations of NEFA were determined

[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.

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by an enzymatic colorimetric procedure (NEFA-C, Wako Chemicals Inc., Dallas, Texas) adapted for use in a 96-well microtiter plate system and expressed as microequivalents of palmitate per liter. Intra-assay coefficients of variation were 8.9 and 2.3% for cortisol and NEFA, respectively.

Bacterial cultures. Escherichia coli O157:H7 strain BDMS T4169 (ATCC 700728) was obtained from the American Type Culture Collection (Manassas, Va.) and was cultivated in anoxic tryptic soy broth (TSB) medium at 99°F. This strain was made resistant to novobiocin and nalidixic acid (20 and 25 μg/mL, respectively) via successive cultivation in TSB containing up to 20 μg/mL of novobiocin and 25 μg/mL nalidixic acid. Overnight cultures (1 L) were harvested by centrifugation (7,500 x g, 10 min) and the cell pellets were re-suspended in TSB medium (150 mL total volume). Sheep were individually inoculated with 10 mL of TSB containing *E. coli* O157:H7 (4×10^{11} cfu) via oral gavage. Fecal samples were collected 3 days prior to dosing and screened for the presence of wild-type *E. coli* O157:H7 and generic *E. coli* resistant to novobiocin and nalidixic acid. On each of the subsequent 5 days after initiation of feeding experimental diets, fecal samples were collected and shedding of inoculated *E. coli* O157:H7 was qualitatively analyzed and populations were enumerated daily as described below.

Bacterial Enumeration. Ten to 15 grams of fecal material were collected from each ewe daily. One gram of each fecal sample was serially diluted (10-fold increments) in sterile phosphate buffered saline (PBS, pH 6.5) and plated on MacConkey's agar that was supplemented with novobiocin (20 μg/mL) and nalidixic acid (25 μg/mL). Plates were incubated for 24 hours at 99°F and colonies that grew on agar plates directly counted (quantitative enumeration). To qualitatively confirm the presence of inoculated *E. coli* O157:H7, daily fecal samples, intestinal contents, and epithelial tissue samples (2 grams) were incubated (24 hours, 99°F) in 20 mL GN Hajna with novobiocin/naladixic acid and streaked on MacConkey's agar plates as above. Plates showing colony growth were classified as positive for the inoculated bacteria (qualitative enumeration).

Statistical analyses. Dry matter intake, daily fecal shedding, and concentrations of cortisol and NEFA were analyzed by repeated measures using the MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) with a compound symmetry covariance structure. Treatment, day, and the interactions were included in the model. Effects of treatment on ADG, urinary concentrations of total ergot alkaloid, and bacterial counts from luminal contents (quantitative) were determined by the MIXED procedure of SAS. Chi-square analysis, using the FREQ procedure of SAS, was used to determine influence of treatment on qualitative bacterial enumeration of epithelial tissue samples. Least squares means were compared using the PDIFF option of MIXED when protected by a significant ($P < 0.05$) treatment effect.

Results and Discussion

Concentration of ergovaline was 1,626 and 260 parts per billion (ppb) for HI-E and LO-E tall fescue seed, respectively. Concentrations of ergovaline were 1,051 ppb in HI-E tall fescue seed diet and 184 ppb in LO-E tall fescue seed diet. Urinary concentrations of total ergot alkaloids were increased ($P < 0.001$) in ewes fed HI-E tall fescue seed (67.3 ng/mg creatinine) compared with LO-E ewes (5.3 ng/mg creatinine). Concentrations of urinary ergot alkaloids were increased within 2 days of steers grazing endophyte-infected tall fescue (Stuedemann et al., 1998). Concentrations of ergovaline in the HI-E tall fescue seed diet in the current experiment were similar to or exceeded published concentrations of ergovaline capable of causing physiological symptoms of fescue toxicosis. Further, a 12-fold increase in urinary alkaloids in HI-E ewes compared with LO-E ewes demonstrates HI-E ewes were exposed to high levels of toxic fescue.

Ewes fed HI-E seed diets had lower ($P < 0.05$) DMI than LO-E ewes (1.8 and 3.5 lb/day DMI for HI-E and LO-E ewes, respectively). Consequently, there was a tendency ($P = 0.06$) for HI-E ewes to lose 0.7 lb/day and LO-E ewes to gain 0.4 lb/day during the 7-day study. Mean concentrations of NEFA tended ($P = 0.11$) to be greater in HI-E (181 ± 18 mEq/L) than in LO-E (140 ± 18 mEq/L) ewes. Nonesterified fatty acids are the by-product of body fat breakdown and are released into circulation during periods of nutrient restriction.

Fecal grab samples collected from all sheep prior to inoculation with *E. coli* O157:H7 were negative for wild-type *E. coli* strains. Fecal shedding data of *E. coli* O157:H7 during the 5-day collection (day 2 through day 6) are shown in Figure 1. There was no treatment x day interaction ($P = 0.18$); however, overall mean shedding of *E. coli* O157:H7 tended ($P = 0.06$) to be increased in HI-E ewes [5.4 cfu ($\log_{10}$)/gram of feces] compared with LO-E- ewes [4.5 cfu ($\log_{10}$)/gram of feces]. Luminal contents from the ileum, cecum, and rectum contained similar ($P > 0.36$) populations of *E. coli* O157:H7 between treatments (Table 1). Tissue samples (after a 24-hour enrichment) from the cecum and rectum had a similar ($P = 0.30$) occurrence of *E. coli* O157:H7; however, *ileum* tissues from HI-E ewes tended ($P = 0.12$) to have an increased incidence of *E. coli* O157:H7 (Table 1). Stress may predispose animals to be more susceptible to opportunistic bacteria such as *E. coli* O157:H7. Cattle grazing endophyte-infected tall fescue have increased body temperature during summer months, reduced milk production and reproductive performance, and decreased growth rate. Ewes consuming HI-E tall fescue seed diets exhibited signs/symptoms of fescue toxicosis including reduced DMI and subsequent BW loss, and increased urinary ergot alkaloids. Further, HI-E ewes tended to have increased fecal shedding of *E. coli* O157:H7 and a tendency for a greater incidence of *E. coli* O157:H7 in *ileum* tissue than LO-E ewes.

Mean concentrations of cortisol were not different ($P = 0.49$) for HI-E ewes (3.2 ± 0.7 μg/dL) and LO-E ewes (4.1 ± 0.7 μg/dL) in the current experiment. Concentrations of cortisol were increased in heifers and cows 3 to 6 hours after ergot alkaloid infusion (Browning et al., 2000). However, concentrations of cortisol in heifers (Aldrich et al., 1993) and lambs (Fiorito et al., 1991) adapted to endophyte-infected tall fescue diet for 10 to 14 days were similar to cortisol in animals consuming endophyte-free tall fescue diets. Concentrations of cortisol were similar between sheep fed HI-E or LO-E tall fescue seed diets and may not be a good indicator of stress induced by endophyte-infected tall fescue seed consumed for 7 days.

Implications

Sheep consuming high endophyte-infected tall fescue seed diets exhibited signs/symptoms of fescue toxicosis and tended to

shed more *E. coli* O157:H7. Management strategies that prevent livestock from grazing endophyte-infected tall fescue and/or alleviate stressors associated with consumption of endophyte-infected tall fescue prior to harvest may reduce fecal shedding of pathogenic bacteria from livestock.

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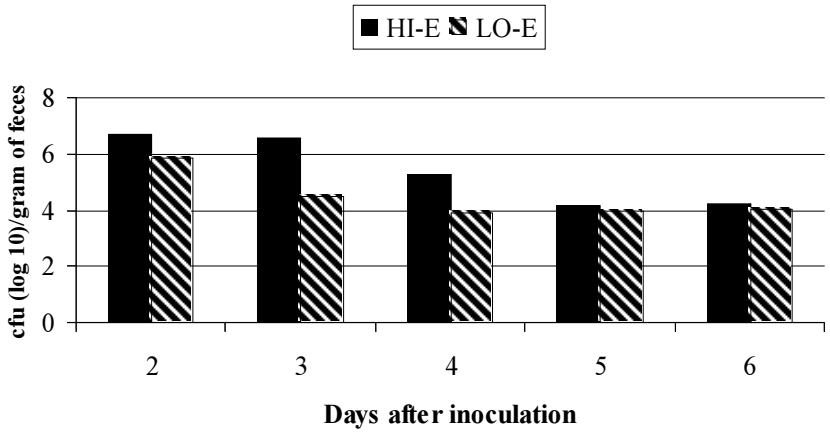

Fig. 1. Fecal shedding [cfu (log_{10})/gram of feces] of *E. coli* O157:H7 in sheep experimentally inoculated with *E. coli* O157:H7 and fed diets of high endophyte-infected (HI-E) or low endophyte-infected (LO-E) tall fescue seed; treatment effect (P = 0.06; SE = 0.49; treatment x day interaction, P = 0.18)

Table 1. Luminal contents [cfu (log_{10})/gram of feces] and tissue samples (number of ewes) of gastrointestinal tract positive for *E. coli* O157:H7 in sheep 7 days after inoculation with antibiotic-resistant *E. coli* O157:H7 and fed diets of high endophyte-infected (HI-E) or low endophyte-infected (LO-E) tall fescue seed.

Item	HI-E	LO-E	SEM
Luminal contents			
Ileum	2.10	2.75	0.61
Cecum	2.27	3.06	0.57
Rectum	2.64	2.09	0.73
Tissue samples			
Ileum	6/6[a]	4/6[b]	--
Cecum	5/6[a]	6/6[a]	--
Rectum	6/6[a]	5/6[a]	--

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

Behavior of Steers Grazing Tall Fescue Fed Different Types of Supplements

J.D. Shockey[1], S.A. Gunter[1,2], P.A. Beck[1,2], and C.B. Stewart[1]

Story in Brief

The objective of this study was to determine grazing behavior of steers grazing K-31 tall fescue pasture infected with the endemic endophyte and fed 2 types of supplements. Sixty Angus cross steers (593 ± 5 lb) were randomly assigned to one of the following treatments: 1) no supplement (CTL), 2) a self fed liquid supplement (Pastures plus 34/6, QLF, Inc., Dodgeville, Wis.; SUP), or 3) ground corn at a rate of 1 lb as fed daily fed 3 days weekly (POSCTL). Behavioral observations were collected every hour from 0630 to 2030 h bi-monthly and classified into the following 7 categories: consuming supplement, grazing, at the mineral feeder, drinking, standing, walking, or lying. There were no differences ($P > 0.05$) among groups in percentage of time lying, drinking, or at the mineral feeder. However, the CTL group grazed longer ($P < 0.05$) than SUP or POSCTL groups. Cattle fed SUP spent a higher percentage ($P < 0.01$) of time standing than the CTL group. There were no differences ($P > 0.05$) in ADG between supplemented and CTL groups. The CTL cattle performed as well as SUP cattle due in part to a potential increase in herbage intake. Increased grazing time will most likely result in greater DMI and BW gains than expected with supplements in this forage-based system tested.

Introduction

There are 30 million acres of tall fescue in the United States, and they play a large role in cattle production in this country. Kentucky 31 tall fescue infected with the endemic endophyte has a negative effect on cattle grazing, especially in summer. The release of novel endophyte tall fescues has reduced the negative effects on cattle. The time and investment required to establish a new stand with a novel endophyte on a site previously inhabited with tall fescue infected with the endemic endophyte requires a considerable risk to the producer. Numerous supplements have been considered to cope with and limit the negative effects on cattle when grazing tall fescue infected with endemic endophyte. The purpose of this study was to access the impact of different forms of supplementation on the behavior of cattle grazing infected tall fescue.

Experimental Procedures

Sixty Angus cross steers (BW = 593 ± 5 lb) were divided into 12 groups and grazed tall fescue/bermudagrass pastures (1 steer/acre) at the Southwest Research and Extension Center located near Hope, Ark. The soil type of pastures was Una Silt Clay loam, which consists of a deep, poorly drained, level soil (slopes of 1%) on a flood plain. The pastures were composed of a mixed grass stand representative of southwest Arkansas. Treatments were randomly assigned as follows: 1) no supplement (CTL), 2) a self-fed liquid supplement (SUP; Pasture Plus 34/6 QLF, Inc., Dodgeville, Wis.), or 3) ground corn at a rate of 1 lb as fed per day fed 3 days weekly (POSCTL). Cattle were shrunk for 16 hr before the start of the trial and were shrunk and weighed every 28 d for the duration of the trial (112 d).

Cattle behavior was assessed by observing the cattle from a remote location so as not to influence their behavior. Behavioral observations were taken every hour starting at 0630 till 2030 h every other Thursday from late April to early August, 2004. Observations were classified into 7 categories: consuming supplement, grazing, at mineral feeder, drinking, lying, standing, or walking. Treatment effects were analyzed using a mixed model (SAS Inst., Inc., Cary, N.C.) with treatment as the fixed effect and pastures as a random effect. Treatment differences were separated using the following contrast statements: 1) no supplement versus the average of supplemented groups, and 2) positive control (corn) versus supplemented with liquid feed.

Results and Discussion

There was no difference in performance between supplemented, SUP and POSCTL, cattle and CTL cattle ($P = 0.98$; Table 1). Body weight and ADG did not differ ($P = 0.98$) as a result of treatment, and ADG averaged 1.15 lb for this grazing study. The rate of ADG by these cattle was similar to that reported by Beck and Gunter (2005) in a study examining the effects of implant abnormalities on ADG on these same pastures.

In May, June, and July, there was an average of an 18% reduction in grazing time for SUP and POSCTL cattle vs. CTL ($P \leq 0.01$; Table 2); however, there was only a tendency for SUP and POSCTL cattle to graze less ($P = 0.09$) in August. These data are supported by the findings of Shockey et al. (2006). They reported, in a study examining the effects of modified glucomannan in liquid feed on grazing behavior, that supplementation reduced total grazing time. Supplemented, SUP and POSCTL, cattle spent an average of 15% more ($P < 0.01$) time standing than did the CTL cattle. In May and July, POSCTL cattle spent more ($P \leq 0.04$) time standing than SUP cattle. In August, CTL cattle spent more ($P < 0.01$) time at the water tank than both POSCTL and SUP cattle, and the SUP calves were observed drinking more than POSCTL ($P = 0.01$); in other months no differences ($P \geq 0.13$) were detected.

Supplemented and POSCTL cattle spent less time grazing than CTL cattle. This fact may have resulted in lower forage intake and mitigated the increase in ADG for the supplemented cattle normal-

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ly express. Any benefit that was expected from supplementation was probably offset by reduced grazing time.

Implications

Herbage dry matter intake is the most important factors affecting the performance of grazing cattle and any supplementation program used should not reduce it. Decreased grazing time by grazing cattle will most likely result in lower dry matter intake and lower growth rate.

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Table 1. Body weight, ADG, and supplemental feed intake of steers grazing endophyte infected tall fescue supplemented with different feeds.

	Treatments[a]				*P*-value[b]	
Item	CTL	POSCTL	SUP	SE	CTL vs Supplemented	PosCTRL vs SUP
Steer BW, lb						
d 0, April 12	596	584	600	22.3	0.86	0.62
d 133, August 24	752	757	744	22.3	0.98	0.69
ADG, lb	1.2	1.2	1.1	0.17	0.98	0.69
Supplement intake, lb/d	---	1.0	4.8		---	---

[a]Control = endophyte infected tall fescue; POSCTL = 1.0 lb daily of ground corn on an as-fed basis; SUP = liquid feed from QLF, Inc. (Pasture Plus 34/6; Dodgeville, WI) with a targeted intake of 2.0 to 3.0 lb/d.
[b]Contrasts: CTL vs Supplemented = Control vs the average of the Supplemented pasture plus 34/6 and Positive control; SUP vs POSCTL = Supplemented liquid feed pasture plus 34/6 vs positive control.

Table 2. Behavior of steers grazing endophyte infected tall fescue supplemented with different feeds.

	Treatments[a]				*P*-value[b]	
Behavior/month, % of time	CTL	POSCTL	SUP	SE	CTL vs Supplemented	POSCTL vs SUP
At supplement feeder/tank						
May	0	0.2	4.1	0.55	< 0.01	< 0.01
June	0	0.2	3.4	0.83	0.06	< 0.01
July	0	0.0	2.5	0.60	0.10	< 0.01
August	0	0.0	4.7	0.70	0.01	< 0.01
Grazing						
May	56.8	49.6	43.7	2.31	< 0.01	0.08
June	59.2	51.5	44.3	3.24	< 0.01	0.13
July	57.0	49.5	43.2	3.25	0.01	0.18
August	64.0	60.3	53.0	3.44	0.09	0.14
At mineral feeder						
May	0.9	0.0	0.5	0.17	< 0.01	0.08
June	0.7	0.0	0.7	0.49	0.58	0.36
July	0.5	0.0	0.7	0.31	0.66	0.14
August	0.7	0.0	0.3	0.33	0.17	0.49
Drinking or at water tank						
May	23.2	19.3	23.9	2.60	0.62	0.23
June	27.0	24.3	27.0	3.88	0.78	0.63
July	30.0	26.8	33.2	2.85	0.99	0.13
August	11.7	4.5	6.1	1.5	< 0.01	0.01
Laying						
May	12.2	13.6	15.6	1.30	0.16	0.29
June	9.0	9.5	12.0	2.00	0.47	0.37
July	9.5	9.2	11.7	2.0	0.71	0.38
August	16.5	21.1	25.3	2.94	0.07	0.32
Standing						
May	6.4	16.3	11.3	1.46	< 0.01	0.02
June	4.2	14.5	11.3	2.24	< 0.01	0.33
July	3.0	13.8	8.7	1.72	< 0.01	0.04
August	6.3	14.2	9.7	1.6	< 0.01	0.15
Walking						
May	0.5	1.0	1.1	0.35	0.25	0.77
June	0.0	0.0	0.8	0.48	0.49	0.23
July	0.0	0.7	0.2	0.32	0.30	0.28
August	0.8	0.0	1.0	0.59	0.32	0.84

[a]CTL = endophyte infected tall fescue; POSCTL = 1.0 lb daily of ground corn on an as-fed basis; SUP = liquid feed from QLF, Inc. (Pasture Plus 34/6; Dodgeville, WI) with a targeted intake of 2.0 to 3.0 lb/d.

[b]Contrasts: CTL vs Supplemented = Control vs the average of the SUP and Positive control; SUP vs PosCTRL = Pasture Plus 34/6 vs positive control.

Perennial Versus Annual Cool Season Grasses as Supplements for Wintering Beef Cows

S.A. Gunter[1,2], P.A. Beck[1,2], J.D. Shockey[1], C.B. Stewart[1], and J.M. Phillips[1,3]

Story in Brief

In November 2003, 138 pregnant crossbred beef cows (average BW = 1,104 ± 22 lb) were weighed, BCS recorded. Cows were sorted into 6 groups of 23 stratified by BCS, BW, breed, and age, then assigned to six 12.5 acre dormant common bermudagrass pastures (3 groups/treatment) for 2 years. Groups of cows had ad libitum access to hay plus 1 of the following 2 supplements beginning in November until May: 1) allowed access to 6 acres of winter annual 3 days/week, or 2) allowed access to 6 acres of tall fescue 3 days/week. The winter annual pastures were also seeded to 'Red River' crabgrass for summer forage production. During the summer, the calves were allowed to grazing the cool season pastures via creep gates, and cows were only allowed to graze the pasture when the forage became over abundant and mature. From mid December until early May, cow BW and BCS did not differ ($P \geq 0.22$) between the annual and perennial cool season pastures when used as supplements to the bermuda/dallisgrass hay. Also, cow BW and BCS did not differ ($P \geq 0.27$) from early May until mid September when they grazed primarily bermudagrass. Conception rate and the post partum interval did not differ ($P \geq 0.61$) between treatments. Calving date, calf birth weight, BW, ADG, weight per day of age, and the 205 day weaning weight did not differ ($P \geq 0.11$) between treatments. These data suggest that either forage type, when used as a supplement to warm season grass hay and a creep pasture, was similar in its ability to supply nutrients to the cows and their nursing calves.

Introduction

Decreasing stored feed requirements of beef cows is a topic that has received considerable attention in recent years. However, beef cattle producers in the southern US still winter cows primarily with hay plus a concentrate based supplement. Complementary forage systems based on a warm season perennial and cool season annual grasses have shown promise as a method of providing supplemental nutrients and decreasing hay requirements (Utley and McCormick, 1978; Hill et al., 1985; Gunter et al., 2002). The common advantages noted among these reports are extension of the grazing season and decreased days and quantities of hay fed. Studies in northern Florida that evaluated the use of wheat or rye with crimson and arrowleaf clovers as a supplement to Argentine bahiagrass hay (DeRouen et al., 1991) demonstrated that winter annual pasture grazing could decrease winter hay dry matter intake (DMI) by as much as 30% compared to bahiagrass hay plus a concentrate based supplement. Gunter et al. (2002) designed a supplemental limit grazing system for gestating and lactating beef cows that eliminated the need for concentrate based supplements and decreased hay requirements. The following study was designed to compare limit grazing of winter annual pasture with that of perennial cool-season pasture for beef cows.

Experimental Procedures

In the fall of 2002, 6 pastures (6 acres each) on the Southwest Research and Extension Center were sprayed with glyphosate and disked to prepare a seedbed. Three of the pastures were planted with 'Jessup' tall fescue infected with endophyte AR542 (MaxQ, Pennington Seed, Inc., Madison, Ga.), while the remaining three 6 acre pastures were planted to annual ryegrass (var Passerel Plus; Pennington Seed, Inc.) as a cover crop. Pastures were limit grazed for 1 year to allow for the establishment of the tall fescue.

In November of 2003, 138 pregnant crossbred beef cows (average BW = 1,104 ± 22 lb) of mostly Angus breeding were weighed, BCS (Wagner et al., 1988) recorded, and a 7 way Clostridial antigen (Vision 7; Bayer Corp., Shawnee Mission, Kan.) administered to increase Clostridial antibodies at calving. Cows were sorted into 6 groups of 23 stratified by BCS, BW, breed, and age, then assigned to six 12.5 acre dormant common bermudagrass pastures (3 groups/treatment). Groups of cows remained in their assigned pasture 2 years and had ad libitum access to hay plus 1 of the following 2 supplements beginning in November: 1) allowed access to 6 acres of winter annual pasture approximately 3 days/week (Monday, Wednesday, and Friday; 0.10 acre per cow per grazing-day [7 hours/day]), or 2) allowed access to 6 acres of tall fescue pasture approximately 3 days/week (Monday, Wednesday, and Friday; 0.10 acre per cow per grazing-day [7 hours/day]). The number of times a week the cool season pastures were grazed was adjusted to compensate for available forage. It was estimated that grazing winter annual pasture 3 days/week would meet or exceed the requirements of the cow for supplemental protein and energy (Gunter et al., 2002).

Winter annual grasses were planted in late September of 2003 and 2004, and the forage was stockpiled until grazing was initiated in December; therefore forage was not limiting in January or February when plant DM production is less than cattle demand. The winter annual pastures were also seeded to 'Red River' crabgrass for summer forage production. Pastures of cows were restricted from supplementation paddocks on non grazing days by the use of electric fences during the winter; during the summer, the calves were allowed to graze the cool season pastures via creep gates and cows were only allowed to graze the pasture when the forage

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became over abundant and rank. Hay was offered in the form of round bales in "ring" type hay feeders and technicians maintained records of the quantity of hay fed in each pasture.

Winter annual grasses were seeded using a Marliss no till drill (Sukup Manufacturing, Jonesboro, Ark.). The pastures were seeded with 90 lb/acre of 'Wintergrazer 70' rye (Pennington Seed, Inc.) via the small grain box, 25 lb of 'Passerel Plus' annual ryegrass/acre via the grass seed box, plus banding phosphorus and potassium via the fertilizer box. Phosphorus and potassium rates were selected to fulfill soil test recommendations (Chapman, 1998). Before planting, standing herbage mass was sprayed with glyphosate then removed from the area by continuously stocking with cattle until the standing herbage mass was visually estimated to be < 2 inches to insure that winter annual grasses had minimal competition. In mid October, late January, and mid March pastures were fertilized with a 50 lb of N/acre using ammonium nitrate.

From April 25 until June 25 (60 d), 6 Angus bulls that had passed a breeding soundness examination remained with the cows, 1 bull per group. Each 12.5 acre pasture was fertilized with 50 lb of N/acre using ammonium nitrate in late April, and late June of each year. Cows always had ad libitum access to a self fed commercial mineral mixture.

Cows and calves were weighed and BCS of the cows were recorded during mid December, early February, early May, late June, early August, and mid September of each year. The morning after calving, calves were weighed, tattooed in both ears with an individual number, and male calves were surgically castrated. In mid May, cows were treated for internal and external parasites (Ivomec; Merck & Co., Inc., Whitehouse Station, N.J.), vaccinated with a 7 way Clostridial antigen (Vision 7), and vaccinated against infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza 3, bovine respiratory syncytial virus plus 5 strains of Leptospirosis (Bovishield 4 + VL5; SmithKline Beecham Animal Health, Exton, Pa.). Cows were checked for pregnancy by rectal palpation in mid September. Post partum interval was calculated by subtracting 283 d from the calving date of the following year to estimate conception date.

The data were analyzed using PROC MIXED (SAS Inst., Inc., Cary, N.C.) as a completely randomized design with the effect of treatment and the covariates of cow age and calving date in the model. The fixed effect was treatment and the random effects were pasture, year, and pasture x year. Least squares means were separated using predicted differences.

Results and Discussion

From mid December until early May, cow BW did not differ ($P \geq 0.75$) between the limit grazed annual and perennial cool season pastures used as supplements for the bermuda/dallisgrass hay (Table 1). Furthermore, cow BW did not differ ($P \geq 0.27$) from early May until mid September when they grazed primarily bermudagrass. From mid December until early May, BCS did not differ ($P \geq 0.22$) between the limit grazed annual and perennial cool season pastures when used as supplements for the bermuda/dallisgrass hay (Table 1). During the summer, BCS did not differ ($P \geq 0.53$) from early May until mid September. During peak lactation (early February to early May), at no time did BCS decrease to a point where rebreeding performance would become a concern. Supporting this conclusion, conception rate did not differ ($P = 0.94$) between treatments and was near an optimum rate for this type of production system and class of cattle. The post partum interval did not differ ($P = 0.61$) between treatments and was less than 79 days, which is necessary to maintain a minimum 365 day calving interval. Apparently, both the perennial and the annual grasses were able to adequately supplement the hay during gestation and lactation to maintain these cows in an adequate plain of nutrition.

Calving date did not differ ($P = 0.86$) between annual grasses (February 21) and the tall fescue (February 21; Table 2). Calf birth weight, BW, ADG, weight per day of age, and the 205 day weaning weight did not differ ($P \geq 0.11$) between treatments. These data suggest that either forage type when used as a supplement to warm season grass hay was similar in its ability to supply nutrients to the growing calves. Based on these 2 years of data from this complementary forage system, either forage type of cool-season grass (annual or perennial) was equivalent in meeting the nutritional need of the cow herd. Hence, the choice of forage type for a specific producer needs to be based on the agronomic factors of production and the economics of production.

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Table 1. Body weight, BCS, conception rate, and post-partum interval of mature beef cows fed bermudagrass/dallisgrass hay supplemented by limit grazing on rye/ryegrass or tall fescue pasture 3 days weekly.

	Treatments[a]			
Item	Annual	Fescue	SE	*P*-value
Cow BW, lb				
Mid December	1,156	1,149	17.9	0.75
Early February	1,240	1,245	20.6	0.79
Early May	1,152	1,157	13.9	0.79
Late June	1,112	1,136	21.1	0.27
Early August	1,107	1,112	19.9	0.77
Mid September at weaning	1,130	1,119	42.5	0.51
BCS[b]				
Mid December	6.1	6.2	0.08	0.34
Early February	6.6	6.4	0.11	0.22
Early May	6.3	6.3	0.31	0.77
Late June	6.0	5.9	0.14	0.78
Early August	5.8	5.8	0.11	0.83
Mid September at weaning	6.0	5.9	0.09	0.53
Conception rate, %	91	90	4.4	0.94
Post-partum interval, d	75	77	1.8	0.61

[a]Annual = limit grazed winter-annual pasture ('Wintergrazer 70 rye and 'Passerel Plus' ryegrass) approximately 3 days weekly and fescue = limit grazed 'Jessup' tall fescue pasture infected with AR542 endophyte approximately 3 days weekly from January until May.
[b]Body condition score range 1 to 9; 1 = emaciated, 9 = obese (Wagner et al., 1988).

Table 2. Birth date and weight, BW, ADG, weight per day of age, and 205-day-weight of calves nursing mature beef cows fed bermudagrass/dallisgrass hay supplemented by limit grazing on rye/ryegrass or tall fescue pasture 3 days weekly.

	Treatments[a]			
Item	Annual	Fescue	SE	*P*-value
Birth date, Julian calendar	52	52	1.2	0.86
Birth weight, lb	82	79	1.4	0.21
Calf BW, lb				
Early May	230	229	3.6	0.75
Late June	336	337	7.1	0.87
Early August	386	381	5.8	0.52
Mid September at weaning	428	410	6.6	0.11
ADG, lb				
Birth to May	2.0	2.0	0.05	0.83
May to weaning	1.9	1.7	0.08	0.11
Birth to weaning	1.8	1.8	0.03	0.15
Weight per day of age, lb	2.3	2.2	0.03	0.12
205-day-weaning weight	456	437	7.2	0.13

[a]Annual = limit grazed winter-annual pasture ('Wintergrazer 70 rye and 'Passerel Plus' ryegrass) approximately 3 days weekly and fescue = limit grazed 'Jessup' tall fescue pasture infected with AR542 endophyte approximately 3 days weekly from January until May.

Effect of Hay Harvest Interval on Forage Quality and Performance of Growing Calves Fed By-product-Based Growing Diets

P. Beck, S. Hutchison, B. Stewart, D. Shockey, and S. Gunter[1]

Story in Brief

Twelve 2-acre crabgrass pastures were harvested for hay, fertilized with 50 lb N and 150 lb K/acre, then harvested at 21, 35, and 49 d of regrowth (average phenologic growth stage of 30, 51, and 56, respectively). Increased harvest interval linearly decreased ($P < 0.01$) CP (14.1, 13.7, and 10.6% of DM, respectively) and increased ($P < 0.01$) NDF content (65.3, 70.6, and 70.2% of DM, respectively). Hays were incorporated into diets which contained 20% (DM basis) of the crabgrass hays, and the primary energy sources were ground corn (33%) and soybean hulls (32%). Diets contained 14.4, 14.4, and 13.6% CP; 0.83, 0.78, 0.82 Mcal NEm/lb; and 0.55, 0.50, 0.53 Mcal NEg/lb; respectively. Diets were fed to beef calves in 12 pens at a rate of 2.3% (DM basis) of BW in one trial (n = 120, initial BW 463 lb) and ad libitum in another trial (n = 60, initial BW 456 lb). Data were analyzed as a completely random design. Least-squares means were separated using orthogonal contrasts for linear and quadratic effects of hay harvest interval. Harvest interval did not affect ($P > 0.22$) ADG of limit-fed calves during step up or growing phase (average of 0.70 and 1.76 lb, respectively) or calves fed ad libitum (average 2.66 lb). Dry matter intake of calves fed ad libitum averaged 17.4 lb/d (3.28% of BW) and was not affected by harvest interval. Feed:gain was not affected ($P > 0.20$) by harvest interval (averaging 7.5 and 6.6 for limit fed and ad libitum fed calves, respectively).

Introduction

Maturity at harvest has a large impact on hay quality; as forages mature, concentrations of fiber and lignin increase. Highly lignified forages remain in the rumen longer because of their slow rate of digestion, decreasing DMI which reduces animal performance. When feeding growing calves mixed diets, producers often use low-quality forages because of the perception that forage quality is insignificant relative to the total diet. However, little research has been reported that compares the effects of harvest interval of warm-season grass hays on dry matter intake and performance of growing beef calves fed by-product based diets. The following research was designed to determine the impact of 3 harvest intervals (21, 35, and 49 d) of crabgrass hay on forage DM yield, nutritive quality; and the impact of forage quality on performance of growing steers fed mixed diets in drylot.

Experimental Procedures

Twelve 2-acre crabgrass pastures were harvested for hay on July 21, 2004, fertilized with 50 lb N and 150 lb K/acre, then harvested at 21, 35, and 49 d of regrowth. These plots were located at the University of Arkansas Division of Agriculture, Southwest Research and Extension Center (33° 42' N, 93° 31' W) near Hope, Ark. Soils of these pastures were primarily Smithdale fine sandy loam, but also include areas of Sawyer loam. These soils are deep and moderately well drained, low in native fertility, and have low soil pH and OM.

After the assigned regrowth interval, pastures were harvested by cutting with a disc mower (Kuhn, model GMD 700 HD, Vernon, N.Y.) and baled into round packages (John Deere 466, John Deere Tractor Works, Moline, Ill.). Individual bales were weighed, labeled, and sampled. Samples were dried, ground, and composited within pasture. Composite samples were analyzed for DM, NDF, ADF, N, and ash. Crude protein was calculated as the percentage of N in the sample x 6.25. Crabgrass hays were composited across pastures within harvest interval for 2 feeding trials.

In the first trial, 120 Angus-sired steer and heifer calves (initial BW = 463 lb) from the Southwest Research and Extension Center cow herd were used to test the effects of forage harvest interval on the performance of calves limit-fed mixed diets at a rate of 2.3% (DM basis) of BW. Calves were weighed following weaning and assigned to 1 of 12 pens stratified by gender (5 steers and 5 heifers/pen) and BW. Pens were then randomly assigned to 1 of 3 treatment diets based on the crabgrass hays harvested following 21, 35, and 49 d of regrowth. Diets (Table 1) contained 20% (DM basis) of the crabgrass hay and the primary energy sources for the diets were from ground corn (33%) and soybean hulls (32%). Round bales of hay were processed in a feed mixer (Kuhn, model 1060, Vernon, N.Y.) before blending with concentrate during the diet mixing process. Diets were stored in the feed alley until delivery to the feedbunks at 0800 h daily.

Calves were weaned during a 14-d start-up period, the calves were allowed ad libitum access to bermudagrass (*Cynodon dactylon* (L.) Pers.) hay for 1 wk and 1 kg/calf of the assigned diet which was increased daily until target intake rates were reached (2.3% of BW DM basis). Diets were then fed for a 70-d growing period. At weaning, the calves were treated for internal and external parasites (Ivomec Plus, Merial Inc, Duluth, Ga.), vaccinated for bovine respiratory disease complex (Cattlemaster 4, Pfizer Inc., New York, N.Y.) and with a 7-way Clostridial plus H. somnus (Vision 7 somnus, Bayer Corp., Shawnee Mission, Kan.). Revaccination occurred 14-d following initial vaccination. Calves were weighed bi-weekly before the morning feeding following 16-h removal of feed and water. Feed was offered once daily at 0800 h in quantities equaling 2.3% of pen BW (DM basis), adjusted bi-weekly. Diet samples were collected weekly for DM, ash, N, NDF, and ADF analysis. Calves were housed in pens (7 m x 33m) that were partially covered by an open-sided barn and constructed of metal panels with interior pens split by electrified fencing. Each pen offered 7 m of bunkspace.

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In the second trial, 60 Angus-sired heifers (initial BW = 456 lb) from the Southwest Research and Extension Center cow herd were used to test the effects of forage harvest interval on the performance and DMI of calves fed mixed diets in amounts sufficient for ad libitum intake. Calves were stepped up to ad libitum intake of a common diet during a 14-d weaning period. Following weaning, the calves were weighed and assigned to 1 of 12 pens stratified by BW (n = 5 heifers/pen). Pens were then randomly assigned to 1 of 3 treatment diets previously described for a 56-d feeding period. Feed was offered once daily at 0800 h in quantities adequate to allow ad libitum consumption. Diet samples were collected weekly for DM, ash, N, NDF, and ADF analysis. Calves were weighed bi-weekly before the morning feeding and orts were collected bi-weekly at 0700 h prior to weighing, orts were weighed and sampled for DM determination.

Forage quality at harvest was analyzed as a completely randomized design with the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) using pasture as the experimental unit and residual error as the error term. The effects of diet fed in drylot on performance of limit-fed or ad libitum-fed diets, in situ DM and NDF disappearance characteristics, and passage rate data for each forage and diet were analyzed as a completely randomized design with the MIXED procedure of SAS using pen as the experimental unit and pasture within treatment as the random effect. Feed:gain as well as DMI of calves in performance trials were analyzed as a completely randomized design with the GLM procedure of SAS using pen as the experimental unit and residual error as the error term. Least-squares means for forage quality, calf performance, passage rate, in situ digestion kinetics, DMI, and feed:gain were separated using orthogonal contrasts which included the linear and quadratic effects of forage harvest interval.

Results and Discussion

Forage DM yield/acre (Table 2) increased linearly ($P < 0.01$) from 2,527 lb to 8,613 lb as the regrowth interval between hay harvests increased from 21 to 49 d. This increase in DM yield was accompanied by a quadratic ($P < 0.01$) increase in growth stage at harvest from 29 (late tillering) with a 21-d harvest interval to 51 (10% head emergence) with a 35-d harvest interval and finally 56 (60% head emergence) for a 49-d harvest interval. With the increase in maturity, there were concomitant linear ($P < 0.01$) decreases in CP and TDN concentrations and increases in detergent fiber concentrations. Crude protein concentration was reduced ($P < 0.01$) by 29% and calculated TDN concentration was reduced by 12% when harvest interval increased from 21 to 49 d.

When calves were limit-fed 2.3% of BW (Table 3), there were no differences ($P > 0.15$) in BW either before or following the start-up period (average BW, 463 and 473 lb, respectively) or following the 70-d growing period (average BW, 594 lb) among the diets based on 20% (DM basis) hay from each harvest interval. During the 14-d start-up period when calves were weaned and adapted to diets, ADG averaged 0.70 lb and did not differ ($P > 0.11$) among treatments. Average daily gain during the 70-d growing period averaged 1.76 lb across treatments and also did not differ among treatments ($P > 0.22$). Because ADG did not differ and DMI was limited to 2.3% of BW, the feed required per lb of gain also did not differ ($P > 0.35$) averaging 7.45 across treatments.

Body weight of calves fed mixed diets ad libitum (Table 4) did not differ ($P > 0.29$) before or following the 56-d growing trial (average BW, 456 and 603 lb, respectively). Average daily gain and total BW gain per calf did not differ ($P > 0.34$) across treatments and averaged 2.66 and 150 lb, respectively. Daily DMI averaged 17.4 lb (3.28% of BW) and did not differ ($P > 0.21$) across treatments. Once again because ADG and DMI did not differ, the feed required per lb gain also did not differ across ($P > 0.22$) treatments, averaging 6.6 lb feed per lb gain. Under the conditions of this research, increasing harvest interval of crabgrass hay has no deleterious impact on animal performance or feed efficiency when fed in high-concentrate diets.

Acknowledgments

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Table 1. Composition of mixed diets fed to growing calves.

	Diet/hay harvest interval[a]		
Ingredient	21	35	49
	----------% DM Basis----------		
Crabgrass hay			
21-d	20.0	-	-
35-d	-	20.0	-
49-d	-	-	20.0
Corn	33.0	33.0	33.0
Soybean hulls	32.0	32.0	32.0
Cottonseed meal	8.4	8.4	8.4
QLF 34/6[b]	5.4	5.4	5.4
Limestone	1.0	1.0	1.0
Salt	0.2	0.2	0.2
Composition			
Crude Protein	14.4	14.4	13.6
NDF	53.1	54.8	58.9
ADF	23.3	26.0	27.2
NEm, Mcal/lb	0.83	0.78	0.82
NEg, Mcal/lb	0.55	0.50	0.53

[a]Hays were harvested following 21, 35, or 49 d of regrowth.
[b]QLF 34/6 (Quality Liquid Feed, Inc., Dodgeville, WI) is a molasses based liquid protein supplement which contained 34% CP (6% from natural protein sources), 60% DM, 0.51 Mcal NEm/lb and 0.36 NEg/lb.

Table 2. Effect of harvest interval[a] of crabgrass hay on DM yield, phenological growth stage, and nutritive characteristics.

	Harvest Interval				Contrast[c]	
Item	21	35	49	SE[b]	L	Q
Yield, lb DM/acre	2,527	6,454	8,613	799.8	<0.01	0.39
Growth Stage[d]	29	51	56	0.95	< 0.01	< 0.01
CP, % DM	15.6	14.3	11.0	0.55	< 0.01	0.15
NDF, % DM	61.3	66.6	69.8	0.98	< 0.01	0.40
ADF, % DM	35.7	38.9	42.7	0.94	< 0.01	0.78
TDN, % DM	62.6	59.1	54.8	1.04	< 0.01	0.79

[a]Hays were harvested following 21, 35, or 49 d of regrowth
[b]SE of the mean (n = 12).
[c]Contrasts included the linear and quadratic affect of forage regrowth interval before harvest.
[d]Phenological growth stage was based on the Biologische Bundesanstalt Bundessortenamt and Chemical Industry (**BBCH**) scale, where a growth stage of 30 corresponds to the beginning of stem elongation, 40 corresponds early boot stage, 50 corresponds to heading, and 60 corresponds to ripening seed heads.

Table 3. Effect of harvest interval[a] of crabgrass hay on performance of growing cattle limit-fed mixed diets.

	Harvest Interval				Contrast[c]	
Item	21	35	49	SE[b]	L	Q
BW, kg						
Day 1	210	209	211	9.68	0.77	0.73
Day 14	215	211	218	9.96	0.65	0.36
Day 84	272	265	274	10.34	0.76	0.15
ADG, kg						
Start up period, d1 to 14	0.36	0.16	0.44	0.26	0.65	0.11
Growing period, d 15-84	0.82	0.77	0.81	0.68	0.79	0.22
Feed:gain, lb:lb[d]	7.56	7.52	7.26	0.22	0.35	0.63

[a]Hays were harvested following 21, 35, or 49 d of regrowth.
[b]SE of the mean (n = 12).
[c]Contrasts included the linear and quadratic affect of forage regrowth interval before harvest.
[d]lb feed required for lb gain.

Table 4. Effect of harvest interval[a] of crabgrass hay on performance of growing cattle fed mixed diets ad libitum.

	Harvest Interval				Contrast[c]	
Item	21	35	49	SE[b]	L	Q
BW, lb						
Day 1	458	460	446	12.8	0.55	0.65
Day 56	614	605	592	14.4	0.29	0.91
ADG, lb/d	2.79	2.60	2.57	0.13	0.34	0.60
Total gain/calf, lb	156	145	145	8.1	0.34	0.60
Daily DMI, lb/calf	17.6	17.6	16.8	0.42	0.21	0.50
Feed:gain, lb:lb[d]	6.35	6.82	6.53	0.48	0.59	0.20

[a]Hays were harvested following 21, 35, or 49 d of regrowth.
[b]SE of the mean (n = 12).
[c]Contrasts included the linear (L) and quadratic (Q) affects of forage regrowth interval before harvest.
[d]Feed required per lb of gain.

Relationships Between Calf Serum Metabolites at Feedlot Entry and Subsequent Carcass Traits in Brangus-Crossbred Calves

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Story in Brief

Our aim was to determine the relationship between serum metabolites of Brangus-crossbred calves (n = 85; BW = 715 ± 20 lb) at feedlot entry with their subsequent carcass characteristics. Calves were weighed, and blood samples collected 2 d after arrival at the feedlot. Serum samples were analyzed for lactate dehydrogenase (LDH) activities, hemoglobin, protein, creatinine, prolactin, triiodothyronine, thyroxine, cortisol, testosterone, and IGF-I. After slaughter, *longissimus* muscle and 12th rib subcutaneous fat were measured, and USDA quality and yield grades were assigned to each carcass. Sixty-eight percent of carcasses graded U.S. Choice or higher. Carcass distributions among yield grade were 18, 52, and 26%, for yield grades 1, 2, and 3, respectively. Serum reverse LDH (rLDH) activity tended ($P = 0.07$) to be lower in calves producing Choice carcasses than calves producing Select carcasses. Thyroxine tended ($P = 0.07$) to be increased in calves producing yield grade 1 carcasses vs. calves that produced yield grade 2 and 3 carcasses. *Longissimus* muscle area was correlated ($P < 0.05$) with concentrations of prolactin ($r = 0.24$), triiodothyronine ($r = 0.22$), and thyroxine ($r = 0.35$). Other serum metabolites were not ($P > 0.10$) related to other carcass characteristics. Heifers had decreased ($P < 0.05$) concentrations of IGF-I, and greater ($P < 0.01$) concentrations of creatinine than steers; however, the percentage of heifers and steers grading U.S. Choice did not differ ($P > 0.10$). Results from this study suggest differences may exist in serum concentrations of LDH at the time of feedlot entry among calves producing Choice or Select carcasses, and LDH may serve as an early physiological marker of carcass quality grade.

Introduction

Ultrasound technology is the most commonly employed method to predict carcass traits in live cattle (Greiner et al., 2003); however, variation among animals, technicians, and machines interact to influence ultrasound accuracy. Therefore, other alternatives to predict carcass traits must be made available to beef cattle producers. Use of physiological markers may provide one such alternative. Blood metabolites as potential markers are promising as only a single blood sample may be utilized to run a series of laboratory analyses. Serum metabolites may then be utilized to predict carcass characteristics. Serum lactate dehydrogenize (LDH) at weaning was lower in calves whose carcasses ultimately graded U.S. Choice vs. Select (May et al., 2004). Thus, LDH is an enzyme that may be utilized to predict carcass traits in live cattle. Our objective, therefore, was to quantify sera metabolites from fall-born Brangus-crossbred calves at the time of feedlot entry to determine relationships among metabolites and carcass characteristics.

Experimental Procedures

Eighty-five Brangus-crossbred calves (BW = 715 ± 20 lb) were used in this study. Calves were developed for 144 d on mixed pastures of bermudagrass and tall fescue. Calves were then placed in the feedlot (Flintrock Feeders, Gruver, Texas) and fed a high energy ration consisting of corn, alfalfa hay, fat, molasses, and vitamin/mineral pre-mix. Calves were weighed, and blood samples collected via jugular venipuncture 2 d after arrival at the feedlot. Serum was harvested from blood by centrifugation at 1500 x g for 25 min and stored at -20°C until analyzed. After slaughter, *longissimus* muscle and 12th rib subcutaneous fat were measured, and U.S. quality and yield grades were assigned to each carcass following a 5-mo finishing phase. All cattle were slaughtered at a commercial packing plant.

Serum samples were analyzed for serum lactate dehydrogenase (LDH) activities, hemoglobin, protein, creatinine, prolactin, triiodothyronine, thyroxine, cortisol, testosterone, and insulin-like growth factor-I (IGF-I). Serum concentrations of prolactin, triiodothyronine, thyroxine, cortisol, testosterone, and IGF-I were quantified by radioimmunoassay. Serum concentrations of LDH activity, hemoglobin, protein, and creatinine were determined with enzymatic reagents and procedures provided by Sigma-Aldrich Co. (St. Louis, Mo.). The coefficients of variation were less than 10% for all assays.

Lactate dehydrogenase is the enzyme responsible for the interconversion of pyruvate and lactate. Forward LDH (fLDH) activity measures the activity associated with LDH converting pyruvate to lactate. Conversely, reverse LDH (rLDH) activity measures the activity associated with LDH converting lactate to pyruvate.

Serum metabolites for each quality and yield grade were analyzed with a one-way ANOVA using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Least squares means were compared using the PDIFF option of GLM when protected by a significant ($P < 0.05$) treatment effect. Pearson correlation coefficients were calculated utilizing the CORR procedure of SAS to assess the relationship between serum metabolites and quality and yield grades.

Results and Discussion

Sixty-eight percent of carcasses graded U.S. Choice or higher whereas, carcass distributions among yield grade were 18, 52, and 26%, for yield grades 1, 2, and 3, respectively. Carcass quality grade

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tended to be influenced by rLDH activity (Table 1). Serum rLDH activity tended to be lower (P = 0.07) in calves producing Choice carcasses than calves producing Select carcasses. May et al. (2004) reported that serum LDH activity was lower at weaning in calves that ultimately graded Choice compared to calves that graded Select. Lactate dehydrogenase is the primary enzyme involved in the inter-conversion of pyruvate to lactate and has been found to have a relationship with cattle carcass traits (Paria, 1997). Jurie et al. (1995) reported that *semitendinosus* muscle from male Limousin cattle had greater LDH activity than thoracic muscle. In the present study, calves whose carcasses ultimately graded Choice vs. Select tended to have reduced rLDH activity in sera. The exact physiological mechanisms responsible for this observation are not clear; however, LDH plays a critical role in lipogenesis as growing cattle may utilize lactate as a carbon source for the synthesis of fatty acids (Whitehurst et al., 1981). Increased fat deposition in muscle tissue attributed to increased fatty acid synthesis may influence subsequent quality grade.

Thyroxine tended (P = 0.07) to be greater in calves with yield grade 1 carcasses vs. calves with yield grade 2 and 3 carcasses. *Longissimus* muscle area was correlated (P < 0.05) with concentrations of prolactin (r = 0.24), triiodothyronine (r = 0.22), and thyroxine (r = 0.35). Other serum metabolites were not related to any other carcass characteristics. Thyroxine has been reported to be an indicator of protein deposition (Hayden et al., 1993), and triiodothyronine is involved in normal and androgen-related growth and protein accretion in beef steers (Kahl et al., 1992). Heifers had lower (P < 0.05) concentrations of IGF-I, and greater (P < 0.01) concentrations of creatinine than steers but, the percentage of heifers and steers grading Choice did not differ (P > 0.10).

Table 1. Least squares means from serum metabolites in carcass characteristics from Brangus-crossbred calves (n = 85)[a].

	Quality Grade			Yield Grade			
Variable	Choice	Select	Pooled SE	1	2	3	Pooled SE
Forward lactate dehydrogenase, IU/mg	875.2	889.3	30.8	875.2	929.0	926.1	31.5
Reverse lactate dehydrogenase, IU/mg	361.4[b]	413.0[c]	25.0	373.1	415.1	425.7	23.3
Hemoglobin, µg/mL	16.1	15.5	3.0	17.9	17.8	14.1	3.0
Protein, mg/mL	114.2	118.1	7.3	127.4	116.7	112.7	7.5
Creatinine, mg/mL	2.5	2.2	0.15	2.5	2.4	2.3	0.2
Prolactin, ng/mL	29.8	29.8	7.7	45.3	22.7	18.7	7.8
Triiodothyronine, ng/mL	3.7	3.4	0.21	4.1	3.5	4.0	0.2
Thyroxine, ng/mL	100.3	100.9	4.6	109.0[b]	92.4[c]	95.3[c]	4.7
Cortisol, ng/mL	61.2	60.6	4.0	59.4	64.5	59.1	4.0
Testosterone, ng/mL	0.03	0.04	0.02	0.03	0.04	0.02	0.02
IGF-I, ng/mL	174.1	176.8	20.0	159.3	180.5	198.9	20.3

[a]Blood serum metabolites were measured 2 d following entry into the feedlot. Calves were approximately 12 mo of age at time of feedlot entry. At slaughter, *longissimus* muscle and ribfat thickness were measured, and U.S. quality and yield grades were assigned to each carcass following a 5-mo. finishing phase.
[bc]Within each quality and yield grade, means without a common superscript letter differ (P = 0.07).

Implications

Results from this study suggest differences may exist in serum concentrations of LDH at the time of feedlot entry among calves producing Choice or Select carcasses, and LDH may serve as an early physiological marker of carcass quality grade.

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Effects of Ca Salts of Conjugated Linoleic Acid and Previous Rate of Weight Gain on Growth Performance, Immune Function, and Carcass Characteristics of Beef Cattle

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Story in Brief

Crossbred beef steers (n = 35; initial BW = 886.3 lb), that had been on a 56-d growth study and fed diets with Ca salts of palm oil (PO) or Ca salts of conjugated linoleic acid (CLA) and formulated for a low (L; 1.50 lb/d) or a high rate of gain (H; 3.0 lb/d), were used on this finishing study to evaluate the effects of previous growth rate and dietary fat source on growth performance, immune function, and carcass characteristics. Dietary treatments consisted of a corn-soybean meal based diet with either 4% Ca salts of PO or CLA. Steers were offered feed for ad libitum consumption until an average slaughter weight of 1,243 lb. Steers fed CLA had lower ($P \leq 0.05$) ADG, ADFI, final BW, hot carcass weight, and dressing percentage than steers fed PO. At harvest, steers fed CLA tended to have greater blood concentrations of B cells ($P = 0.07$) and $\gamma\delta$-TCR$^+$CD8$^-$ cells ($P = 0.05$). Compared to H steers, L steers had greater ($P = 0.04$) ADG and tended to have greater ($P = 0.08$) concentrations of CD8$^+$ cells at harvest, better ($P = 0.07$) yield grades, and lower F/G ratios ($P = 0.10$), as well as lower CD4$^+$CD8$^-$/CD4$^-$CD8$^+$ ($P = 0.07$) and CD4$^+$/CD8$^+$ ($P = 0.08$) ratios on d 1 and 28. In conclusion, feeding CLA negatively affected growth and carcass traits of feedlot steers.

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 (Chin et al., 1994), 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 (Poulson et al., 2004). Conjugated linoleic acid supplementation to pigs resulted in altered immune cell function. Changes included increased T-lymphocyte proliferation (a measure of cell mediated immunity), enhanced production of immunoglobulins (a measure of humoral immunity), increased percentages of CD8$^+$ (cytotoxic) T-cells, and decreased percentages of CD4$^+$ (helper) T-cells (Bontempo et al., 2004).

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 (Schoonmaker et al., 2004). However, research investigating the interaction of CLA supplementation and previous nutrition on growth performance, immune function, and carcass characteristics 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 immune response, growth performance, and carcass traits of beef cattle.

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., 2006) 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 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 the 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 as they received 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.

Animals were weighed on d 0, 14, 28, 42, and at harvest (d 56, 72, 84, 86, and 113). Growth performance variables evaluated included ADG, ADFI, and F/G. At d 0, 28 (n = 18), and at harvest (n = 16), jugular blood samples were taken for mononuclear cell isolation for flow cytometry analysis. 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. Hot carcass weights were determined following trimming on the day of slaughter. Following a 48-h chilling period, carcass measurements including adjusted 12th rib fat thickness, *longissimus* muscle area, kidney, pelvic, and heart fat (KPH), marbling score, skeletal maturity, and USDA quality and yield grades were determined.

Data from growth performance, carcass characteristics, and flow cytometric analyses at harvest were analyzed as a completely randomized design using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). The model included the effects of previous rate of live weight gain and fat supplementation, block and their interactions. Flow cytometry analyses (d 0 and 28) were evaluated using

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the MIXED procedure of SAS. Fixed effects included fat source, rate of gain, time, block, and the fat source x rate of gain interaction. Pen was used as the experimental unit.

Results and Discussion

The fat source by previous growth rate interaction was not significant ($P > 0.47$) for growth performance during the finishing phase, thus the main effects of fat source and previous growth rate are presented (Table 2). Steers supplemented with Ca salts of CLA had decreased final weight ($P = 0.03$), ADG ($P = 0.05$), and ADFI ($P < 0.01$) compared to steers supplemented with palm oil. There was no effect ($P = 0.94$) of CLA supplementation on F/G ratio. However, steers with low rates of gain during the growing phase had higher ($P = 0.04$) ADG and tended to have lower ($P = 0.10$) F/G ratios during the finishing phase (Table 2).

The effect of Ca salts of CLA on ADFI, ADG, and efficiency has been reported previously in feedlot cattle. Gassman et al. (2000) reported that 2.5% of CLA supplementation to finishing steers decreased feed intake by 20% and ADG by 25%. The greater ADG and the tendency for improved feed efficiency during the finishing phase of animals with low rate of gain during the growing phase suggest a period of compensatory gain in these steers. Greater ADG and feed efficiency have been observed in cattle with growth restriction during the growing phase (Sainz et al., 1995).

The fat source by previous growth rate interaction was not significant ($P > 0.49$) for hot carcass weight, dressing percentage, fat thickness, marbling, quality grade, percentage of kidney, pelvic, and heart fat, and yield grade (Table 3). Steers supplemented with palm oil that had a low rate of gain during the growing phase had a greater *longissimus* muscle area than steers with a high rate of gain during the growing phase (12.4 vs. 11.6 in^2); however, rate of gain during the growing phase had no effect on *longissimus* muscle area if the steers were supplemented with CLA (11.8 vs. 12 in^2 for low and high gain, respectively; fat x gain interaction, $P = 0.04$). There were main effects of supplemental fat source and previous rate of gain on carcass traits. Steers supplemented with CLA had lower hot carcass weights ($P < 0.01$), and dressing percentages ($P = 0.04$) than steers fed palm oil (Table 3). Steers with restricted rate of gain during the growing phase tended ($P = 0.10$) to have lower rib fat thickness and more desirable ($P = 0.08$) yield grade compared to non-restricted steers (Table 3).

The effects of CLA supplementation on carcass characteristics have been reported previously. Gassman et al. (2000) observed that feeding 2.5% of CLA tended to decrease carcass weight but they did not find an effect on dressing percentage. Carcasses from crossbred heifers supplemented with 2% CLA tended to have lower marbling scores compared to animals supplemented with corn oil (Gillis et al., 2004).

Supplementation with CLA tended ($P = 0.09$) to decrease the circulating concentration of monocytes on d 0 and 28. Steers with lower rate of gain during the growing phase tended to have lower $CD4^+CD8^-/CD4^-CD8^+$ ratios ($P = 0.07$) and $CD4^+/CD8^+$ ratios ($P = 0.08$) when compared to steers with high rates of gain during the growing phase on d 1 and 28 (Table 4). At harvest (Table 5), steers supplemented with CLA tended to have greater ($P = 0.07$) blood concentrations of B cells. In addition, supplemental CLA increased ($P = 0.05$) the blood concentration of $\gamma\delta$-TCR^+CD8^- T lymphocytes at harvest. Steers with lower rate of gain during the growing phase tended to have greater concentration of blood $CD8^+$ T-cells (0.9 vs. 1.1, $P = 0.08$) when compared to animals with high rates of gain during the growing phase.

Similar results of the effects of CLA on the proportions of lymphocyte subsets have been observed previously. Supplementation with *trans*-10, *cis*-12 CLA isomer in mice increased the proportion of B cells in the spleen compared to the control group (Yamasaki et al., 2003). Low concentration of monocytes may be related to the anti-inflammatory activities of CLA by reducing the release of pro-inflammatory cytokines (Changhua et al., 2005) or by stimulating the production of anti-inflammatory cytokines (O'Shea et al., 2004). The results of the present experiment suggest that CLA may affect the proportions of $\gamma\delta$-TCR^+CD8^- T-cells in blood. These cells participate in the maintenance of host tissue integrity and provide an initial line of defense against infectious diseases.

Implications

Supplemental Ca salts of conjugated linoleic acid in finishing steers decreased live body weight at slaughter, average daily gain, average daily feed intake, hot carcass weight, dressing percentage, and circulating monocytes. Rate of gain during the growing phase produced compensatory gain during the finishing phase and affected carcass characteristics, and blood cell concentrations.

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Table 1. Ingredient composition (% of DM) of experimental diets.

	Treatments[a]	
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[b]	4.0	-
Ca-CLA[c]	-	4.1
Monensin[d]	+	+
Vitamin premix[e]	+	+
Trace mineral premix[f]	+	+

[a]Concentrate diet with Ca-salts of palm oil or Ca-salts of conjugated linoleic acid (CLA).
[b]Ener GII (96.5% DM, 82 to 85% fat, and 9 to 11% Ca), Virtus Nutrition, LLC, Corcoran, CA.
[c]Calcium salts of CLA (96.5% DM, 80 to 84% fat, 9 to 11% Ca), Virtus Nutrition, LLC, Corcoran, CA.
[d]Rumensin 80 (Elanco, Indianapolis IN), 22.5 mg of monensin/kg diet DM
[e]Premix supplied per kg of diet: 850 IU of vitamin A, 170 IU of vitamin D_3, and 0.33 IU vitamin E.
[f]Premix supplied per kg of diet: 13 mg of Zn as $ZnSO_4$, 4 mg of Cu as $CuSO_4$, 0.07 mg of Se as Na_2SeO_3, 0.2 mg of I as $CaIO_4$, and 0.05 mg of Co as $CoCO_3$.

Table 2. Influence of Ca salts of conjugated linoleic acid (CLA) supplementation and previous rate of gain on growth performance.

Item	Treatments		Rate of gain			$P \leq$[a]		
	Palm oil	CLA	Low	High	SEM	Fat	Gain	Fat × gain
Initial BW, lb	886	889	872	903	5.13	0.73	0.01	0.53
Final BW, lb	1259	1229	1250	1237	7.95	0.03	0.32	0.65
ADG, lb	3.50	3.15	3.51	3.14	0.10	0.05	0.04	0.86
ADFI[b], lb	26.17	23.96	25.61	24.52	0.36	0.01	0.08	0.47
Feed/Gain[b]	7.68	7.71	7.40	7.99	0.22	0.94	0.10	0.64

[a]Fat = effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = effect of rate of growth in growing phase, low vs. high; Fat × Gain = interaction of fat supplementation and previous rate of growth.
[b]As-fed basis

Table 3. Influence of Ca salts of conjugated linoleic acid (CLA) supplementation and previous rate of gain on carcass characteristics.

	Treatments		Rate of gain			$P \leq$[a]		
Item	Palm oil	CLA	Low	High	SEM	Fat	Gain	Fat × gain
Carcass weight, lb	754	725	741	739	4.78	0.01	0.04	0.80
Dressing %	59.9	59.0	59.3	59.6	0.25	0.04	0.42	0.81
LMA[b], in^2	12.0	11.9	12.1	11.8	0.14	0.56	0.17	0.04
Fat thickness, in	0.47	0.45	0.42	0.50	0.03	0.65	0.10	0.54
Marbling score[c]	625	626	615	635	13.1	0.96	0.33	0.49
Quality grade[d]	613	614	602	625	12.7	0.93	0.24	0.73
KPH[e] fat, %	1.8	1.6	1.7	1.7	0.09	0.14	0.91	0.74
Yield grade	3.0	2.9	2.8	3.1	0.11	0.35	0.08	0.51

[a]Fat = effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = effect of rate of growth in growing phase, low vs. high; Fat × gain = interaction of fat supplementation and previous rate of growth.
[b]Longissimus muscle area
[c]Coded: minimum slight = 100, minimum small = 200, etc.
[d]Coded: minimum select = 500, minimum choice = 600, etc.
[e]Kidney, pelvic, and heart

Table 4. Influence of Ca salts of conjugated linoleic acid (CLA) supplementation and previous rate of gain on concentration of blood lymphocyte subsets, ratios of different lymphocyte subpopulations, and concentration of monocytes in circulation on d 1 and 28 of the finishing phase.

	Treatment		Rate of gain			$P \leq$[a]		
Variable	Palm oil	CLA	Low	High	SEM	Fat	Gain	Fat × gain
Lymphocyte/monocyte concentration × $10^3/\mu L$								
$CD4^+$	1.5	1.5	1.5	1.4	0.20	0.87	0.67	0.77
$CD8^+$	0.8	0.7	0.9	0.6	0.14	0.45	0.19	0.69
$CD4^+CD8^-$	1.6	1.5	1.5	1.5	0.18	0.74	0.96	0.63
$CD4^+CD8^+$	0.2	0.2	0.2	0.2	0.03	0.77	0.91	0.84
$CD4^-CD8^+$	0.8	0.7	0.9	0.6	0.12	0.71	0.17	0.61
$CD4^+CD8^-/CD4^-CD8^+$	2.3	2.4	1.9	2.8	0.29	0.95	0.07	0.40
$CD4^+/CD8^+$	1.9	2.0	1.7	2.3	0.21	0.96	0.08	0.41
$\gamma\delta$-TCR^+CD8^-	1.2	1.5	1.3	1.3	0.20	0.24	1.00	0.79
$\gamma\delta$-TCR^+CD8^+	0.5	0.5	0.5	0.5	0.10	0.89	0.72	0.66
B cells	2.5	2.7	2.9	2.3	0.39	0.84	0.37	0.56
Monocytes	0.7	0.5	0.7	0.5	0.09	0.09	0.14	0.34

[a]Fat = effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = effect of rate of growth in growing phase, low vs. high; Fat × gain = interaction of fat supplementation and previous rate of growth.

Table 5. Influence of Ca salts of conjugated linoleic acid (CLA) supplementation and previous rate of gain on concentration of blood lymphocyte subsets, ratios of different lymphocyte subpopulations, and concentration of monocytes in circulation at harvest.

	Treatment		Rate of gain			$P \leq$[a]		
Variable	Palm oil	CLA	Low	High	SEM	Fat	Gain	Fat × gain
Lymphocyte/monocyte concentration, total cells × $10^3/\mu L$								
$CD4^+$	2.0	2.1	2.2	1.9	0.27	0.83	0.44	0.24
$CD8^+$	1.0	1.0	1.1	0.9	0.07	0.69	0.08	0.86
$CD4^+CD8^-$	1.9	2.0	2.1	1.8	0.19	0.60	0.32	0.15
$CD4^+CD8^+$	0.2	0.2	0.2	0.2	0.01	0.46	0.24	0.72
$CD4^-CD8^+$	1.0	0.9	1.0	0.9	0.08	0.60	0.14	0.94
$CD4^+CD8^-/CD4^-CD8^+$	2.0	2.3	2.1	2.2	0.22	0.28	0.74	0.26
$CD4^+/CD8^+$	1.8	2.1	1.9	2.0	0.18	0.27	0.76	0.25
$\gamma\delta$-TCR^+CD8^-	0.8	1.2	1.0	1.1	0.14	0.05	0.61	0.09
$\gamma\delta$-TCR^+CD8^+	0.4	0.4	0.4	0.4	0.04	0.91	0.53	0.59
B cells	1.3	2.0	1.6	1.7	0.22	0.07	0.60	0.15
Monocytes	0.6	0.9	0.9	0.6	0.17	0.26	0.23	0.21

[a]Fat = effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = effect of rate of growth in growing phase, low vs. high; Fat × gain = interaction of fat supplementation and previous rate of growth.

Influence of Live Weight Gain and Calcium Salts of Conjugated Linoleic Acid on Growth Performance and Immune Function of Growing Cattle

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Story in Brief

Forty-eight crossbred beef calves (initial BW = 772 lb) were used to determine the effects of live weight gain and conjugated linoleic acid (CLA) on immunity and growth performance during a 56-d study. Calves were blocked by weight, stratified by gender, and assigned to 16 pens. Pens within each block were assigned randomly to 1 of 4 diets arranged as a 2 x 2 factorial. Main effects were rate of gain (diets formulated for calves to gain 1.5 [L] or 3.0 [H] lb/d), and fatty acid source (4% Ca salts of palm oil [PO] or 4% Ca salts of CLA). Feeding CLA tended to increase (P = 0.07) ADG from d 1 to 56, and decrease (P = 0.06) F/G from d 29 to 56 in cattle fed L diets, and tended to decrease the percentage of monocytes (P = 0.09) and eosinophils (P = 0.06) in H diets. Total white blood cell (P = 0.02) and lymphocyte concentrations (P = 0.05) were greater in L vs. H diets. Feeding CLA decreased the proliferation of peripheral blood mononuclear cells (PBMC) stimulated with phytohemagglutinin (PHA; P = 0.04) or concanavalin A (P = 0.03) in H but not in L diets. Responses of PBMC to PHA were lower (P = 0.003) in L than in H diets. Monocyte/macrophage phagocytosis was not affected by CLA or rate of gain (P > 0.22). In conclusion, CLA may increase growth performance and modulate immunity in growing cattle but responses depend on time and rate of growth.

Introduction

Research utilizing different intake levels of concentrate or forage based diets have demonstrated that growing programs in beef cattle can affect body composition and future feedlot performance. Conjugated linoleic acid (CLA), a mixture of positional and geometric isomers of the omega-6 essential fatty acid linoleic acid, is produced by ruminal biohydrogenation (Belury, 2002). Supplemental CLA increased feed efficiency (Chin et al., 1994), decreased subcutaneous fat thickness, and increased lean tissue in steers (Gassman et al., 2000). Several studies in animals and humans have also reported effects of CLA on immunity. Conjugated linoleic acid supplementation resulted in increased T-cell proliferation and enhanced production of interleukin 2 (IL-2), tumor necrosis factor-α (TNF-α), and immunoglobulin (Ig) A, IgM, and IgG (Bontempo et al., 2004). The combination of feeding for different rates of weight gain and CLA supplementation may result in alterations in growth performance and immune function of growing beef cattle. The objective of this research was to determine the effects of feeding total mixed diets for 2 rates of live weight gain and supplemental Ca salts of CLA isomers on immune response and growth performance of cattle.

Experimental Procedures

Forty-eight crossbreed beef heifer (n = 12) and steer (n = 36) calves (13 to14 mo of age, 772 ± 67.9 lb initial BW) of predominantly Angus breeding were obtained from the University of Arkansas cow-calf facility in Savoy for a 56-d growing trial. Animals were stratified by body weight (4 blocks) within gender and assigned randomly to pens with 3 animals per pen and 4 pens per dietary treatment (12 animals per dietary treatment). Dietary treatments (Table 1) were assigned in a completely randomized design with a 2 x 2 factorial arrangement. The 4 diets were: low live weight gain (1.5 lb/d) with 4% rumen-protected Ca salts of palm fatty acid distillate (LPFA; EnerGII, Virtus Nutrition, LLC, Corcoran, Calif.); low live weight gain with 4% rumen-protected Ca salts of mixed isomers of CLA (LCLA; Virtus Nutrition, LLC); high live weight gain (3.0 lb/d) with 4% Ca salts of palm fatty acid distillate (HPFA); and high live weight gain with 4% Ca salts of mixed isomers of CLA (HCLA). Diets were balanced to obtain the desired rates of gain according to model 1 NRC net energy equations (NRC, 1996). Fat supplements were mixed with the concentrates and offered as part of the total ration to experimental animals. Diets were formulated to result in the desired rates of gain when feeding a constant amount of DM (17.5 lb/d) and were fed once daily at approximately 0800 h. Calves were adapted to the diets over a 15-d period, by increasing the proportion of concentrate fed by 20% every 3 d until the desired ration composition was reached.

Animals were weighed on d 0, 14, 28, 42, and 56. On d 0, 28, and 56, jugular blood samples were collected from 24 steers (6/treatment) to determine proportions and concentration of total white blood cells, as well as to determine lymphocyte proliferation responses to phytohemagglutinin (PHA; Sigma Chemical Co., St. Louis, Mo.), concanavalin A (CONA; Sigma Chemical Co.) and pokeweed mitogen (PWM; Sigma Chemical Co.), and the phagocytic ability of harvested monocytes/macrophages.

In order to determine the effect of dietary treatments on the immune function of calves, concentrations (number of cells/μL) of total white blood cells (WBC), and differential WBC (lymphocytes, neutrophils, monocytes, eosinophils, basophils) were analyzed on an automated hematology analyzer (Cell-Dyn 3500 system, Abbott Laboratories, Abbot Park, Ill.) standardized for analysis of bovine blood. For the in vitro profliferation of peripheral blood mononuclear cell (PBMC) response, polymorphonuclear cells were isolated from whole blood by density gradient centrifugation, then resuspended in cell culture medium (RPMI 1640) supplemented with 10% fetal bovine serum at 2 x 10^6 cells/mL and plated in triplicate in 96-well round-bottom plates with 2 x 10^5 cells/well. Mitogens used were phytohemagglutinin (PHA; Sigma Chemical Co.), pokeweed mitogen (PWM; Sigma Chemical Co.), and concanavalin A

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(ConA; Sigma Chemical Co.). Mitogens were diluted in RPMI medium (Sigma Chemical Co.) and administered in 50-µL aliquots/well at a concentration of 5, 15, and 20 µg/mL, respectively. Cultures not stimulated with mitogen received 50 µL of medium/well in place of mitogen. Cell cultures were incubated for 48 h at 39.2°C and 5% CO_2. After this time, 1 µCi of tritiated-thymidine was added to each well and cultures incubated for an additional 18 h. Cells were harvested on glass fiber mats and the mats were transferred to scintillation vials, then the radioactivity (cpm) was measured on a liquid scintillation analyzer. Differences in cpm of stimulated (mitogens) and control (medium only) were calculated by subtracting the arithmetic mean of cpm from triplicate control cultures from the arithmetic mean of cpm from the corresponding stimulated cultures. The results were referred to as "Δ cpm". Stimulation indices (SI) were calculated by dividing the mean counts per minute (cpm) of the triplicate mitogen-stimulated cultures by the mean cpm of the unstimulated control cultures.

Monocyte/macrophage phagocytosis of pig red blood cells (PRBC) was measured by diluting 2 x 10^6 isolated PBMC/mL in Leibovitz's L-15/McCoy's Hahn medium. A glass cover slip was added to each well of a six-well plate and 2 mL of cell suspension was added to each well in duplicate for each sample. Cells were incubated for 8 h at 102.6°F and 5% CO_2. Following the 8-h incubation period, medium from each well was removed and replaced by 2 mL of fresh LM Hahn medium. Plates were incubated for an additional 24 h at 102.6°F and 5% CO_2. Following incubation, 2 mL of a 5% PRBC suspension were added to each well. Plates were incubated with PRBC for 8 h at 102.6°F and 5% CO_2. After this time, cover slips were removed and stained. Phagocytic ability of monocytes/macrophages was determined by observing 200 monocytes/macrophages per coverslip and recording the number of monocytes/macrophages that had phagocytosed PRBC and the number of PRBC that had been engulfed per monocyte/macrophage.

Data from growth performance and monocyte/macrophage phagocytosis were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). The model included the effects of fat source, rate of weight gain, block, and their interactions. Blood cell proportions and concentrations and lymphocyte blastogenesis were evaluated using the MIXED procedure of SAS. Fixed effects included fat source, rate of gain, block, time, and the fat source x rate of gain interaction. Pen was used as the experimental unit.

Results and Discussion

The ADG (1.9 lb/d) of cattle fed the high-energy diets (HPFA and HCLA) was greater (P = 0.002) than the ADG (1.4 lb/d) of animals fed the low energy diets (LPFA and LCLA) from d 1 to 56 of the growing phase. In addition, the F/G of HPFA and HCLA groups (9.7) was less (P = 0.02) than the F/G (14.6) for cattle in the LPFA and LCLA groups from d 1 to 56.

The predicted growth rate for animals fed the high-energy diet was greater than that observed in the present experiment (3 vs. 1.9 lb/d), but in animals fed the low energy diet the predicted growth was similar to the actual growth rate (1.5 vs. 1.4 lb/d). This may be the result of a constant feed intake during the period of experimentation without adjusting the intake to meet the increasing energy needs for maintenance as the animals grew. In addition, calves were adapted to the diets over a 15-d period, and performance during this period negatively impacted the overall ADG of calves fed the high-energy diet.

Calcium salts of CLA tended to increase ADG from d 1 to 56 (fat source x rate of gain interaction, P = 0.07, Table 2) and decreased F/G from d 29 to 56 (fat source x rate of gain interaction, P = 0.06) when supplemented to animals with a low rate of live weight gain, but had no impact when supplemented to animals with high rate of gain. Effect of CLA on ADG and efficiency has been reported previously in beef cattle. Angus x Hereford heifers supplemented with diets with 2% of Ca salts of CLA had greater ADG and gain:feed was improved compared to those fed diets with 4% corn oil or control diets (Gillis et al., 2004). The mechanisms by which CLA may affect ADG and F/G in low rate of weight gain but not in high rate of weight gain animals are not clear. However, these results may be related to changes in the energy partitioning and balance between the groups. Supplementation for 9-wk with CLA in dairy cows during the transition period and early lactation induced a progressive reduction in milk fat (11 to 21%) relative to the control group, and the decrease was significant by the third week of lactation (Castañeda-Gutiérrez et al., 2005). Consistent with the reduction in milk fat, experiments supplementing CLA in early lactation cows have often reported an increase in milk yield (Bernal-Santos et al., 2003); however, this is not always observed (Castañeda-Gutiérrez et al., 2005). The milk yield response in the early lactation studies has been attributed to the greater availability of energy caused by reduction of milk energy output in a physiological state where synthesis activity in the mammary gland is upregulated (Bernal-Santos et al., 2003).

Supplementation with CLA decreased the concentrations of circulating WBC (P = 0.02) and monocytes (P = 0.04). Animals fed for low growth rate (LPFA and LCLA) had greater WBC concentrations (P = 0.02) and total circulating lymphocytes (P = 0.05) compared to animals with a high rate of growth (HPFA and HCLA).

Supplementation with CLA tended to decrease the percentages of monocytes (P = 0.09) and eosinophils (P = 0.06) as well as the eosinophil concentration in animals fed for high rate of growth, but had no effect in animals with a low rate of growth (fat source x gain interaction, P = 0.08). There was a time effect on monocyte (P < 0.001) and eosinophil (P = 0.03) concentrations, and on the percentage of monocytes (P = 0.002) and eosinophils (P = 0.02). These values decreased from d 1 to 56 (data not shown). Diet or rate of gain did not affect neutrophil and basophil concentrations, the numbers of neutrophils, lymphocytes, and basophils, or the neutrophil:lymphocyte ratio (Table 3).

The lower concentration of leukocytes and in particular of monocytes in animals supplemented with CLA may indicate lower stimulation of the phagocytic, humoral, and cellular immune activity in these animals. Monocytes and macrophages produce proinflammatory cytokines (IL-1, IL-6 and TNF-α) that play an important role in immunoregulation. To attenuate the negative effects of proinflammatory cytokines, CLA can be supplemented in the diet. Conjugated linoleic acid has been shown to have anti-inflammatory activities in humans, and domestic and laboratory animals by reducing the release of pro-inflammatory cytokines, or by stimulating the production of anti-inflammatory cytokines.

Conversely, the greater WBC and monocyte concentrations in LPFA and LCLA groups may suggest greater cellular and humoral immune activity in these individuals. The decrease in eosinophil concentrations and percentage of monocytes and eosinophils associated with CLA in the high rate of growth group, but not in the low rate of growth group may indicate that CLA decreased the inflammatory response differently based on energy content of the diet. Bassaganya-Riera et al. (2001) reported that CLA supplementation to early weaned pigs preceding a disease challenge prevented

disease associated growth suppression.

Supplementation with CLA with the high rate of growth diet decreased the stimulation index (SI) of PBMC stimulated with PHA (P = 0.04) and ConA (P = 0.03) but had no effect when fed with the low rate of growth diet (fat x gain interaction). Animals with a high growth rate had greater (P = 0.003) proliferative responses to PHA at d 28 and 56 compared with animals with a low rate of growth. There was no effect of CLA or rate of growth on the proliferative response of unstimulated or PWM stimulated cells (Table 4).

The effects of CLA on lymphocyte proliferation in animals with a high growth rate compared to animals with a low rate of growth may indicate a differential effect of CLA based on diet energy level. In contrast with these results, research reported in humans, and laboratory and domestic animals demonstrated an increase in lymphocyte proliferation of individuals supplemented with CLA (Nugent et al., 2005).

Implications

Results of this experiment present evidence that controlling growth rate and feeding calcium salts of conjugated linoleic acid in growing beef cattle affected growth performance and immune function. Future studies are needed to clarify the consequences of restricting rate of growth and supplementing conjugated linoleic acid during the growing phase on the performance of finishing cattle.

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Table 1. Ingredient composition of experimental diets fed.

	Treatments[a]			
	Low weight gain		High weight gain	
Item	LPFA	LCLA	HPFA	HCLA
	% of DM			
Ingredient				
Corn, cracked	2.86	2.75	45.42	45.31
Cottonseed hulls	50.86	50.86	10	10
Soybean meal	9.94	9.94	6.86	6.86
Wheat middlings	5.71	5.71	9.14	9.14
Bermudagrass hay	24	24	20.57	20.57
Molasses, cane	1.43	1.43	2	2
Dicalcium phosphate	0.4	0.4	-	-
Limestone	0.06	0.06	0.58	0.58
Salt	0.29	0.29	0.29	0.29
Urea	0.29	0.29	0.98	0.98
Ca salts of palm oil	4	-	4	-
Ca-CLA	-	4.11	-	4.11
Monensin	+	+	+	+
Vitamin premix	+	+	+	+
Trace mineral premix	+	+	+	+

[a]LPFA = low rate of gain with Ca-salts of palm oil; LCLA = low rate of gain with Ca-salts of CLA; HPFA = high rate of gain with Ca-salts of palm oil; HCLA = high rate of gain with Ca-salts of CLA.

Table 2. Influence of live weight gain and Ca salts of conjugated linoleic acid (CLA) supplementation on ADG and feed/gain.

	Treatments[a]							
	Low weight gain		High weight gain			$P \leq$ [b]		
Item	LPFA	LCLA	HPFA	HCLA	SEM	Fat	Gain	Fat × Gain
d 1 to 28								
ADG, lb	0.66	0.93	1.14	1.07	0.08	0.29	0.03	0.11
F/G	26.92	18.81	15.35	16.38	3.97	0.98	0.05	0.40
d 29 to56								
ADG, lb	1.98	2.08	2.74	2.66	0.04	0.76	0.001	0.13
F/G	9.31	8.63	6.57	6.88	0.16	0.34	0.001	0.06
d 1 to 56								
ADG, lb	1.32	1.51	1.94	1.87	0.05	0.32	0.002	0.07
F/G	16.49	12.65	9.99	9.35	1.04	0.22	0.02	0.12

[a]LPFA = low rate of gain with Ca-salts of palm oil; LCLA = low rate of gain with Ca-salts of CLA; HPFA = high rate of gain with Ca-salts of palm oil; HCLA = high rate of gain with Ca-salts of CLA.
[b]Fat = main effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = main effect of rate of growth, low vs. high; Fat × Gain = interaction of fat supplementation and rate of growth.

Table 3. Influence of live weight gain and Ca salts of conjugated linoleic acid (CLA) supplementation on differential leukocyte counts (total cells and percentage of white blood cells [WBC]).

	Treatments[a]							
	Low weight gain		High weight gain			$P \leq$[b]		
Item	LPFA	LCLA	HPFA	HCLA	SEM	Fat	Gain	Fat × Gain
Leucocyte count, total cells × $10^3/\mu L$								
WBC	11.8	9.7	9.7	9.1	0.46	0.02	0.02	0.14
Neutrophils	2.5	2.1	2.4	2.1	0.17	0.13	0.87	0.70
Lymphocytes	7.9	6.2	5.9	6.0	0.50	0.14	0.05	0.11
Monocytes	0.78	0.72	0.85	0.68	0.04	0.04	0.80	0.29
Eosinophils	0.51	0.51	0.52	0.23	0.07	0.08	0.08	0.08
Basophils	0.08	0.08	0.08	0.06	0.009	0.13	0.41	0.49
Leukocyte, %								
Neutrophils	21.5	22.2	25.4	24.2	1.74	0.89	0.12	0.69
Lymphocytes	66.3	63.6	59.2	65.0	2.82	0.60	0.32	0.17
Monocytes	6.9	7.7	9.1	7.7	0.57	0.58	0.09	0.09
Eosinophils	4.5	5.6	5.4	2.5	0.93	0.38	0.26	0.06
Basophils	0.74	0.82	0.78	0.69	0.09	0.95	0.61	0.33
N:L[c] ratio	0.35	0.38	0.48	0.40	0.04	0.58	0.11	0.26

[a]LPFA = low rate of gain with Ca-salts of palm oil; LCLA = low rate of gain with Ca-salts of CLA; HPFA = high rate of gain with Ca-salts of palm oil; HCLA = high rate of gain with Ca-salts of CLA.
[b]Fat = main effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = main effect of rate of growth, low vs. high; Fat × Gain = interaction of fat supplementation and rate of growth.
[c]Neutrophil:lymphocyte ratio

Table 4. Influence of live body weight gain and Ca salts of conjugated linoleic acid (CLA) supplementation on lymphocyte blastogenic response and macrophage phagocytosis[a]

	Treatments[b]							
	Low weight gain		High weight gain			$P \leq$[c]		
Item	LPFA	LCLA	HPFA	HCLA	SEM	Fat	Gain	Fat × Gain
Lymphocyte proliferation, cpm × 10^3								
Unstimulated	0.29	0.26	0.24	0.28	0.02	0.86	0.50	0.11
PHA	104	99	131	117	6.3	0.16	0.003	0.49
PWM	60	50	59	52	8.0	0.32	0.95	0.90
ConA	170	178	176	168	9.6	0.97	0.80	0.44
Lymphocyte proliferation, stimulation index[d]								
PHA	424	466	647	460	49.7	0.17	0.05	0.04
PWM	218	234	311	207	34.4	0.23	0.36	0.11
ConA	700	835	868	662	67.1	0.60	0.97	0.03
Monocyte/macrophage phagocytosis[e]								
% Phagocytic	6.8	10.6	6.4	10.6	3.00	0.22	0.95	0.95
Average PRBC	1.2	1.4	1.3	1.3	0.10	0.33	0.72	0.58

[a]Peripheral blood samples were taken from 24 animals on d 1, 28, and 56 to determine the proliferative response of lymphocytes administered phytohemagglutinin (PHA, 5 µg/mL), pokeweed mitogen (PWM, 15 µg/mL), and concanavalin A (ConA, 20 µg/mL). Values are means of 4 pens representing each dietary treatment, and are displayed as counts per minute (cpm).
[b]LPFA = low rate of gain with Ca-salts of palm oil; LCLA = low rate of gain with Ca-salts of CLA; HPFA = high rate of gain with Ca-salts of palm oil; HCLA = high rate of gain with Ca-salts of CLA.
[c]Fat = main effect of fat supplementation, Ca-salts of palm oil vs. Ca-salts of CLA; Gain = main effect of rate of growth, low vs. high; Fat × Gain = interaction of fat supplementation and rate of growth.
[d]Stimulation indices were calculated by dividing the mean cpm of the triplicate wells containing mitogens by the mean cpm of the wells (unstimulated) containing complete medium only.
[e]Peripheral blood was taken from 24 animals on d 56 to determine the percentage of phagocytic monocyte/macrophages and average number of pig red blood cells (PRBC) phagocytosed by monocyte/macrophages. Values are means of 4 pens representing each dietary treatment.

Effects of On-arrival vs. Delayed Modified Live Virus (MLV) Vaccination on Health, Performance, and Serum Infectious Bovine Rhinotracheitis (IBR) Titer Levels of Newly Received Stocker Cattle

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Story in Brief

Stress associated with weaning and shipment of stocker cattle is known to compromise immune function; thereby, reducing the effective response to vaccination. The objective of this study was to evaluate the effect of timing of modified live virus (MLV) vaccination on health, performance, and immune response of newly-received stocker cattle. Crossbred bull and steer calves (n = 524) were weighed (BW = 433.4 ± 5.3 lb) and randomly assigned to two MLV vaccination treatments: 1) vaccination upon arrival (AV), or 2) delayed (14 d) vaccination (DV). All cattle were processed according to routine procedures with the exception of initial MLV vaccination timing. Subsequent weights were recorded on d 14, 28, and 42. Blood samples were collected on d 0, 14, 28, and 42 to determine differences in serum infectious bovine rhinotracheitis (IBR) titer levels, and comparisons were made on an equivalent post-vaccination period basis. Body weight gain per day was greater ($P < 0.01$) for DV calves from d 1 to 14 (1.94 vs. 2.55 lb/d) and from d 1 to 42 (1.43 vs. 1.65 lb/d, $P = 0.05$). Days to first pull, total treatment cost, percentage death loss, and pasture ADG after the 42-d receiving period did not differ ($P > 0.15$). Treatment rate for bovine respiratory disease was high for both AV and DV (75.3 and 70.2%, respectively) calves, but did not differ ($P = 0.21$). Serum IBR titer levels were greater ($P = 0.04$) for DV calves 14 d following re-vaccination (AV = d 28 vs. DV = d 42). Delaying vaccination 14 d may increase ADG in stocker cattle during the receiving period compared to vaccinating upon arrival; however, overall gain was not different during the subsequent grazing period. Serum IBR titer levels were greater in DV calves, indicating improved immune response to vaccination.

Introduction

Bovine respiratory disease (BRD) complex is among the most economically important diseases in stocker or feedlot cattle. Current recommended beef cattle receiving strategies include classification of cattle groups into 1 of 3 risk categories (high-, medium-, or low-risk) for BRD. This allows a producer to assess the probability of a particular shipment of cattle in developing BRD complex, and manage specified risk categories accordingly. Risk category is determined by several factors including level of stress, immune status, nutritional condition, pathogen load, environment, mineral level status and the skill level of management personnel. Traditionally, receiving protocols include vaccination against BRD viruses within 24 h after arrival for low- and medium-risk cattle, and 24 to 48 h after arrival for high-risk cattle.

In high-risk calves, previous studies suggest that the transportation stress period can endure for as long as 15 d post-arrival (Purdy et al., 2000). Although little is known about how vaccine response (titer levels) is affected by timing of vaccination during this stressful period, it is well documented that stress compromises immune function and therefore the ability to properly respond to vaccination (Chirase et al., 2004). Other complications with on-arrival administration of a modified live virus (MLV) vaccine may include reduced gain performance due to effects of the antigens contained in the vaccine. The objective of this study was to evaluate the effect of delayed (14 d) MLV vaccination vs. traditional on-arrival MLV vaccination on health, performance, and serum infectious bovine rhinotracheitis (IBR) titer levels of newly received stocker calves.

Experimental Procedures

Five hundred and twenty-four crossbred bull and steer calves (BW = 433 ± 5.3 lb) were procured from a local Arkansas sale barn and shipped to the University of Arkansas Livestock and Forestry Branch Station located near Batesville. Four separate shipment dates representing each block in the experimental model were received on September 9, 2004 (Block 1, n = 110), September 16, 2004 (Block 2, n = 87), January 13, 2005 (Block 3, n = 160) and February 17, 2005 (Block 4, n = 167).

Upon arrival, cattle were weighed, assigned a unique ear identification tag and arrival gender (bull vs. steer) was determined. The following day (d 0), bulls and steers were evenly distributed and randomly assigned to 1 of 2 treatments; (1) arrival (d-0) vaccination (AV), or (2) 14-d delayed vaccination (DV). Calves were re-weighed, administered a clostridial bacterin with tetanus toxoid (Covexin-8®; Schering-Plough Animal Health, Inc., Elkhorn, Neb.), treated for internal and external parasites (Ivomec®; Merial, Iselin, N.J.), and bull calves were castrated using the California banding method. Moreover, AV treatment calves were vaccinated with a 5-way MLV vaccine (Express® 5; Boehringer-Ingelheim Vetmedica, Inc., St. Joseph, Mo.). Delayed vaccination cattle did not receive a 5-way MLV at this time. Cattle were then sorted into their assigned 1.0 acre pens and provided 1% of BW (DM basis) of a receiving supplement (Table 1) and free-choice access to bermudagrass hay for the entire 42-d receiving trial.

Cattle were weighed at 14-d intervals during the trial (d 14, 28, and 42 of the trial). On d 14, both AV and DV cattle received a booster vaccination of Covexin-8®. The AV cattle received a booster vaccination of 5-way MLV, and DV cattle received their initial

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dosage of 5-way MLV. On d 28, DV cattle received a booster vaccination of 5-way MLV.

Calves were observed each morning by station personnel for symptoms of respiratory illness. Cattle with observed visual symptoms of BRD were pulled and considered morbid if rectal temperature was ≥ 104°F. Morbid animals were given antibiotic therapy following a pre-determined antibiotic treatment protocol. Treatment data were recorded for individual animal including treatment date, amount, type, and cost of antibiotic administered.

Blood samples were randomly collected from 3 animals in each pen to determine serum IBR titer level differences. Blood was collected via intervenous venapuncture on d 0, 14, 28, and 42 for AV and d 0, 28, 42, and 56 for DV. Titer level comparisons were made on both a trial day basis and post-vaccination equivalent basis. For the trial day basis, titer level results were compared for each treatment at the period ending date (d 0, 28, and 42). Post-vaccination period equivalent comparisons were made for IBR titer level based on the number of days post-initial vaccination (d 14 AV vs. d 28 DV).

Individual animal was considered the experimental unit and incorporated in a Randomized Complete Block design. Performance data, days to first pull, and treatment cost were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Random effects included truckload block; whereas, gender and initial BW were used as covariates in the model. Morbidity and mortality rate were evaluated for main effects of block and treatment and analyzed using the CATMOD procedure of SAS.

Results and Discussion

Performance. Body weight was greater (P = 0.007) for calves in the DV treatment on d 14 and also tended (P = 0.07) to be greater on d 42 (Table 2). Average daily gain was greater (P = 0.007) for DV cattle from d 0 to14 of the trial (1.94 vs. 2.55 lb/d). Although non-significant (P > 0.05), it was interesting to note that AV cattle had a numerical advantage (1.34 vs. 1.17 lb/d) in ADG from d 14 to 28. Because of the performance reduction in AV cattle for d 0 to 14, and in DV cattle for d 14 to 28, results would suggest that stress associated with the initial vaccination of a MLV vaccine is detrimental to performance. There were no differences in gain performance between the 2 treatments from d 28 to 42 (P = 0.12); however, for the entire receiving period (d 0 to 42), ADG was greater (P = 0.05) for calves in the DV treatment. Perhaps the overall ADG advantage seen in DV cattle was due to the 14-d delay which allowed for animals to adjust to the new environment and recover from previous stress before receiving a 5-way MLV. However, no differences (P > 0.05) were detected for pasture ADG in the subsequent grazing period.

Health. No differences (P > 0.05) were detected for effects of MLV vaccination timing on morbidity, mortality, or treatment cost of stocker cattle during the receiving period (Table 3). Initial treatment rate for BRD was high for both AV and DV (75.3 and 70.2%, respectively) calves, but not different (P = 0.21). Overall, 93% of BRD pulls occurred within the first 14 days of receiving. Results of the current study would suggest no advantage when administering a 5-way MLV vaccine to high-risk stocker cattle on-arrival because the majority (93%) of BRD morbidity occurred between d 0 and 14, no difference in morbidity or mortality was noted for AV vs. DV calves, and performance for DV cattle was greater.

Serum IBR Titer Level. Vaccine response was evaluated using serum IBR titer analysis (Fig. 1). No differences were detected for IBR titer level on d 0. On an equivalent post-vaccination basis, DV had greater (P ≤ 0.05) IBR titer levels 28 d and 42 d after initial vaccination. When treatments were compared at the conclusion of the receiving period (d 42) DV exhibited greater (P = 0.006) IBR titer levels. Results of IBR titer level comparisons would suggest an improved vaccine response for DV. However, it is important to note that natural exposure and subsequent host immune response may also contribute to increased IBR antibodies.

Implications

In newly received high-risk stocker cattle, delaying 5-way modified live virus (MLV) vaccination 14 days increased performance during the receiving period compared to on-arrival 5-way MLV vaccination. Serum infectious bovine rhinotracheitis (IBR) titer levels were greater when 5-way MLV vaccination was delayed, which would suggest an improved acquired immune response to IBR. Because no differences in morbidity or mortality were noted for vaccination upon arrival vs. delayed vaccination, and performance for delayed vaccination cattle was greater, results of the current study would suggest no production or economic advantage when administering a 5-way MLV vaccine on-arrival to high-risk stocker cattle.

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Table 1. Composition of the receiving grain supplement (As-fed basis).

Ingredient	% of diet
Corn, cracked	67.0
Cottonseed meal	19.0
Corn gluten feed	12.5
Limestone	1.5
Rumensin® 80[a]	0.04

[a]Supplied 40 mg monensin/lb of supplement (Elanco Animal Health, Indianapolis, IN).

Table 2. Effect of Bovine Respiratory Disease (BRD) vaccination timing on performance of stocker cattle during the receiving period.

Weight or ADG	On Arrival[a]	Delayed[a]	SE[b]	P-Value
BW, lb [d]				
Day 0	435.4	431.4	2.42	0.33
Day 14	459.4	468.4	3.03	0.007
Day 28	478.8	484.4	2.93	0.16
Day 42	494.3	502.5	4.08	0.07
ADG, lb/d [c]				
D 0 to 14	1.94	2.55	0.22	0.007
D 14 to 28	1.34	1.17	0.15	0.45
D 28 to 42	0.99	1.23	0.10	0.12
D 0 to 42	1.43	1.65	0.09	0.05
Pasture ADG, lb[d]	1.96	1.85	0.08	0.15

[a]Treatments were vaccination of incoming stocker cattle with Express® 5 (Boehringer Ingelheim) modified live IBR, PI3, BRSV and BVD type I and II vaccine either on arrival at initial processing (d 0) or on d 14. Cattle were re-vaccinated 14 d following initial vaccination.
[b]Standard Error of the mean (n = 524).
[c]All analysis (except d 0 BW) was conducted using BW and gender on d 0 as covariates.
[d]Grazing performance calculated subsequent to the 42-d receiving period.

Table 3. Effect of Bovine Respiratory Disease (BRD) vaccination timing on morbidity, mortality and treatment cost of stocker cattle during the receiving period.

Item	On Arrival[a]	Delayed[a]	SE[b]	P-Value
Body Temperature on d 0, °F	103.3	103.2	0.23	0.83
Treatment, %				
Initial[c]	75.3	70.2	0.10	0.21
Re-treat[d]	29.4	35.1	0.11	0.08
Days to 1st treatment	5.7	5.1	1.10	0.44
Death loss, %	2.3	0.8	0.75	0.19
Treatment Cost, $[e]	10.29	10.64	2.36	0.75

[a]Treatments were vaccination of incoming stocker cattle with Express® 5 (Boehringer-Ingelheim) modified live IBR, PI3, BRSV and BVD type I and II vaccine either on arrival at initial processing (d 0) or on d 14. Cattle were re-vaccinated 14 d following initial vaccination.
[b]Standard Error of the mean (n = 524).
[c]Initial, cattle with observed symptoms of BRD and temperature in excess of 104° F were injected with Micotil (Elanco) at 1.5 cc/ 100 lb BW.
[d]Re-treat, 72 h following initial, cattle with observed symptoms of BRD and temperature in excess of 104° F were injected with Baytril (Bayer) at 4.0 cc/ 100 lb BW.
[e]Treatment cost for BRD assuming value of Micotil $1.10/cc and Baytril $0.53/cc.

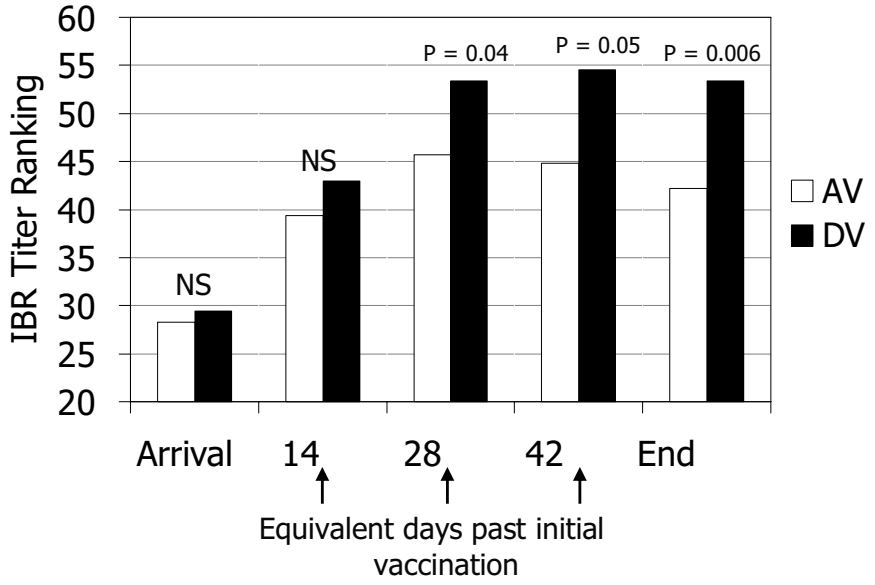

Fig. 1. Infectious bovine rhinotracheitis (IBR) titer level ranking for arrival vaccination (AV) or delayed vaccination (DV) at arrival (d 0), equivalent days past initial vaccination, and end (d 42).

Using Programmed Feeding to Manage the Nutrition of Young Beef Cows

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Story in Brief

On November 10, 2005, 52 non lactating cows (BW = 958 ± 2.8 lb) of mostly Angus breeding were stratified by BCS, parity, BW, and distributed randomly into four 2 acre drylots pens. The cows were bred to calve in the February 2006 for the first (n = 37) or second (n = 15) time. Cows in 2 pens were program-fed a high concentrate diet during 2 feeding periods, gestation (84 d) and lactation (56 d). The diet was formulated to be 12.1% chopped corn stalks, 67.8% hominy feed, 1.5% cottonseed meal, 2.3% minerals, 0.5% urea, and 15.9% water on an as fed basis (79% DM). Cows on the other 2 drylots were fed long stem bermudagrass hay plus a hominy feed based supplement. Cow BW and BCS tended ($P \leq 0.09$) to be improved by programmed feeding compared to hay feeding. Total dry matter intake (DMI) was reduced 27% or more ($P < 0.03$) for cows that were program-fed compared to hay-fed cows during gestation and lactation. Program fed cows had a pregnancy rate of 92% compared to 80% for hay-fed cows ($P = 0.37$). Calving date, calf birth weight, agility, vigor, and calving ease did not differ ($P \geq 0.42$) between treatments. On March 30, May 11, and July 6, calves from program-fed cows tended ($P \leq 0.14$) to be heavier than the calves nursing hay-fed cows. These data suggests that calves nursing program-fed cows probably had a higher plain of nutrition and performed better than calves nursing hay-fed cows. The trends noted in calf performance were possibly the result of increased milk production with programmed feeding.

Introduction

Reducing hay requirements for wintering beef cow herds is an important topic, especially after summers of prolonged drought that result in a reduced hay harvest. Many farmers immediately consider buying additional hay from distant locations and transporting it to their farms. Because hay is difficult to transport inexpensively, the digestible energy from purchased hay is often expensive relative to the more energy dense by product feeds. Gunter et al. (2000) showed that using by product feeds can reduce feed cost for wintering beef cows by as much as 55% compared to purchased hay and supplements.

One benefit of using high concentration diets is that the energy intake by young growing cows would be precisely regulated and during lactation BCS would not be depleted before the breeding season. Pregnancy rate should be improved relative to cows consuming a large percentage of medium or low quality roughages. The purpose of this trial was to evaluate the use of energy dense diets based on by product feeds relative to medium quality hay plus a supplement fed to cows calving for the first or second time.

Experimental Procedures

On November 10, 2005, 56 non lactating cows (BW = 958 ± 2.8 lb) of mostly Angus breeding that were bred to calve in February 2006 for the first (n = 37) or second (n = 15) time were stratified by BCS (Wagner et al., 1988), age (hence, parity), and BW and were distributed randomly into four 2 acre drylot pens. Cows had been previously bred by timed AI in 2 groups on the 19th and on the 26th of April 2005, then exposed to a Angus sire for 30 days starting on April 23 and 30, respectively. Cows in 2 pens were program-fed a high concentrate diet formulated to meet the NRC (1996) requirements during both feeding periods, gestation (84 d) and lactation (56 d). The program-fed diet consisted of 12.1% chopped corn stalks, 67.8% hominy feed, 1.5% cottonseed meal, 1.4% minerals, 0.9% limestone, 0.5% urea, and 15.9% water on an as fed basis (79% DM, and 12.3% CP [DM basis] and 0.94 Mcal of NE_m/lb of DM). The mineral mixture was 15.0% Ca, 7.0% P, 5.0% Mg, 1.0% S, 14.0% NaCl, 1,000 mg/kg Mn, 2,355 mg/kg Fe, 1,250 mg/kg Cu, 3,000 mg/kg Zn, 26 mg/kg Se, 20 mg/kg Co, 25 mg/kg I, 661,500 IU/kg vitamin A, 66,150 IU/kg vitamin D, and 221 IU/kg vitamin E (Sunbelt Custom Minerals, Sulphur Springs, Texas). Cows in the other 2 drylots were fed long stem bermudagrass hay for ad libitum intake plus a hominy feed based supplement. With programmed feeding, the amount of feed delivered daily was based on the calculated NE_m concentration in the diets as described by Galyean (1999). Hominy feed was selected as an alternative to corn because of its relatively high energy density (2.35 Mcal of NE_m/kg) and CP concentration (11.5% of DM), but relatively inexpensive delivered cost ($83.00/ton) compared to whole shelled corn ($107.25/ton). The diet was mixed weekly in a mixer wagon (Kuhn, Model 1060, Vernon, N.Y.) and program-fed at amounts to meet the NE_m requirement of the cows. The amount of feed delivered daily was adjusted every 28 d to account for changes in the physiological stage of production (NRC, 1996). Cows fed primarily hay (9.4% CP and 0.49 Mcal of NE_m/lb [DM basis]) were fed a supplement made hominy feed (87.5%) and the previously mentioned mineral mixture (12.5%) at a rate of 1.5 lb daily during the first two 28 day periods and 3 lb daily (hominy feed, 91.7%; mineral mixture, 8.3%) during the third 28 day period; during lactation, the cows were fed 5 lb daily of supplement (hominy feed, 85.0%; mineral mixture, 5.0%, cottonseed meal, 10.0%) where cottonseed meal was added to meet the protein requirement of lactation.

At the beginning of the trial (day 0; November 10, 2005), cows were weighed unshrunk and evaluated for BCS before the morning feeding and at approximately 28 d intervals. Program fed cows were adapted to the diet by allowing them access to 1 bale of bermudagrass hay (860 lb) and feeding 5.8 lb of feed DM on the first day;

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the bale of hay was never replenished and the amount of diet fed daily was increased by 15.2 lb of DM until target intake was reached. Diet samples were collected weekly and composited within gestation and lactation phases of production. Cows were bred by timed AI April 20, 2006 then bred natural service for 60 days starting on April 25 with an Angus bull. Beginning on March 30 at the end of the programmed feeding period, cows were allowed to graze tall fescue (Kentucky 31, *Festuca arundinacea*) pasture. Cows were reweighed after 14, 42, and 89 days on pasture. Blood was harvested on August 7, 2006 and analyzed for pregnancy specific protein B at a commercial laboratory (BioTracking LLC, Moscow, ID) to determine pregnancy.

Cows and calves were weighed and BCS of the cows were recorded on November 10, December 8, January 5, February 2, March 2, March 30, April 13, and May 11. On March 30 and May 11, milk samples were collected and sent to the Dairy Herd Improvement Association (DHIA) Milk Laboratory at Louisiana State University (Baton Rouge, La.) for percentage fat and protein determination. The morning after calving, calves were weighed, tattooed in both ears with an individual number, and male calves were surgically castrated. On April 13, cows were treated for internal and external parasites (Ivomec; Merck & Co., Inc., Whitehouse Station, N.J.).

The experiment was analyzed using PROC MIXED of SAS (SAS Inst. Inc., Cary, N.C.) as a completely randomized design with the effect of treatment and the covariates of cow age and calving date in the model. The fixed effect in the model was treatment and the random effect was pen. Least squares means were separated using predicted differences.

Results and Discussion

Gestation period. Cow BW and BCS did not differ ($P \geq 0.61$) between the program-fed and hay-fed cows from November 10 to January 5; on February 2, program-fed cows tended ($P = 0.09$) to weigh 10% more than hay-fed cows (Table 1). It can be noted that the BW of both groups increased with advancing gestation from November 10 to January 5, although BCS changed relatively little ($P \geq 0.36$). Average cow BW decreased from January 5 to February 2 because some cows had calved in late January. Total DMI was 39, 30, and 27% less ($P < 0.01$) for program-fed cows relative to the hay-fed cows for the first, second, and third 28 day periods of gestation, respectively. The reduction noted for hay intake between days 57 and 84 (within the last 28 days of pregnancy) by the hay-fed cows is classic response to increasing size of the fetus and limited abdominal capacity (Gunter et al., 1990). Body condition score at calving tended ($P = 0.10$) to be less for cows on the hay based diets compared to the program-fed cows.

Lactation period. Cow BW did not differ ($P \geq 0.15$) between treatments on March 2 or 30 during the feeding period (Table 2). After the cows were placed on pasture, the BW of the cows fed hay and supplement tended ($P \leq 0.10$) to be less than cows that had been program-fed. Supporting the trends noted in BW, BCS on March 30 and April 13 tended to be less ($P \leq 0.07$) for cows fed hay and supplement than cows that had been program-fed the high-concentrate diet. On May 11 and July 7, when the cows had been on pasture from 42 to 89 days, this difference noted in BCS between the treatments had begun to diminish ($P \geq 0.12$). The program-fed cows had greater BCS during the breeding season than the hay-fed cows, which would suggest the potential for a higher conception rate (Wagner et al., 1988). Pregnancy rate measured on August 7 via the blood test for pregnancy specific protein B showed that the program-fed cows groups had a 15% greater pregnancy rate than the hay-fed groups, but the difference can not be attributed to the treatments ($P = 0.37$). Total DMI was 31 and 29% less ($P \leq 0.03$) for cows program-fed a high concentrate relative to the hay-fed cows for the first and second 28 day periods of lactation, respectively.

Calving date did not differ ($P = 0.42$) between the program-fed cows (February 17) and the hay-fed cows (February 12; Table 3). Calf birth weight, agility, vigor, and calving ease did not differ ($P \geq 0.54$) between treatments. On March 30, calves from program-fed cows tended ($P = 0.14$) to be 12% heavier that the calves nursing hay-fed cows; this same trend ($P \leq 0.14$) in BW was also noted on May 11 and July 6, after the cows and calves had been on pasture from 42 to 89 days. Also, ADG between birth and March 30 tended ($P = 0.12$) to be greater for calves nursing program-fed cows than hay-fed cows, but no trend ($P = 0.38$) in ADG was noted between March 30 and July 6. Tests for the composition of the milk showed that it did not differ ($P \geq 0.34$) on March 30 or May 11 (Table 2). The tendency for improved BW and ADG for calves nursing program-fed cows on March 30 probably resulted from differences in total milk production because its composition did not differ (Table 2).

These data suggest that program-fed cows can maintain BCS to a better degree than hay-fed cows. Also, calves nursing program-fed cows probably had a higher plain of nutrition than calves nursing hay-fed cows. The trend noted towards and improvement in calf performance with programmed feeding was most likely the result of increased milk production because no difference was noted in milk composition.

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Table 1. Body weight, BCS, DMI, and BCS at calving of beef cows fed bermudagrass/dallisgrass hay plus supplement or program-fed a high-concentrate diet before calving.

Item	Treatments[a]		SE	*P*-value
	Hay	Program-fed		
Cow BW, lb				
November 10	960	950	20.5	0.77
December 8	956	942	21.1	0.68
January 5	997	1,015	22.0	0.61
February 2	949	1,045	22.1	0.09
BCS[b]				
November 10	6.0	6.0	0.07	0.87
December 8	6.1	6.0	0.08	0.71
January 5	6.1	6.1	0.07	0.92
February 2	6.0	6.2	0.13	0.36
Total DMI, lb/d[c]				
Days 0 to 28	19.1	11.6	0.11	< 0.01
Days 29 to 56	19.1	13.3	0.01	< 0.01
Days 57 to 84	16.8	12.2	0.01	< 0.01
BCS at calving	5.7	6.0	0.08	0.09

[a]Hay = *ad libitum* hay (9.4% CP and 53.1% TDN) plus 1.5 lb daily (87.5% hominy feed and 12.5% 1822 minerals on an as-fed basis; 94% DM) for the first and second 28-period and 3 lb daily of the last 28-day (91.7% hominy feed and 8.3% 1822 minerals on an as-fed basis; 94% DM) period of supplement; Program fed = 13.9 lb of DM/cow daily of a total mixed diet (12.1% chopped corn stalks, 67.8% hominy feed, 1.5% cottonseed milk, 1.4% 1822 minerals, 0.9% limestone, 0.5% urea, and 15.9% water on an as-fed basis; 79% DM).
[b]Body condition score range 1 to 9; 1 = emaciated, 9 = obese (Wagner et al., 1988).
[c]Hay plus supplement for Hay treatment.

Table 2. Body weight, BCS, conception rate, post-partum interval, DMI, and milk composition of beef cows fed bermudagrass/dallisgrass hay or program-fed a high-concentrate diet before calving and during the first 56 d of lactation.

Item	Treatments[a]		SE	*P*-value
	Hay	Program-fed		
Cow BW, lb				
March 2	928	962	21.6	0.39
March 30, cattle went to pasture	846	924	29.0	0.20
April 13	881	979	23.1	0.10
May 11	847	940	23.5	0.09
July 6	913	968	23.1	0.24
BCS[b]				
March 2	5.7	6.2	0.13	0.12
March 30, cattle went to pasture	5.3	6.1	0.13	0.05
April 13	5.3	6.2	0.16	0.07
May 11	5.6	6.4	0.24	0.14
July 6	5.9	6.2	0.19	0.42
Pregnancy rate, %	80	92	7.8	0.37
DMI, lb/d[c]				
Day 0 to 28	21.0	14.4	0.003	< 0.01
Day 29 to 56	21.6	15.3	0.80	0.03
Milk composition on March 30				
Percentage of fat	2.0	2.2	0.23	0.67
Percentage of protein	2.9	3.2	0.15	0.34
Milk composition on May 11				
Percentage of fat	4.0	3.9	0.21	0.79
Percentage of protein	3.0	3.0	0.08	0.94

[a]Hay = *ad libitum* hay (9.4% CP and 53.1% TDN) plus 5 lb during lactation/cow daily of supplement (hominy feed, 85.0%; mineral mixture, 5.0%, cottonseed meal, 10.0% on an as-fed basis; 94% DM); Program-fed = 13.9 lb of DM/cow daily of a total mixed diet (12.1% chopped corn stalks, 67.8% hominy feed, 1.5% cottonseed meal, 1.4% 1822 minerals, 0.9% limestone, 0.5% urea, and 15.9% water on an as-fed basis; 79% DM).
[b]Body condition score range 1 to 9; 1 = emaciated, 9 = obese (Wagner et al., 1988).
[c]Hay plus supplement for hay treatment.

Table 3. Birth weight, BW, total BW gain, and ADG of calves nursing beef cows fed bermudagrass/dallisgrass hay or program-fed a high concentrate diet during lactation.

Item	Treatments[a]		SE	*P*-value
	Hay	Program-fed		
Calving date, Julian calendar	43	48	3.5	0.42
Birth weight, lb[b]	71	74	2.9	0.56
Agility[c]	1.1	1.2	0.17	0.65
Vigor[d]	4.9	4.8	0.15	0.54
Calving ease[e]	1.0	1.1	0.07	0.47
Calf BW, lb[bc]				
March, 30	137	154	5.0	0.14
May 11	198	217	5.5	0.13
July 6	292	322	9.0	0.14
ADG, lb				
Birth to March 30	1.4	1.9	0.14	0.12
March 30 to July 6	1.6	1.7	0.09	0.38
Birth to July 6	1.6	1.8	0.06	0.16

[a a]Hay = *ad libitum* hay (9.4% CP and 53.1% TDN) plus 5 lb during lactation/cow daily of supplement (hominy feed, 85.0%; mineral mixture, 5.0%, cottonseed meal, 10.0% on an as-fed basis; 94% DM); Program-fed = 13.9 lb of DM/cow daily of a total mixed diet (12.1% chopped corn stalks, 67.8% hominy feed, 1.5% cottonseed meal, 1.4% 1822 minerals, 0.9% limestone, 0.5% urea, and 15.9% water on an as-fed basis; 79% DM).
[b]Birth weight used as a covariate.
[c]Agility score: 1.0 = moves well and correct posture, 2.0 = moves showing slight stiffness in legs, and 3.0 = significant stiffness in gate (Gunter et al., 2003).
[d]Vigor score: 1 = alert and active, 2 = alert, and 3 = appears healthy, but somewhat listless (Gunter et al., 2003).
[e]Calving ease: 1.0 = unassisted birth (Vandervelde et al., 1990).

A Case Study of the Cow Size and Production Efficiency Relationship

W.A. Whitworth[1], C.R. Stark, Jr.[1], and T.G. Montgomery[2]

Story in Brief

The choices made by beef cattle producers when culling cows from the herd should be based on sound economic and production data. Some producers have assumed that a larger cow will wean a heavier calf and therefore will be more profitable. This mindset has led producers to add large breed genetics to their commercial cow herds in pursuit of larger frames and the assumed increased profits. A better culling criteria than cow size is cow production efficiency (CPE). The CPE may be defined in numerous ways, but the most common measurement is pounds of weaned calf divided by cow weight at weaning. From this ratio, the more critical measure of dollars of weaned calf per dollar of cow maintenance expense can be determined. To calculate these measurements, producers must connect market prices of calves and cows with the calf weaning weights, cow weights at the time of calf weaning, and maintenance costs for the herd. A case study conducted on the Southeast Research and Extension Center cow herd at Monticello, Arkansas indicated that larger cows have the lowest CPE ratios. Economic analysis of these production results revealed that feeding cost differences between high and low efficiency cows could be more than $50 per cow. Calf revenue difference per cow across the cow efficiency groups was found to exceed $75.

Introduction

When making culling decisions on the cow herd, a producer should first identify what herd production goals are desirable. Two keys of herd production are calf weaning weights and cow production efficiency. Commercial producers are in the business of producing pounds of calf to sell and get paid primarily on a dollars per pound basis. Calf weaning weights should thus be increased as long as the additional size does not create calving problems such as problems from overly large birth weights.

Cow production efficiency is simply the calf weight-to-cow weight ratio. The Arkansas Cow Herd Performance Testing Program guidelines of the University of Arkansas Cooperative Extension Service (UA-CES) state that cows should wean 50% of their body weight when their calves are 205 days of age (Barham, 2006). Conversion of actual calf weaning weights to adjusted 205-day weights is necessary to account for differences in calf ages and differences in cow ages.

The most difficult calculation for many beef producers is the dollar expense of maintaining the cow herd and the necessary replacement animals to maintain steady production. Costs per cow will vary between different producers. If actual costs of production are not available, most state extension services publish cow-calf enterprise budgets that specify direct, ownership, and total costs for a representative herd. A survey of the most recent published budgets from Arkansas, Mississippi, Oklahoma, Tennessee, and Texas found that total cost was estimated at $354 per cow for a 1,000 pound cow (one animal unit) (Hogan et al., 2006a, 2006b; Mississippi State University, 2006; Oklahoma State University, 2006; Texas A&M University, 2006; University of Tennessee, 2006). If actual cow weights have been recorded, adjustments for cow size can be made from this estimated total cost.

Experimental Procedures

Southeast Research and Extension Center Cow Herd Analysis. Examination of the relationship between cow size, calf weaning weight, and maintenance cost per cow was made as a case study of the Southeast Research and Extension Center (SEREC) cow herd that is maintained in association with the University of Arkansas at Monticello Division of Agriculture. The study herd was composed of multiparous *Bos indicus*-influenced (≥ 3/8 Brahman) females 3 years of age or older who had raised at least one calf. All cows that raised and weaned a calf in the years 2000 to 2005 were included in the data set. All calves were sired by Beefmaster bulls. Herd records from 5 years were analyzed to calculate average cow weights, 205-day adjusted calf weaning weights, and cow production efficiency (CPE). The CPE values for first-calf heifers were not included in the analysis since these females are producing a calf and continuing to grow in size themselves. Herd results for the remaining females were summarized after being ranked in descending order by CPE value. The total herd for each year was then divided into high, middle, and low groups by CPE values, and averages were calculated by group and over all years for each of the data components (Table 1).

Results from the herd analysis were consistent for each production year used in this study. Among the 3 annual cow groups, as ranked in descending order by CPE ratio, the average cow weights were lowest each year for the upper third of the herd (High Group) with an average of 1,223.0 lb over all years. The low group for CPE ratio had the highest average cow weights at 1,428.1 lb over all years.

The averages for 205-day adjusted calf weaning weights were highest for the high efficiency group of cows with an average of 567.2 lb over all years. Calves from the low group of cows had the lowest 205-day adjusted calf weaning weight averaging 464.0 pounds over all years studied. These weight results run counter to common beliefs that calf weights would be highest for the largest cows.

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A desirable goal for CPE is 0.5000 where a cow is weaning a calf that weighs 50% of the cow's weight. Using the 205-day adjusted calf weaning weight, the SEREC cow herd had an overall CPE Ratio of 0.3960 for all groups over all years. When the cows for each year were divided into high, middle, and low efficiency cohorts, the high group had a CPE ratio of 0.4648, the middle group CPE ratio averaged 0.3986, and the low group averaged 0.3276. These results indicate, as expected, that larger cows have the lowest CPE Ratios.

Economic Benefits of Culling. Producers who cull their cow herd have often removed the smaller females with the mindset that larger cows will produce heavier calves and thereby generate more pounds of beef to sell per cow. A more desirable practice for identifying economic benefits is to consider the production efficiency of the cow, maintenance costs associated directly with cow size, and calf weaning weight.

The most recent UA-CES cow-calf production budgets estimate annual direct costs of pasture fertilizer, supplemental energy feed, and salt/minerals to be $87.01 per cow. Taking this value as our benchmark for a 1,000 pound cow (one animal unit), we can estimate the additional or reduced costs of other cow sizes. The SEREC high efficiency cow group averaged 1,223.0 pounds in weight. Given the assumption that any cow consumes 2% of their body weight, this average cow weight suggests increased maintenance costs of $19.40 per cow above our benchmark. Less efficient cow groups had even higher cost increases of $25.27 for the middle efficiency group and $37.25 for the low efficiency group above the benchmark (Table 2).

The calf weaning weight-cow efficiency relationship reveals the second economic component of herd culling. Arkansas cow-calf production budgets use a 540 pound calf weaning weight to estimate expected revenue. Combining this weight with the recent Arkansas state average price of $116.60 per hundredweight for that calf weight range, the expected revenue per weaned calf is $629.64. Using the actual 205-day average calf weaning weights for the SEREC herd and recent Arkansas state average prices per hundredweight for specific calf weight ranges, estimates can be generated of the additional or reduced revenues for each cow efficiency group.

The average calf weaning weight of 567.2 lb for the high efficiency cow group exceeded the CES budget weight. Combining the extra weight with the appropriate market price resulted in a $10.90 gain per calf over the benchmark revenue value. The middle and low efficiency groups had average calf weaning weights below the benchmark weight. The revenue changes relative to the benchmark were $30.08 less for the middle efficiency group and $64.63 less for the low efficiency group (Table 3).

Implications

What is the economic value of good cow herd culling decisions? Culling can provide economic benefits by removing cows with higher maintenance costs and lower calf weaning weights. A simple measure to identify these cows is the cow production efficiency ratio. This case study of the Southeast Research and Extension Center beef herd showed that the low efficiency cow group had $37.25 higher direct maintenance costs per cow than the Arkansas Cooperative Extension Service cow-calf budget estimate and produced $64.63 less revenue per cow from calf sales due to a lower average calf weaning weight. Combining these values, the total potential gain from culling low efficiency cows and replacing them with average production animals would be $101.88 per cow.

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Table 1. Production results for high, middle, and low groups as ranked by cow production efficiency (CPE) ratios.

Year	High*				Middle				Low			
	No. of cows	Cow wt	205-Day calf wt	CPE ratio	No. of cows	Cow wt	205-Day calf wt	CPE ratio	No. of cows	Cow wt	205-Day calf wt	CPE ratio
2005	23	1174.7	539.5	0.4599	24	1243.1	477.1	0.3839	24	1416.9	416.9	0.2963
2004	21	1240.2	563.9	0.4557	21	1313.4	507.4	0.3865	22	1482.0	453.0	0.3075
2003	21	1269.8	593.6	0.4688	21	1335.5	528.6	0.3957	21	1426.9	498.7	0.3502
2002	11	1218.3	562.1	0.4644	12	1299.6	526.8	0.4056	12	1418.3	448.0	0.3226
2000	14	1210.0	581.8	0.4811	15	1263.4	552.9	0.4378	15	1376.5	519.5	0.3796
Average		**1223.0**	**567.2**	**0.4648**		**1290.4**	**514.2**	**0.3986**		**1428.1**	**464.0**	**0.3276**

*High indicates upper one third of herd, middle the mid-range of the herd and low indicates the lower one third of cow herd based on CPE ratio.

Table 2. Feeding cost differences per cow for high, middle, and low groups as ranked by cow production efficiency (CPE) ratios.

	Southeast Research and Extension Center		
Cooperative Extension Service budget	**High***	**Middle**	**Low**
Cow weight = 1,000 lb	1,223.0	1,290.4	1,428.1
Maintenance cost = $87.01	$106.41	$112.28	$124.26
Change over/under CES budgeted value	+$19.40	+$25.27	+$37.25

*High indicates upper one third of herd, middle the mid-range of the herd, and low indicates the lower one third of cow herd based on CPE ratio.

Table 3. Calf revenue differences per cow for high, middle, and low groups as ranked by cow production efficiency (CPE) ratios.

	Southeast Research and Extension Center		
Cooperative Extension Service budget	**High**	**Middle**	**Low**
Calf weight = 540 lb	567.2	514.2	464.0
Sales price = $116.60/cwt	$112.93	$116.60	$121.77
Revenue change from CES budgeted value = $629.64	+$10.90	-$30.08	-$64.63

*High indicates upper one third of herd, middle the mid-range of the herd, and low indicates the lower one third of cow herd based on CPE ratio.

The Use of Serum Components and Ultrasonic Measurements at Weaning to Predict Feedlot Gain and Carcass Merit[1]

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Story in Brief

The objective of this study was to determine if weaning characteristics of lactate dehydrogenase (LDH) activity, lactate, cortisol, insulin-like growth factor I (IGF-I), prolactin (PRL) concentration, and ultrasonic measurements were related to subsequent feedlot gain and carcass composition. Forty-six crossbred steers (447 ± 3.7 lb BW) were weaned (216 ± 2.6 d of age) and blood samples collected. Ultrasound measurements of *longissimus dorsi* muscle (REAU), fat thickness (FTU), intramuscular fat (%FATU), and rump fat (RUMP) were recorded at weaning and feedlot phases. Hot carcass weight (HCW), ribfat thickness (RF), *longissimus dorsi* muscle area (REA), marbling score (MARB), yield grade (YG), and quality grade (QG) were determined at harvest. Weaning FTU correlated with YG ($r = 0.28$; $P < 0.05$), while REAU correlated with HCW and REA ($r = 0.55$ and 0.60; $P < 0.01$). Concentrations of lactate at weaning were inversely correlated with YG ($r = -0.27$; $P < 0.10$) while serum activity of LDH was inversely correlated ($r = -0.25$; $P < 0.10$) with MARB. Concentrations of IGF-I were correlated with REAU and FTU during the feedlot phase ($r = 0.29$ and 0.41 respectively; $P < 0.05$), and HCW, REA, and RF at harvest ($r = 0.40$, 0.38, and 0.39; $P < 0.01$). Weaning measurements of lactate concentration, LDH activity, and ultrasound measurements may be useful in predicting carcass composition.

Introduction

Carcass characteristics, including quality grade (QG) and yield grade (YG), are driving forces for pricing in the beef cattle industry. Predicting cattle gain and carcass composition with new technologies may result in earlier and more precise estimations. Ultrasound technology has been used extensively to predict carcass merit in the beef cattle industry, and has been used in both breeding and terminal programs. When using an experienced technician, ultrasonic images are reliable and repeatable in feedlot cattle (Perkins et al., 1992).

Genetics and environment affect animal physiological responses, which govern animal growth and development. Serum activity of lactate dehydrogenase (LDH) has been found to affect carcass quality grades (May, 2002). Hormones such as cortisol, prolactin, insulin-like growth factor (IGF-I), and thyroid hormones [thyroxine (T_4) and triiodothyronine (T_3)] are known to have effects on immune function, metabolism, and growth (Blecha and Baker, 1986; Anderson et al., 1988; and Hennighausen et al., 1997). The objective of this study was to investigate relationships among traits at weaning and feedlot gain and carcass characteristics. A second objective was to investigate the effectiveness of LDH, lactate, cortisol, IGF-I, prolactin, and ultrasonic measurements at weaning as predictors of steer feedlot gain and carcass characteristics.

Experimental Procedures

Forty-six crossbred steers (447 ± 3.7 lb) were weaned (216 ± 2.6 d) and transported approximately 20 min to a working facility at the University of Arkansas Savoy Cow Calf Unit where they were maintained for 2 weeks. Upon arrival each animal was weighed and a blood sample taken via the jugular vein. Approximately 10 ml of blood was extracted from the animal twice (Vacutainer™ 10 ml tubes). All blood samples were stored at 5°C until centrifuged at 1,200 x g and serum decanted and stored at -20°C. Ultrasound measurements were determined by a certified ultrasound technician and images analyzed (Centralized Ultrasound Processing (CUP) laboratory; Walter and Associates, LLC) at weaning and at d 63 of a 136 d feedlot phase.

The animals were then transported 13.5 miles to the University of Arkansas Forage Research Unit in Fayetteville for the backgrounding phase. Each steer was supplemented with 3.96 lb/d of a corn:soybean meal (12% CP) ration and had ad libitum access to tall fescue pasture for a 135 d grazing period. Following the backgrounding phase, steers were weighed and transported 184.2 miles to a feedlot at the Willard Sparks Beef Research Center, Oklahoma State University, Stillwater. Each steer was administered an implant containing estradiol benzoate (Component E-S, Vet-Life, Overland Park, Kan.). Steers were reimplanted with estradiol and trenbalone acetate (Revalor-S, Intervet, Millsboro, Del.) on d 57 of the feedlot phase. Steers were weighed at 28 d intervals, fed for an average of 136 ± 3 d, and harvested at Tyson Foods Inc., Emporia, Kan. Hot carcass weight (HCW) was collected after evisceration, and ribfat thickness (RF) between the 12th and 13th ribs, *longissimus dorsi* muscle area (REA), marbling score (MARB), yield grade (YG), and quality grade (QG) were collected after a 48 h chill.

The Accutrend™ Lactate Analyzer (Roche Diagnostics, Alameda, Calif.) was used to determine lactate concentration in whole blood. Serum lactate dehydrogenase activity, in the forward and reverse direction (LDHf and LDHr), was corrected for total blood protein. Both LDH activities and serum protein were determined by colorimetric kinetic assay. Concentration of cortisol, T_3, T_4, IGF-I, and prolactin were determined using validated radioimmunoassay procedures.

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Pearson correlations were calculated and used to assess relationships between variables determined at weaning and steer feedlot gain, carcass quality grades, and yield grades. Stepwise regression analyses were used to further investigate relationships between predictor and response variables.

Results and Discussion

Means and standard errors for the predictor variables determined at calf weaning are presented in Table 1. Steers had a modest postweaning growth rate (1.4 ± 0.3 lb/d) and were representative of average steers that enter a feedlot.

Serum cortisol concentration at weaning was positively correlated (r = 0.28; P < 0.05) with FTU measured at weaning (Table 2). Serum activity of LDHr showed a negative correlation with T_4 (r = - 0.32; P < 0.05), although concentration of T_3 only tended to be correlated (r = - 0.24; P < 0.10) with LDHr. Concentration of T_3 was positively correlated (r = 0.38; P < 0.01) with FTU at weaning, however T_4 showed no relationship. Serum activity of LDHr and concentration of IGF-I were correlated with REAU (r = 0.28 and 0.42 respectively; P < 0.05).

Pearson correlation coefficients between traits at weaning and the feedlot phase are presented in Table 3. Weaning FTU correlated with feedlot FTU and RF following harvest (r = 0.38; P < 0.01). Results from Crews et al. (2002) reported muscle area measurements of steers at weaning, yearling, and before harvest had high positive correlations ranging from 0.79 to 0.86, indicating that continual measures of muscle area from the same animal are similar. Weaning FTU was significantly correlated with YG (r = 0.28; P < 0.05). Moderate correlations with ultrasound fat thickness measurements at weaning to carcass yield grade may indicate an earlier more reliable method of selection . Weaning %FATU did not correlate with MARB, indicating a reduced chance of predictability for that trait. Weaning REAU was correlated with HCW and REA (r = 0.55 and 0.60 respectively; P < 0.01), indicating that steers with larger ribeye area at weaning yielded a heavier carcass. Previous research using ultrasound measurements during the feedlot phase were only within 5 to10 d before harvest. The cattle in this study were measured approximately 83 d before harvest and correlations remained significant, indicating the possibility of earlier detection of carcass characteristics during the feedlot phase.

Concentrations of lactate at weaning showed a negative correlation with YG (r = -0.27; P < 0.10; Table 3) indicating a high concentration of lactate in the blood is associated with lower steer performance. Serum activity of LDHr negatively correlated (r = -0.25; P < 0.10) with MARB indicating an increase in LDHr activity reduced quality grades among the steers which is similar to results reported by May (2002). Cortisol, T_4, and T_3 concentrations showed no relationships with carcass merit. Serum IGF-I concentration at weaning correlated with REAU and FTU during the feedlot phase (r = 0.29 and 0.41 respectively; P < 0.05), and with HCW, REA, and RF at harvest (r = 0.40, 0.38, and 0.39; P < 0.01). Concentrations of prolactin at weaning were positively correlated (r = 0.29, 0.30, and 0.34 respectively; P < 0.05) with HCW, REA, and ADG during the backgrounding phase.

Pearson correlation coefficients of ultrasound measurements during the feedlot phase and carcass characteristics are presented in Table 4. Feedlot REAU correlated with HCW and REA (r = 0.60 and 0.71 respectively; P < 0.01). Feedlot FTU correlated with RF and YG (r = 0.66 and 0.48; P < 0.01). Feedlot %FATU was positively correlated (r = 0.52; P < 0.01) with MARB.

Five variables that were collected at weaning explain approximately 32% of the variation in YG. The stepwise analysis yielded an equation of:

$$YG = 2.46 + 10.24(FTU) - 0.077(lactate) - 0.004(prolactin) - 0.01(cortisol)$$

Weaning BW, FTU, and T_3 were variables shown to predict RF ($R^2 = 0.43$). The interpretation yielded the following equation:

$$RF = 0.06 + 0.001(BW) + 3.59(FTU) - 0.13(T_3)$$

Three variables also account for 53% of variation in REA. The stepwise analysis generated the following equation:

$$REA = 1.60 + 0.02(AGE) + 0.01(BW) + 0.16(lactate)$$

Variation in marbling score was significantly effected by LDHr ($R^2 = 0.08$). That stepwise analysis yielded an equation of:

$$MARB = 376.13 - 54.73\ (LDHr)$$

Ultrasound did not explain a significant portion of the variation in ADG during the backgrounding phase. While physiological components did have relationships with backgrounding ADG, the stepwise procedure did not add meaningful interpretation beyond the Pearson correlation coefficients. Ultrasound and serum components assessed at weaning were not adequate predictors of ADG of steers during the feedlot phase.

Implications

Ultrasound measurements at weaning were not as reliable at predicting steer carcass composition as ultrasound measurements in the feedlot. Therefore, serum components at weaning may be more accurate predictors of steer performance and subsequent carcass traits than ultrasound measurements. Our results indicate that serum lactate concentration and LDH activity determined at weaning coupled with ultrasound measurements in the feedlot would be useful in accurately predicting steer feedlot gain and carcass composition.

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Table 1. Means, standard errors, minimum value, and maximum value of traits for crossbred steers at weaning.

Trait[a]	Mean	SE	Minimum	Maximum
Age (d)	216	2.6	177	247
BW (lbs)	447	3.7	330	548
REAU (in^2)	6.87	0.14	4.9	9.2
FTU (in)	0.63	0.08	0.39	1.3
%FATU (%)	3.4	0.04	2.85	4.06
RUMP (cm)	1.75	0.09	1.00	3.25
Lactate (mM/L)	3.7	0.26	1.8	12.2
LDHf (IU/mg PROT)	10.4	0.4	5.5	18.2
LDHr (IU/mg PROT)	2.3	0.07	1.5	4.4
Protein (mg)	122.3	1.1	108.6	143.4
T4 (ng/mL)	43.3	1.0	29.6	67.5
T3 (ng/mL)	2.2	0.06	1.7	3.9
Cortisol (ng/mL)	36.1	1.7	4.4	59.9
IGF-I (ng/mL)	197.1	7.0	94.0	297.0
Prolactin (ng/mL)	35.9	4.8	7.2	202.5

[a] Traits are age of steer at time of measurement, body weight at weaning (BW), *longissimus dorsi* area ultrasound (REAU), fat thickness ultrasound (FTU), percent intramuscular fat ultrasound (%FATU), rumpfat measurement ultrasound (RUMP), lactate, lactate dehydrogenase forward activity (LDHf), lactate dehydrogenase reverse activity (LDHr), serum protein, thyroxine (T4), triiodothyronine (T3), cortisol, insulin-like growth factor I (IGF-I), and prolactin.

Table 2. Pearson correlation coefficients among ultrasound measurements and serum components at weaning.

Trait	FTU	%FATU	RUMP	Lactate	LDHf	LDHr	Cortisol	T4	T3	IGF-I	Prolactin
REAU	0.19	-0.09	0.12	-0.13	0.17	0.28*	-0.04	-0.04	-0.14	0.42**	0.17
FTU		0.17	0.08	0.01	-0.23	-0.07	0.28*	0.14	0.38**	0.19	0.40**
%FATU			0.26†	-0.04	0.04	0.16	0.25†	-0.17	-0.13	0.009	-0.06
RUMP				-0.03	0.04	-0.04	0.23	0.05	-0.06	0.37**	-0.02
Lactate					0.002	-0.04	0.13	-0.15	0.08	0.11	0.14
LDHf						-0.11	-0.09	0.02	-0.14	-0.05	-0.19
LDHr							-0.17	-0.32*	-0.24	-0.004	-0.15
Cortisol								-0.05	0.35**	0.16	0.09
T4									0.40**	0.23	0.12
T3										-0.04	0.21
IGF-I											0.32*

[a] Traits are *longissimus dorsi* area ultrasound (REAU), fat thickness ultrasound (FTU), percent intramuscular fat ultrasound (%FATU), rumpfat measurement ultrasound (RUMP), lactate, lactate dehydrogenase forward activity (LDHf), lactate dehydrogenase reverse activity (LDHr), serum protein, thyroxine (T4), triiodothyronine (T3), cortisol, insulin-like growth factor I (IGF-I), and prolactin.

** P < 0.01

* P < 0.05

† P < 0.10

Table 3. Pearson correlation coefficients of ultrasound measurements and serum components at weaning[a] with ultrasound measurements in the feedlot and carcass characteristics[b].

	Feedlot traits			Carcass traits				
Weaning traits	REAU	FTU	%FATU	HCW	REA	RF	MARB	YG
REAU	0.73**	0.25†	-0.40**	0.55**	0.60**	0.46**	-0.25†	0.18
FTU	0.20	0.38**	-0.21	0.09	0.14	0.38**	0.005	0.28*
%FATU	0.09	0.28*	0.22	-0.07	0.09	0.24	0.06	0.10
RUMP	0.23	0.30*	0.06	0.21	0.16	0.19	-0.13	0.13
Lactate	-0.13	-0.12	-0.009	-0.12	-0.001	-0.24†	0.03	-0.27†
LDHf	0.18	0.14	-0.09	0.03	0.19	0.09	-0.19	-0.07
LDHr	0.31*	-0.04	-0.24	0.13	0.09	0.08	-0.25†	0.06
Cortisol	0.04	0.18	0.10	0.09	0.09	-0.10	0.04	-0.12
T4	-0.16	0.20	-0.03	-0.08	-0.18	0.009	-0.15	0.12
T3	-0.09	0.07	-0.09	-0.11	-0.15	-0.16	0.03	-0.05
IGF-I	0.29*	0.41**	-0.18	0.40**	0.38**	0.39**	-0.12	0.24
Prolactin	0.20	0.20	0.006	0.29*	0.30*	0.11	0.12	-0.02

[a] Traits are *longissimus dorsi* area ultrasound (REAU), fat thickness ultrasound (FTU), percent intramuscular fat ultrasound (%FATU), rumpfat measurement ultrasound (RUMP), lactate, lactate dehydrogenase forward activity (LDHf), lactate dehydrogenase reverse activity (LDHr), serum protein, thyroxine (T4), triiodothyronine (T3), cortisol, insulin-like growth factor I (IGF-I), and prolactin.

[b] Traits are ultrasound measurements for *longissimus dorsi* muscle (REAU), fat thickness (FTU), and percent intramuscular fat (%FATU), hot carcass weight (HCW), *longissimus dorsi* muscle area (REA), ribfat thickness (RF), marbling score (MARB) and yield grade (YG).

** P < 0.01

* P < 0.05

† P < 0.10

Table 4. Pearson correlation coefficients of ultrasound measurements during the feedlot phase with those after harvest.

	Carcass trait[a]				
	HCW	REA	RF	MARB	YG
Feedlot trait[b]					
REAU(in^2)	0.60**	0.71**	0.30*	-0.02	-0.01
FTU(in)	0.32*	0.27†	0.66**	-0.23	0.48**
%FATU(%)	-0.24†	-0.22	-0.12	0.52**	-0.03

[a] Traits are hot carcass weight (HCW), *longissimus dorsi* muscle area (REA), ribfat thickness (RF), marbling score (MARB), and yield grade (YG).
[b] Traits are ultrasound measurements for *longissimus dorsi* muscle (REAU), fat thickness (FTU), and percent intramuscular fat (%FATU).
**P < 0.01
*P < 0.05
†P < 0.10

Effects of Age at Castration and Transportation Stress on Physiological Responses of Newly Weaned Beef Calves[1]

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Story in Brief

Effects of transportation and age of castration on serum cortisol, insulin-like growth factor-I (IGF-I), triiodothyronine (T_3), thyroxine (T_4), and lactate dehydrogenase (LDH) activity were determined in newly weaned beef calves. Charolais- (n = 29) and Angus-sired (n = 25) calves were surgically castrated at birth (CB; within 24 hours) or 2 days post-weaning (CW; 197 ± 21 days of age). At weaning (day 0), blood samples were collected, and calves were transported to an auction barn where they were maintained for 24 hours. Blood samples were collected at 2, 4, and 9 days after weaning and transport to the auction barn. Concentrations of T_3 were greater ($P < 0.01$) in CB calves compared to CW calves (1.41 vs. 1.24 ± 0.03 ng/mL). Concentrations of T_4 did not differ due to castration treatment ($P > 0.50$); however concentrations of T_4 tended ($P = 0.07$) to be higher in Angus-sired calves than Charolais-sired calves). Concentrations of cortisol on day 0 and 2 were increased ($P < 0.01$) in CB calves over CW calves (31 vs. 21 ± 1.9; and 35 vs. 20 ± 2.1 ng/mL, respectively) but did not differ on days 4 and 9 between the 2 groups (age at castration by day interaction; $P < 0.01$). Forward LDH activity was similar ($P > 0.05$) between CB and CW calves on days 0, 2, and 9, but was higher ($P < 0.05$) in CW calves compared with CB calves on day 4 (age at castration by day interaction; $P = 0.03$). Concentrations of IGF-I were affected by an age of castration x sire breed interaction ($P < 0.01$). Angus-sired calves had higher concentrations of IGF-I than Charolais-sired calves in the CW group, but not in the CB group. Both forward and reverse LDH activity were affected by sire breed ($P < 0.01$). Stressors from weaning, castration, and (or) transportation alter the physiological responses of calves and may explain certain performance differences in newly weaned cattle.

Introduction

Restraint, handling, and novelty are some of the many physiological stressors beef cattle can endure on a daily basis. In addition, there are physical stressors including hunger, thirst, fatigue, injury, and high temperatures (Grandin, 1997). Stressful events, such as castration and transport, have been shown to suppress important elements of the bovine immune response (Fisher et al., 1997). Such measurements of stress to consider include catabolic hormones, such as cortisol, that suppress immune function, and IGF-I, and thyroid hormones (T_4 and T_3), which help to mediate growth and metabolism (Blecha and Baker, 1986). Serum activity of LDH is associated with metabolism and carcass composition in steers (May, 2004). Stressors experienced by livestock are generally complex and the animal's ability to respond and adapt to a stress stimuli will likely influence subsequent performance. The objective of this study was to investigate the effects of age at castration on physiological responses of beef calves to weaning and transportation stress.

Experimental Procedures

All animal procedures used in this study were approved by the committee for animal welfare at the Dale Bumpers Small Farms Research Center, Booneville, Ark. Spring-born (average birth date March 4 ± 3 days), Angus and Charolais-sired calves were surgically (knife) castrated at birth (CB; n = 25; within 24 hours) or at weaning (CW; n = 29; 197 ± 2 days). All steers were managed similarly and did not receive steroid implants prior to or during the experiment.

Calves were weaned and then transported (day 0 of experiment) to a local livestock auction barn (16 miles from the USDA-ARS research farm) where calves were maintained in pens for 24 hours. Blood samples were collected on day 0 prior to transport, and on day 2, 4, and 9 (8:00 am) after weaning and transport to the auction barn. All blood samples were stored at 41°F until centrifuged at 1,200 x g and then stored at -4°F. Serum lactate dehygrogenase activity, in the forward and reverse direction, was determined by using a modified kinetic blood assay and was corrected for total blood protein. Serum cortisol, T_3, T_4, and IGF-I concentrations were determined by radioimmunoassay procedures (New Mexico State University, Las Cruces).

Statistical Analysis. Data were analyzed as repeated measures using a mixed models procedure (SAS Inst., Inc., Cary, N.C.). The fixed effects were breed of sire and age at castration, and day of measurement was the repeated measure. Treatment means were compared using the PDIFF option of PROC MIXED when protected by a significant ($P < 0.05$) treatment effect.

Results and Discussion

Concentration of T_3 was greater ($P < 0.01$) in CB calves compared to CW calves (1.41 + 0.03 vs 1.24 + 0.03 ng/mL). There also was a day effect ($P < 0.01$; Fig. 1) with concentrations being greater on days 0 and 2 than on days 4 and 9. There was no difference in T_4 concentrations due to castration treatment ($P > 0.50$). However, concentrations of T_4 tended to be higher ($P = 0.07$) in Angus-sired

[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.

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calves compared with Charolais-sired calves (53 vs. 49 ± 2 ng/mL, respectively), and there was a day effect (P < 0.01; Fig.2) with concentrations on day 2 being greater than on other days.

There was a day by castration treatment interaction effect for cortisol (P < 0.01). Concentrations of cortisol were greater (P < 0.01) in CB calves than CW calves on days 0 and 2 (31 vs. 21 ± 1.9; and 35 vs. 20 ± 2.1 ng/mL, respectively; Fig. 3), but did not differ on days 4 and 9. Fisher et al. (1997) reported increased concentrations of plasma cortisol by surgical castration within 0 to 12 h in bull calves. We speculate that decreased concentrations of cortisol in CW calves may be due to an extended exposure to endogenous steroids in CW calves compared with CB calves. Charolais-sired calves had higher (P = 0.02) concentrations of cortisol than Angus-sired calves (24.94 vs 21.51 ng/mL)

There was an age at castration by day interaction (P = 0.03) for forward activities of LDH (Fig. 4). Forward activities of LDH were similar (P > 0.05) in CB calves compared with CW calves on days 0, 2, and 9; however, activities were increased in CW compared with CB calves on day 4 (8.5 vs. 7.5 ± 0.3 IU/mg of protein). Angus-sired calves had higher (P < 0.01) activities than Charolais-sired calves (7.94 vs 7.04 IU/mg of protein). Reverse activities of LDH did not differ between CB and CW calves (P > 0.50), but did differ (P < 0.01) by breed of sire and day of measurement. Charolais-sired calves had higher (P < 0.01) concentrations than Angus-sired calves (3.37 + 0.07 vs 2.88 + 0.08 IU/mg of protein). Concentrations on days 0 and 2 did not differ (P > 0.05), but were higher on day 4 (P < 0.05) and lower on day 9 (P < 0.05; Fig. 5). Results reported by May (2004) indicated that reverse activities of LDH were associated with lower quality grade in crossbred Brangus steers.

For concentrations of IGF-I, there was a sire breed by age of castration interaction (P < 0.01; Fig.6). Concentrations were higher for Angus-sired calves than for Charolais-sired calves for CW calves, but not for CB calves. There was also a day effect (P < 0.01; Fig. 7) for concentrations of IGF-I. Concentrations of IGF-I differed at all days (P < 0.05) decreasing from day 0 to day 4 and increasing again on day 9. It is possible that IGF-I has distinctive properties at different stages of growth, because genetic effects of the IGF-I are developmentally and physiologically regulated (Werner et al., 1994).

Implications

Stressors from weaning, castration, and (or) transportation alter the physiological responses of calves and may explain subsequent performance differences in beef cattle. Exposure to endogenous steroids may minimize stress associated with weaning, castration, and (or) transportation in newly weaned beef cattle.

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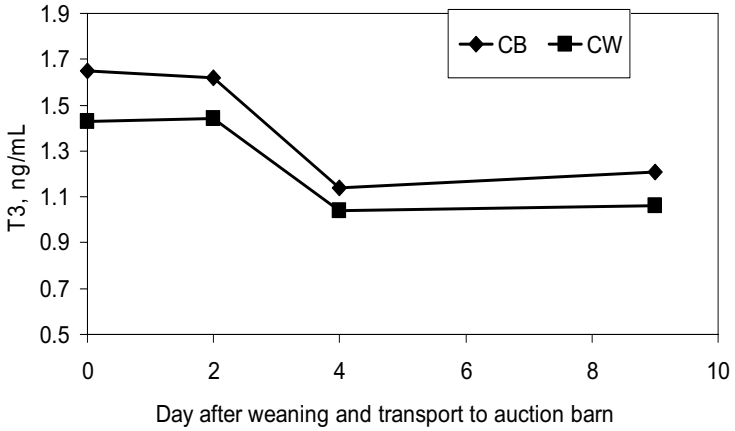

Fig. 1. Concentration of triiodothyronine (T_3) in calves castrated at birth (CB) or at weaning (CW). Age at castration effect (P < 0.01) and day effect (P < 0.01).

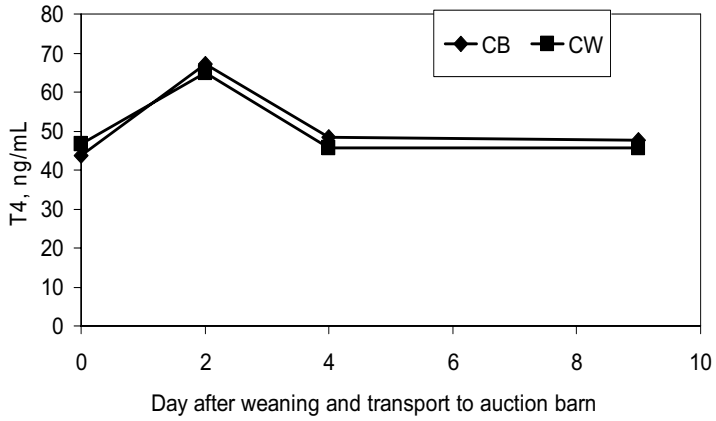

Fig. 2. Concentration of thyroxine (T_4) in calves castrated at birth (CB) or at weaning (CW). Day effect (P < 0.01).

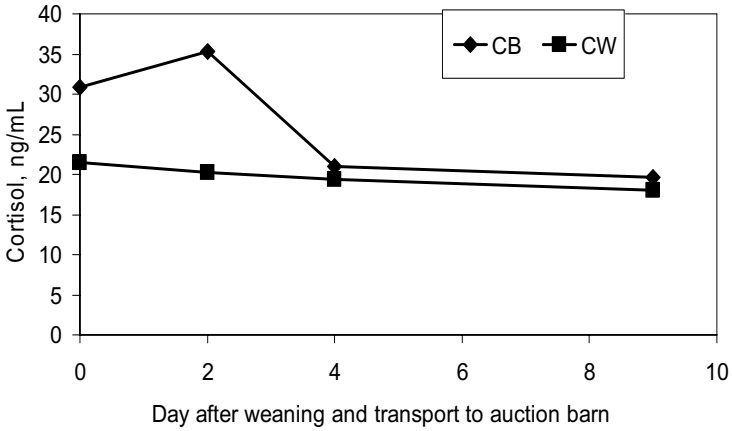

Fig. 3. Concentration of cortisol in calves castrated at birth (CB) or weaning (CW). Age at castration by day interaction (P < 0.01).

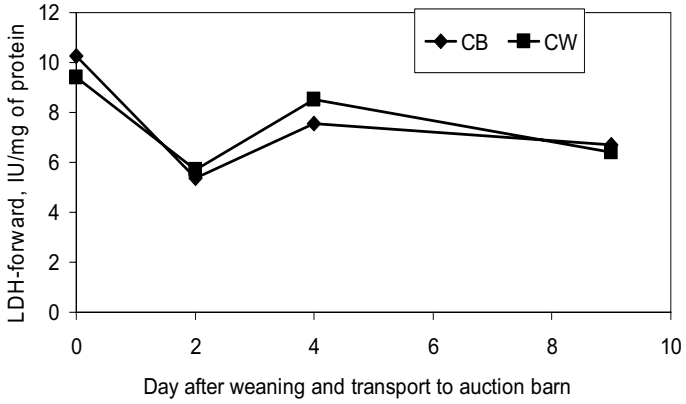

Fig. 4. Lactate dehydrogenase (LDH) forward activity in calves castrated at birth (CB) or weaning (CW). Age of castration by day interaction (P = 0.03).

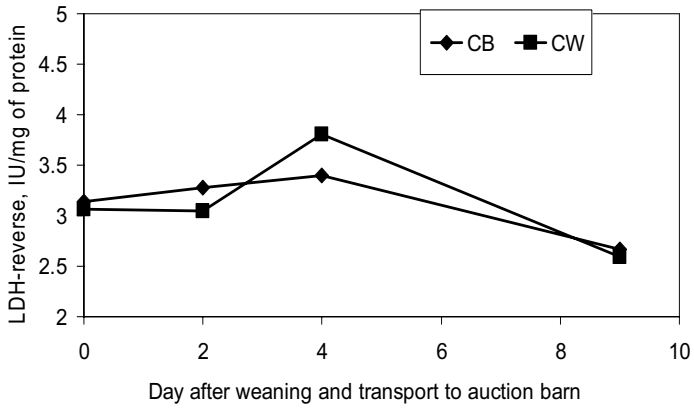

Fig. 5. Lactate dehydrogenase (LDH) reverse activity in calves castrated at birth (CB) or weaning (CW). Day effect (P < 0.01).

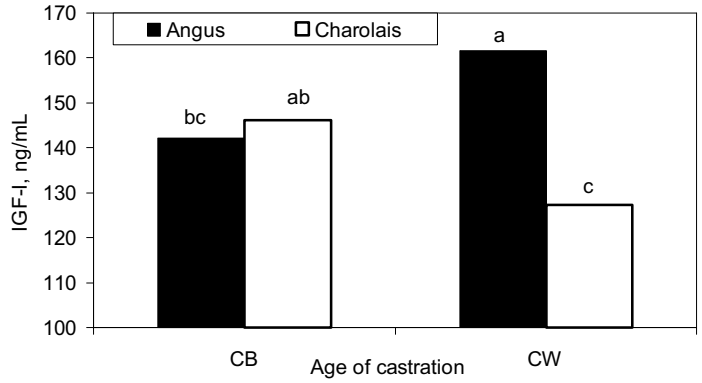

Fig. 6. Effects of sire breed and age at castration [birth (CB) or weaning (CW)] on concentration of insulin-like growth factor-I (IGF-I). Interaction (P < 0.01).

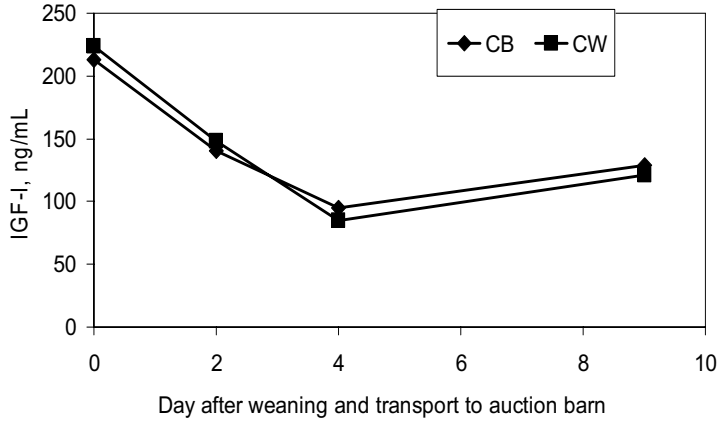

Fig. 7. Concentration of insulin-like growth factor-I (IGF-I) in calves castrated at birth (CB) or weaning (CW). Day effect (P < 0.01).

Effects of Selected Weather Factors Prior to Feeding on Feed Intake of Beef Bulls During Feedlot Performance Tests

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Story in Brief

Weather conditions prior to feeding were analyzed to identify and quantify effects on feed intake of performance-tested beef bulls. Feed intake data originated from bulls (n = 1,874) in University of Arkansas Cooperative Bull Tests at Fayetteville, Hope, and Monticello during 52 trials from 1978 to 1990. Bulls were given a 21-d adjustment period then individually full-fed a total mixed ration twice daily in the same stall for 140 d. Initial weight and age were recorded at start of each test with weights taken at 28-d intervals. Photoperiod and climate data were obtained from U.S. Naval Observatory (Washington, D.C.) and National Climatic Data Center (Asheville, N.C.), respectively. Variables included maximum temperature; rainfall; day length; and barometric pressure and relative humidity from 0400 to 0800 h and from 1100 to 1500 h. Data were pooled, divided into five 28-d periods with each period analyzed separately using all animals over all tests. Initial age and weight were included in principal components (PCs) regression as independent variables to adjust for initial animal differences. Feed intake was influenced ($P < 0.001$) by numerous PCs representing initial weight, initial age, and numerous climatic variables throughout the study. Coefficients for numerous weather-related factors ranged from positive to negative during the study period. No weather variable had a consistent effect throughout all 5 periods. Results indicated climate conditions prior to feeding influence feed intake throughout a feeding period and that the effects of these conditions may vary as the feedlot stay progresses.

Introduction

Weather conditions play a role in how cattle perform in the feedlot. In turn, cattle performance has the potential to impact profits of feedlots and ranchers that practice retained ownership. Knowledge of weather variables that play a major role on feed intake could better prepare feedlot personnel and producers for managing weather-related events. Various production strategies could allow for better management of weather-related events. North Dakota research (Anderson, 2004) indicated bedding feedlot pens through the winter can improve feedlot performance and carcass quality. Muddy conditions decrease feed intake, slow ADG, increase footrot problems, and negatively affect feed efficiency. Wet and muddy conditions may also increase the amount of tag or animal manure attached to the hide. Wet hair coats and difficulty reaching feed bunks associated with muddy conditions exacerbate effects of cold weather. Weather conditions prior to daily feeding times may be an important factor affecting feed intake. Therefore, the objective of our study was to analyze effects of selected climatic conditions immediately prior to feeding on feed intake of beef bulls during feedlot performance tests.

Experimental Procedures

Feed intake data originated from bulls (n = 1,874) evaluated in 52 individual 140-d University of Arkansas Cooperative Bull Tests at Fayetteville (one test per yr; average start date: Nov 19), Hope (two tests per yr; average start dates: Aug 18 and Feb 3), and Monticello (one test per year; average start date: Nov 5). On arrival at test stations, bulls were weighed, identified by tattoo or brand, and ear-tagged with a test identification number. Bulls were sorted into groups of 10 according to weight, and the groups randomly assigned to exercise lots. Bulls in each of the groups remained together throughout the test. Individual animals within groups were assigned to a feeding stall prior to the official test. Bulls were given a 21-d period prior to the 140-d feeding trial to lessen weaning stress and become adjusted to the new surroundings, feeding procedures, and diet. This preliminary period also served to somewhat reduce the effects of previous treatment (feeding and management). Each bull was provided with approximately 93 ft^2 under roof for shade and protection from inclement weather and approximately 159 ft^2 in an exercise lot. Lots were paved with each containing 10 adjacent individual feeding stalls.

Diet, Feeding, and Weighing Procedures. Each bull was allowed 2 h of eating time in the early morning (0800 to 1000 h) and late afternoon (1500 to 1700 h). Individual intake was measured by weighing feed and orts each day. A total mixed ration prepared commercially from the same formula was fed each year at each location (Table 1). When not in feeding stalls, bulls had access to fresh water and commercial mineral mixture containing calcium, phosphorus and trace-mineralized salt. Weights were taken at the beginning of each test and at 28-d intervals. All weights were partially shrunk because calves were weighed immediately before the morning feeding and had not been allowed access to water since the evening feeding of the previous day.

Photoperiod and Weather Data. Daily photoperiod information for Fayetteville, Hope, and Monticello was obtained from sunrise/sunset tables (U.S. Naval Observatory, Washington, D.C.). Weather data for the period Jan. 1977 to Dec. 1990 were obtained from the National Climatic Data Center (Asheville, N.C.). Weather variables used in the study included: maximum dry bulb temperature, rainfall, day length, and barometric pressure, and relative humidity from 0400 to 0800 h and from 1100 to 1500 h. The arithmetic mean intake and mean environmental variables by location of test and period of test are presented in Table 2.

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Statistical Analysis. Feed intake data from 52 feedlot performance tests at 3 Arkansas locations over 13 yr were pooled and divided into five 28-d periods beginning with the start of each test, with each period analyzed separately, using all animals over all tests. Because each location used different start dates, the 28-d periods were different calendar dates corresponding to the weigh dates of animals. Statistical analyses were performed using SAS Version 8.2 (SAS Institute, Inc., Cary, N.C.).

Variables considered in selecting the model to describe feed intake for each period were initial weight and age in days at start of test; maximum temperature; rainfall; day length; barometric pressure from 0400 to 0800 h and 1100 to 1500 h (BP0408 and BP1115, respectively); and relative humidity from 0400 to 0800 h and 1100 to 1500 h (RelH0408 and RelH1115, respectively). All variables were standardized to a mean zero and a variance of one. Time periods 0400 to 0800 and 1100 to 1500 represented 4-h windows immediately prior to morning and afternoon feeding periods, respectively. These periods were chosen to analyze effects of weather conditions immediately prior to feeding on feed intake.

Because the weather variables tended to be highly collinear, regression of feed intake on them would be problematic. To avoid these issues, principal components were calculated from the standardized original variables. A principal component is a linear combination of the original set of independent variables. There are as many principal components as there are original variables. As a group, they account for all of the variation in original variables and are mutually independent. Feed intake was then regressed on a subset of the principal component values for each animal using standard regression techniques. The number of principal components to include in the regression model was determined using the principal components regression (PCR) method within the partial least squares (PLS) procedure of SAS. The PRINCOMP procedure of SAS was used to generate eigenvalues (Table 3) and coefficients for independent variables (Table 4) within each principal component. Eigenvalues for each period on trial are presented in Table 3. Eigenvalues greater than 1.0 originating from standardized variables (mean 0 and standard deviation of 1) are considered to represent significant dimensions and assisted in determining the number of PCs worthy of further consideration. Six PCs had eigenvalues greater than 1.0 in all 5 periods while a seventh PC had eigenvalues greater than 1.0 in periods 2 through 4. For 7 PCs with eigenvalues greater than 1.0, initial weight, initial age and 5 weather variables (maximum temperature, rainfall, day length, barometric pressure and relative humidity) were dominant influences within these PCs and it is this group of independent variables that are discussed.

Results and Discussion

Seven PCs associated with initial weight, initial age and 5 selected weather variables had a strong influence ($P < 0.001$) on feed intake during each period (Table 3). Unlike weather variables, however, initial weight and initial age displayed positive coefficients throughout the 5 trial periods. Regression model estimates for initial weight for periods 1 through 5 were 51.36, 55.21, 52.98, 49.27 and 44.60, respectively. Model estimates for initial age for periods 1 through 5 were 9.58, 14.16, 13.63, 9.96 and 3.21, respectively. This is not surprising and agrees with numerous findings that older animals typically consume more feed per unit BW than younger ones. Assuming cattle started on feed at heavier BW are generally older, age-related effects on intake are partly responsible for the positive relationship between initial weight on feed and dry matter intake (DMI; NRC, 1987). The NRC (1984) and Fox et al. (1988) suggested a 10 percent increase in predicted DMI by cattle started on feed as yearlings vs. cattle started on feed as calves.

Final regression model estimates of 5 selected weather variables are presented in Table 4. It is interesting that none of the selected weather variables had a consistently positive or negative effect across all 5 periods; although, effect of maximum temperature tended to be negative, displaying negative coefficients in 4 of 5 periods. Period 4 was the only period in which maximum temperature had a positive coefficient. Coefficients for rainfall were positive in periods 2 and 4 while negative coefficients were present in periods 1, 3 and 5. Day length displayed a somewhat similar pattern with 2 negative (periods 1 and 4) and 3 positive coefficients (periods 2, 3, and 5).

In contrast to maximum temperature, the effect of barometric pressure tended to be positive both in the morning and in the afternoon. Coefficients for BP0408 were positive in periods 2 through 5 and negative only in period 1. Barometric pressure in the afternoon (BP1115) followed a similar pattern with positive coefficients in periods 2 through 5 and a negative coefficient in period 1. Relative humidity tended to be positive both in the morning and the afternoon. Coefficients for the morning relative humidity (RelH0408) were positive for period 1 and periods 3 through 5. The coefficient for period 2 was negative. The afternoon relative humidity (RelH1115) showed a somewhat different pattern with periods 1, 2, and 5 displaying positive coefficients and periods 3 and 4 having negative coefficients. During period 1, except for relative humidity, all coefficients are negative. This may be related, in part, to bulls still adjusting to new surroundings, diet and test conditions, even though adequate time for acclimation was allowed before starting the tests.

Indications are that several weather-related variables play a dominant role on feed intake of performance-tested cattle. These results agree with Hahn (1985) who indicated that humidity, precipitation, and wind speed are strong modifiers of temperature effects and that temperature alone is inadequate to represent weather impacts. In addition, the effect of any one particular weather factor may not be consistent over an entire feedlot stay (i.e., the effect may be positive at some points and negative at others during the overall feeding period). This makes weather effects on feedlot performance difficult, if not impossible, to accurately predict.

Implications

Results indicated feed intake of performance-tested beef cattle is strongly influenced by a number of weather factors prior to feeding times and the effect may be either positive or negative at various stages in the feeding period. Additional research is required to better understand weather effects on feed intake.

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

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

[a]1,000 IU/lb Vitamin A also added
[b]NRC, 1976
[c]NRC, 1996

Table 2. Arithmetic mean intake and mean environmental variables by location of test and period of test.

Variable[a]	Period of test				
Loc[b]	1	2	3	4	5
Feed intake (lb)					
Fay	558	605	637	671	686
Hope1	565	746	810	823	807
Hope2	558	705	771	793	784
Mont	542	632	666	689	722
Max temp (°F)					
Fay	70	64	65	73	81
Hope1	79	84	92	99	101
Hope2	101	97	88	80	77
Mont	82	77	77	78	83
BP0408 (in)					
Fay	30.1	30.2	30.1	30.0	30.0
Hope1	30.1	30.0	30.0	30.0	30.0
Hope2	30.0	30.1	30.1	30.1	30.2
Mont	30.1	30.1	30.2	30.1	30.0
RelH0408 (%)					
Fay	82	82	83	83	81
Hope1	79	77	79	84	84
Hope2	85	84	85	82	79
Mont	81	81	77	81	77
BP1115 (in)					
Fay	30.1	30.1	30.1	30.0	30.0
Hope1	30.1	30.0	30.0	30.0	30.0
Hope2	30.0	30.1	30.1	30.1	30.2
Mont	30.1	30.1	30.2	30.1	30.1
RH1115 (%)					
Fay	60	62	64	58	55
Hope1	57	52	52	59	55
Hope2	52	51	55	59	58
Mont	56	59	57	59	52
Rainfall (in)					
Fay	3.0	2.2	2.6	3.2	4.8
Hope1	4.1	3.0	5.6	4.6	3.7
Hope2	2.6	3.0	4.5	5.8	4.2
Mont	4.9	4.7	3.7	5.3	4.1
Day length (min)					
Fay	593	587	620	676	739
Hope1	666	723	780	829	858
Hope2	769	712	656	612	596
Mont	628	611	630	671	722

[a]BP0408 = barometric pressure from 0400 to 0800; RH0408 = relative humidity 0400 to 0800; BP1115 = barometric pressure from 1100 to 1500; RH1115 = relative humidity from 1100 to 1500.
[b]Fay = Fayetteville; Hope1 = Hope Feb test; Hope2 = Hope Aug test; Mont = Monticello

Table 3. Eigenvalues of the correlation matrix for each period on trial.

	Period on trial					
PC #	1	2	3	4	5	P-value
1	9.75	7.98	7.69	8.25	8.56	<0.001
2	2.82	3.21	2.88	2.79	3.30	<0.001
3	2.11	2.30	2.21	2.09	2.57	<0.001
4	1.56	1.97	2.07	1.78	1.99	<0.001
5	1.37	1.26	1.66	1.44	1.36	<0.001
6	1.17	1.25	1.37	1.23	1.13	<0.001
7	-	1.13	1.18	1.08	-	<0.001

Table 4. Final regression model estimates of selected major weather variables on feed intake during feedlot performance tests.

	Period on trial				
Weather variable[a]	1	2	3	4	5
	Parameter estimates				
Maximum temperature	-2.69	-8.66	-0.85	19.75	-8.60
Rainfall	-6.12	0.23	-2.96	4.89	-3.58
Day length	-3.14	39.41	12.89	-17.41	16.57
BP0408	-1.11	7.14	6.22	15.40	11.93
BP1115	-0.86	10.41	6.47	13.42	11.13
RelH0408	8.66	-14.59	0.00	3.94	3.73
RelH1115	4.87	9.24	-6.38	-10.90	0.42

[a]BP0408 = barometric pressure from 0400 to 0800; BP1115 = barometric pressure from 1100 to1500; RH0408 = relative humidity 0400 to 0800; RH1115 = relative humidity from 1100 to 1500.

Effect of Supplement Timing on Blood Measurements and Reproductive Performance in Beef Heifers Grazing Annual Ryegrass in the Spring

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Story in Brief

Forty Gelbvieh x Angus heifers (443 lb initial BW) were allocated randomly by weight to one of eight bermudagrass pastures overseeded with annual ryegrass to determine the impact of providing degradable carbohydrates at different intervals prior to breeding on conception rates, growth rates, and serum urea N concentrations. Two replicates received no supplement (C); 3 replicates each received 3.0 lb/head of supplement (32.5% ground corn, 32.5% cracked corn, 30% wheat middlings, and 5% liquid molasses) at approximately 0930 h daily beginning either 60 (60S) or 30 (30S) d prior to timed insemination (May 7). Heifers were weighed without prior removal from pasture and water at the initiation of the study and at approximately 28-day intervals. Blood samples were collected 7 d following the start of supplement and the day prior to timed insemination at 1230 and 1530 h. Available forage was measured and forage samples were clipped from each pasture on or immediately following weigh days. Total gains (avg 192 lb) did not differ ($P > 0.10$) among treatments. Serum urea nitrogen was lower ($P < 0.05$) from 60S than 30S on March 15, but not on April 13 or May 6. Serum glucose was not affected by treatment ($P > 0.94$), but was different among months ($P < 0.05$). Glucose increased between March and April ($P < 0.01$) and between April and May ($P < 0.05$). First-service conception rates were 33, 50, and 46% ($P > 0.10$) from C, 30S, and 60S, respectively. Overall conception rate from timed artificial insemination and natural service combined was 88.9, 79.6, and 61.5% for C, 30S, and 60S treatments, respectively, but was not different among treatments ($P > 0.14$). Preliminary results after yr 1 of the study suggests that timing supplementation strategically may alter blood measurements that have been previously shown to affect reproductive performance.

Introduction

Arkansas producers frequently take advantage of the ability of cattle to obtain a high percentage of their protein and energy needs from both grazed and harvested forages. Recent studies of forages in Arkansas found that 59% of harvested forage samples tested contained adequate protein for a lactating beef cow, while only 29% contained adequate TDN (Davis et al., 1999). This suggests that a high proportion of forages have a high ratio of protein to energy. In addition, in Arkansas and the southeastern United States, beef cows and beef heifers frequently graze high quality cool season forages and small grains that have very high protein content, particularly relative to available energy in the rumen, thereby creating a situation in which rumen ammonia concentration and thus serum ammonia and serum urea nitrogen concentration may become elevated. Previous work has shown that the ratio of protein to fermentable carbohydrates in forages consumed by ruminants has important effects on blood and milk urea nitrogen. Low concentrations of readily fermentable carbohydrates contribute to the release of ammonia in the rumen and increased serum urea nitrogen. Forage from well-managed cool-season pastures often contains more than 25% CP and 20% rapidly degradable protein. Numerous studies have shown that high concentrations of serum urea nitrogen affect reproductive function and cause decreased pregnancy rates (Chapa et al., 2001). We hypothesize that supplementation of heifers grazing high protein cool season forages with energy sources prior to breeding may alter the serum urea nitrogen concentrations and enhance the reproductive performance.

Experimental Procedures

This study was conducted at the University of Arkansas Division of Agriculture Southeast Research and Extension Center at Monticello.

Animals. Forty Gelbvieh x Angus heifers (442 lb initial BW) were allocated randomly by weight to one of eight groups and assigned randomly to one of eight pastures of bermudagrass (*Cynodon dactylon*) overseeded with annual ryegrass (*Lolium multiflorum*). Grazing began when adequate forage (1,700 to 2,000 lb/acre) was available. Available forage was measured on or immediately following weigh days. Forage samples were clipped from each pasture and composited into one large (400 g dry matter) sample for analysis of rumen degradable nitrogen in situ.

Treatments. Two replicates were provided no supplement feed (C). Three replicates were provided 3.0 lb/hd of a corn-based supplement feed (32.5% ground corn, 32.5% cracked corn, 30% wheat middlings, and 5% liquid molasses) 60 (60S) days prior to timed insemination (approximately May 5 to 10). Three replicates were provided 3.0 lb/hd with the same corn-based supplement 30 (30S) days prior to timed insemination. Supplement for the 60S treatment was discontinued at the time 30S was initiated. Each treatment group received supplement for a total of 30 days. Supplement was fed 7 d per week at approximately 1000 h daily to avoid disruption of the morning grazing period.

Weighing and Sampling Procedures. Heifers were weighed full at the initiation of the study and at approximately 28-day intervals. Blood samples for serum urea nitrogen (SUN) and glucose determination were obtained via jugular venipuncture 7 days following

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the start of supplement feeding and the day prior to timed insemination at 1230 h and 1530 h. Heifers were returned to their respective pasture following each blood sample collection.

Blood Assays. Serum urea nitrogen and serum glucose were determined on a Ciba-Corning 550 Express clinical analyzer (Global Medical Instrumentation, Ramsey, Minn.).

This paper will only focus on serum urea nitrogen and glucose concentrations in the months of March, April, May and June. It will examine the preliminary results of supplement effects and time effects on both variables, and will present preliminary results in regard to conception rates, to timed insemination (TAI), and overall pregnancy rates. The project will be conducted for a minimum of 2 years with the possibility of a third year if necessary. This paper discusses results of the first year.

Breeeding. A 6-day CIDR (controlled internal drug releasing device) protocol followed by timed artificial insemination similar to that described by Martinez et al. (2000) was used. Briefly, on April 28 CIDRs (Eazibreed, Pfizer, New York, N.Y.) were inserted and GnRH (gonadtrophin releasing hormone; 100 ug, IM.; Cystorelin; Merial; Duluth, Ga.) were given to all heifers. On May 4, CIDRs were removed and prostaglandin shots (25 mg IM; Lutalyse, Pfizer, New York, N.Y.) were given. On May 6, heifers were bled at 1230 h and 1530 h; then supplement was given to the 30S group following first bleeding. A second GnRH shot (100 ug) was given at approximately 4 pm on May 6, and all heifers were bred by timed artificial insemination (TAI) beginning at 900 h on May 7. At 10 d after TIA, heifers were moved to the Livestock and Forestry Branch Experiment Station at Batesville, and were exposed to a bull of proven fertility for an additional 50 d. Conception rate to TAI was determined by ultrasound at approximately 30 d post TAI, and overall pregnancy rate was determined at calving.

Statistical analysis. The MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) was used to evaluate all continuous response variables. Data for repeated blood samplings 7 days following introduction of supplement feeding were analyzed as repeated measurements. Differences in conception rate to TAI and overall pregnancy rates were analyzed by Chi Square test.

Results and Discussion

Total gains averaged 192 lb and did not differ ($P > 0.10$) among treatments. Average serum glucose and SUN by month and treatment are presented in Table 1. There was a treatment by month interaction ($P < 0.05$) for SUN. Serum urea nitrogen was lower ($P < 0.05$) from 60S than 30S on March 15, but not on April 13 or May 6. Serum glucose concentration did not differ among treatments ($P > 0.94$, Table 1), but was different among months ($P < 0.05$, Table 2). Glucose concentration was lowest in March and increased in April and May. Conception rate to TAI and overall pregnancy rates are depicted in Figure 1. First-service conception rates to TAI were 33, 50, and 46% ($P > 0.10$) from C, 30S, and 60S, respectively. Overall pregnancy rates (TAI and natural service combined) were 88.9, 79.6 and 61.5% for C, 30S, and 60S respectively, but were not different among treatments ($P > 0.14$). After one year of the study, it appears that timing supplementation strategically may alter blood measurements that have been shown to affect reproductive performance.

Implications

The preliminary results from this study indicate that serum urea nitrogen concentrations in all heifer groups grazing ryegrass in the early spring were higher than concentrations that have been shown to cause a decrease in pregnancy rates. The 60S group had moderately lower SUN concentrations than the other two treatment groups in the early sampling period, suggesting that supplementation of this group at 60 d prior to TAI was beneficial in reducing SUN concentrations. Numerical differences were observed in both conception rate to TAI and overall pregnancy rate, but these differences were not statistically significant. Replication of this study will be required to validate these findings.

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Table 1. Serum urea nitrogen, and serum glucose by treatment and month of sampling.

		Treatment[1]			
Item	Month	C	30S	60S	SE
SUN[2]	March	26.2[ab]	29.1[a]	25.2[b]	1.44
	April	13.0	11.7	13.8	0.98
	May	7.0	7.8	8.6	0.85
	Average[3]	15.4	16.2	15.9	1.09
GLU[2]	March	79.9	87.5	92.7	7.01
	April	102.3	95.8	95.7	5.27
	May	101.4	105.7	100.1	5.34
	Average[3]	94.5	96.3	96.2	5.03

[1]C = Control with no supplement, 30S = Supplemented for 30 d starting 30 d before timed AI, 60S = Supplement for 30 d starting 60 d before timed AI.
[2]SUN: Serum urea nitrogen (mg/dl); GLU: serum glucose (mg/dl).
[3]Averages are average serum urea nitrogen and serum glucose within each treatment (column).
[a,b,c] Means in a row with different superscripts differ ($P < 0.05$).

Table 2. Serum glucose concentration by month across treatments.

Month	GLU[1]	SE
March	86.7[a]	4.1
April	97.9[b]	3.1
May	102.4[b]	3.1

[1]GLU: Serum glucose (mg/dl)
[a,b,c]Means with different superscripts are different (P < 0.05).

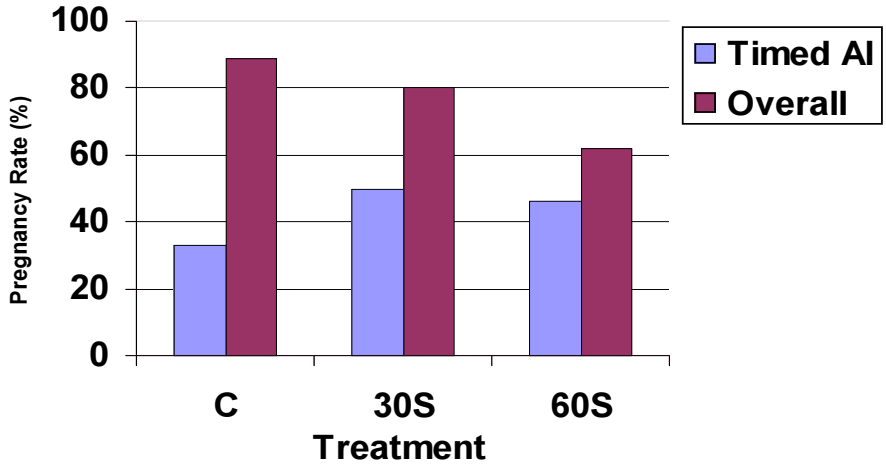

Fig. 1. Pregnancy rate to timed artificial insemination (TAI) and overall pregnancy rate by treatment (C = Control with no supplement, 30S = Supplemented for 30 d starting 30 d before TAI, 60S = Supplemented for 30 d starting 60 d before timed AI; conception rate to TAI was determined by ultrasound at approximately 30 d post AI and overall pregnancy rate was determined at calving).

Effects of Body Condition and Bovine Somatotropin on Endocrine and Follicular Dynamics of Postpartum Brahman-influenced Cows[1]

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Story in Brief

Influence of body condition (BC) and bovine somatotropin (bST) on number of follicles, diameter of largest follicle, and concentrations of growth hormone (GH), insulin-like growth factor-I (IGF-I), triiodothyronine (T_3), thyroxine, and prolactin were examined in postpartum Brahman-influenced cows. Cows (n = 99) were managed for low (BCS = 4.3 ± 0.1) or moderate (BCS = 6.1 ± 0.1) BC at parturition and treated with bST every 2 wk for 6 wk beginning at 35 d prior to breeding (d 0) or no bST (control). Blood was collected on d -35, -28, -21, -7, and 0. Cows received a controlled internal drug releasing (CIDR) device on d -7. On d 0, CIDR were removed, and cows received prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$). Ultrasound was performed on d 1 to determine diameter of largest follicle. Cows treated with bST had increased ($P < 0.05$) GH on d -28, -21, -7, and 0. Cows treated with bST in low BC had increased ($P < 0.05$) IGF-I vs. control-low BC cows on d -28, -21, -7, and 0. Prolactin and T_3 and were greater ($P < 0.05$) in moderate BC vs. low BC cows. Diameter of largest follicle was correlated with IGF-I ($r \geq 0.18$; $P \leq 0.08$), T_3 ($r \geq 0.17$, $P \leq 0.10$), and prolactin ($r \geq 0.20$, $P \leq 0.05$). Somatotropin increased IGF-I in low BC cows, and IGF-I was correlated with diameter of the largest follicle. Endocrine influences on follicular dynamics may be mediated by BC, GH, and (or) IGF-I.

Introduction

Growth hormone (GH) may serve as an endocrine mediator of nutritional status on reproduction (Hess et al., 2005) through direct or indirect mechanisms. A direct effect of GH is possible because the GH receptor is located within large cells of the corpus luteum of ruminants (Yuan and Lucy, 1996). An indirect effect of GH on ovarian function is through insulin-like growth factor-I (IGF-I) secretion (Lucy et al., 1999) that stimulates ovarian development (Armstrong and Benoit, 1996). Nutrient restriction uncouples the positive relationship of the GH-IGF-I axis with increased concentrations of GH and reduced IGF-I (Butler et al., 2003). Britt (1992) estimated 60 to 80 d for a bovine follicle to grow from the early pre-antral stage to the mature stage ready for ovulation. Thus, alterations of endocrine function affecting follicular development in cows would begin several weeks prior to ovulation. Effects of body condition score (BCS) and bovine somatotropin (bST) on ovarian and endocrine function in beef cattle remains to be elucidated. Objectives were to evaluate the effects of body condition (BC) and bST on number of small and large follicles, diameter of the largest follicle, and concentrations of GH, IGF-I, triiodothyronine (T_3), thyroxine (T_4), and prolactin in postpartum Brahman-influenced cows.

Experimental Procedures

Spring-calving crossbred (1/4 to 3/8) multiparous Brahman-influenced cows were managed to achieve low or moderate BC at parturition. Cows grazed stockpiled and spring-growth, endophyte-infected tall fescue (*Festuca arundinacea* Schreb.) pastures to obtain desired BC at a stocking rate of either 1 cow/0.8 acres (low BC) or 1 cow/2 acres (moderate BC) for approximately 162 d prior to initiation of treatment. Mean BCS of low (n = 50; mean BW = 931.0 ± 34.8 lb) and moderate (n = 49; mean BW = 1,168.9 ± 35.3 lb) BC cows was 4.3 ± 0.1 and 6.1 ± 0.1 (1 = emaciated to 9 = obese), respectively.

Beginning 32 ± 2 d postpartum, cows within each BC were randomly assigned to treatment with or without bST in a 2 x 2 factorial arrangement. Control cows received no treatment, and treated cows were administered bST (500 mg, s.c.; Posilac, St. Louis, Mo.) on d -35, -21, and -7. On d -7, all cows received a controlled internal drug-releasing (CIDR, 1.38 g of progesterone [P_4]; Pharmacia & Upjohn Co., Kalamazoo, Mich.) device. On d 0 (start of 70-d breeding season), CIDR were removed, and all cows received prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$, 25 mg, i.m.; Lutalyse, Pharmacia & Upjohn Co., Kalamazoo, Mich.). Calves were maintained with cows at all times.

Ultrasonography (Aloka SSD 500 V ultrasound scanner equipped with a 7.5 MHz linear array transrectal transducer; Aloka Co. Ltd., Wallingford, Conn.) was performed on d 1 after CIDR removal and $PGF_{2\alpha}$ to determine number of small (2 to 9 mm) and large (≥ 10 mm) follicles and diameter of the largest follicle. Blood samples were obtained from cows at bST treatment (d -35, -21, and -7) and d -28 and 0. Serum concentrations of hormones were determined in duplicate aliquots using radioimmunoassay procedures. Serum samples, collected on d -35, -28, and -21, were analyzed for concentrations of P_4 to determine the percentage of anestrous cows at the initiation of treatment. Cows were classified as either cyclic (concentrations of $P_4 \geq 1$ ng/mL in 2 consecutive weekly blood samples) or anestrus (concentrations of $P_4 < 1$ ng/mL in 2 consecutive weekly blood samples).

[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.

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Data were analyzed by ANOVA as a 2 x 2 factorial arrangement of treatments within a completely randomized design with cow as the experimental unit. Number of small and large follicles, and diameter of the largest follicle were analyzed by ANOVA utilizing the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). Comparisons of concentrations of GH, IGF-I, T_3, T_4, and prolactin on d -35, -28, -21, -7, and 0 were analyzed using the MIXED procedure of SAS for repeated measures. If the interaction of treatment x day, BC x day, or treatment x BC x day interaction was significant ($P < 0.05$), then mean separations were evaluated on each day using the PDIFF function of SAS. Pearson correlations were generated with the CORR procedure of SAS to evaluate relationships among the variables measured.

Results and Discussion

Eighty-eight percent (87/99) of cows were anestrous at the initiation of bST treatment. Number of small and large follicles 1 d following CIDR removal and $PGF_{2\alpha}$ was not influenced ($P > 0.10$) by treatment and (or) BC. Diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$ was influenced ($P = 0.06$) by a treatment x BC interaction. Diameter of the largest follicle was greater for control-moderate BC (17.5 ± 1.0 mm), bST-moderate BC (17.0 ± 1.0 mm), and bST-low BC (16.2 ± 1.0 mm) cows vs. control-low BC (13.0 ± 1.0 mm) cows. Our observations agree with Lucy (2000) that treatment with GH influences ovarian follicular development.

Serum concentrations of GH were influenced ($P = 0.01$) by a treatment x BC x day interaction (Fig. 1A). Following bST treatment, low and moderate BC cows had increased concentrations of GH with bST-low BC cows having greater concentrations of GH than bST-moderate BC cows. Administration of bST increases concentrations of GH in beef cattle (Bilby et al., 1999).

Serum concentrations of IGF-I were influenced ($P = 0.001$) by a treatment x BC x day interaction (Fig. 1B). On d -28, -21, -7, and 0, bST-moderate BC cows had greater concentrations of IGF-I compared with bST-low BC, control-moderate BC, and control-low BC cows. However, bST-low BC cows had greater concentrations of IGF-I than control-low BC cows on d -28, -21, -7, and 0, indicating the GH:IGF axis may have been re-coupled in low BC cows treated with bST. Recently, Lake et al. (2006) reported that beef cows with a BCS of 4 at parturition had increased GH and decreased IGF-I during early lactation compared with cows with a BCS of 6, suggesting that regulation of IGF by GH may have been uncoupled in thin cows. In the present study, treatment of low BC cows with bST prior to initiation of the breeding season increased concentrations of IGF-I, suggesting that regulation of IGF-I synthesis by GH may be influenced by bST administration in thin beef cows.

Serum concentrations of IGF-I at d -28 ($r = 0.18$; $P = 0.08$), -7 ($r = 0.22$; $P = 0.03$), and 0 ($r = 0.19$; $P = 0.07$) were positively correlated with the diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$. This may further explain why the diameter of the largest follicle of bST-low BC cows was similar to the diameter of the largest follicle of control-moderate BC and bST-moderate BC cows.

Serum concentrations of T_3 were influenced by a BC x day interaction ($P = 0.001$; Fig. 1C). On all sample dates, moderate BC cows had greater concentrations of T_3 compared with low BC cows. Serum concentrations of T_4 were influenced by a treatment x day ($P = 0.001$; Fig. 1D) and BC x day ($P = 0.001$; Fig. 1E) interaction. On d -28 and 0, bST-treated cows had increased concentrations of T_4 vs. control cows. Concentrations of T_4 were greater in moderate BC cows on d -28, -21, -7, and 0 vs. low BC cows. Direct effects of thyroid hormones on ovarian function are unclear. Spicer et al. (2001) reported direct stimulatory effects of T_3 and T_4 on thecal cell steroidogenesis which may result in increased estrogen production by the follicle. In the present study, concentrations of T_3 on d -35 ($r = 0.24$; $P = 0.02$), -28 ($r = 0.18$; $P = 0.09$), -21 ($r = 0.25$; $P = 0.01$), -7 ($r = 0.17$; $P = 0.10$), and 0 ($r = 0.23$; $P = 0.03$) were positively correlated with diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$. Further research is warranted to determine the relationship of thyroid hormones and ovarian function in cattle.

Serum concentrations of prolactin were influenced by a BC x day interaction ($P = 0.001$; Fig. 1F). On all sample dates, moderate BC cows had greater concentrations of prolactin compared with low BC cows. Similar to concentrations of T_3, concentrations of prolactin on d -35 ($r = 0.28$; $P = 0.01$), d -28 ($r = 0.25$; $P = 0.02$), -21 ($r = 0.29$; $P = 0.01$), -7 ($r = 0.28$; $P = 0.01$), and 0 ($r = 0.20$; $P = 0.06$) were positively correlated with the diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$. Prolactin is important for the maintenance and secretory activity of the corpus luteum in rodents (Freeman et al., 2000); less is known of prolactin effects on follicular dynamics in beef cattle. To our knowledge, this is the first report describing relationships among concentrations of prolactin prior to breeding and diameter of the largest follicle following CIDR-$PGF_{2\alpha}$ in beef cattle.

Implications

Increased concentrations of GH and IGF-I of thin cows suggests the nutritional and endocrine status prior to breeding may be influenced by treatment with bST. The positive relationships among IGF-I, T_3, and prolactin, and diameter of the largest follicle may be components of the complex hormonal milieu mediating nutritional effects on ovarian function in cattle.

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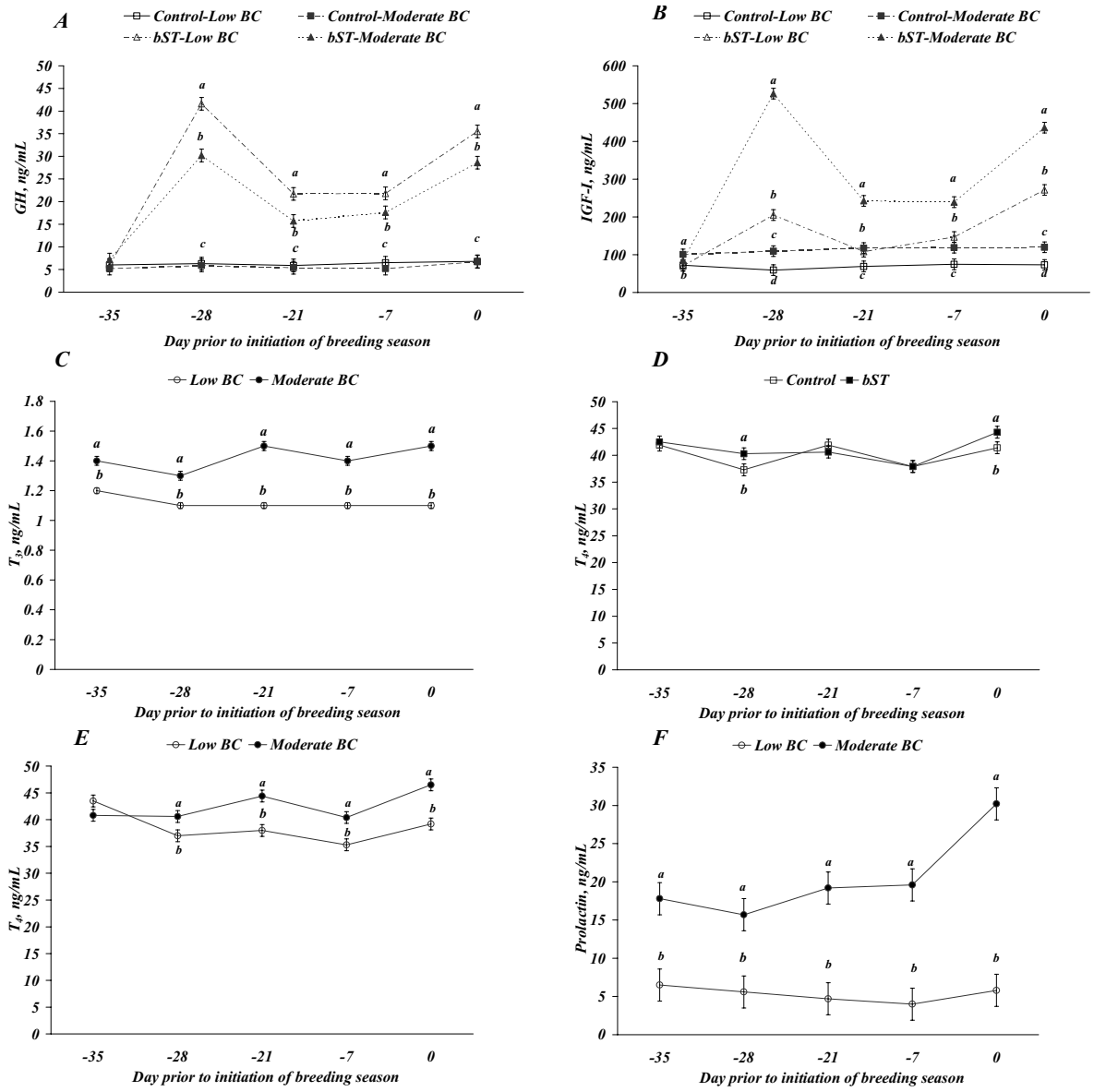

Fig. 1. Serum concentrations of growth hormone (GH), insulin-like growth factor-I (IGF-I), triiodothyronine (T_3), thyroxine (T_4), and prolactin of low (BCS = 4.2 ± 0.1) and moderate (BCS = 6.1 ± 0.1) body condition (BC) Brahman-influenced cows treated with or without bovine somatotropin (bST). Cows were control (no bST) or treated with bST every 2 wk for 6 wk prior to the initiation of the breeding season (d 0). Serum was collected at bST treatment (d -35, -21, and -7) and on d -28 and 0.
[a,b,c,d]Means without common superscripts differ (P < 0.05).

Effects of Body Condition and Bovine Somatotropin on Estrus and Reproductive Performance of Postpartum Brahman-influenced Beef Cows[1]

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

Story in Brief

Influence of body condition (BC) and bovine somatotropin (bST) on estrous characteristics and fertility were examined in postpartum Brahman-influenced cows. Cows (n = 99) were managed for low (BCS = 4.3 ± 0.1) or moderate (BCS = 6.1 ± 0.1) BC at parturition and treated with bST every 2 wk for 6 wk beginning 35 d prior to breeding (d 0) or no bST (control). Cows received a controlled internal drug-releasing (CIDR) device containing progesterone on d -7. On d 0, CIDR were removed, and cows received prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$). Estrous behavior was detected by radiotelemetry. Ultrasonography was performed on d 70 to determine pregnancy. First-service conception (56 vs. 26%) and pregnancy (30 vs. 12%) rates were increased ($P < 0.05$) in bST-treated vs. control cows during the first 3 d of the breeding season. During the first 30 d of the breeding season, first-service conception rate was greater ($P = 0.01$) for bST-moderate BC (67%) vs. control-moderate BC (21%) cows. Interval to conception was lower ($P = 0.04$) for bST-moderate BC vs. control-moderate BC cows. Cumulative 70-d breeding season pregnancy rate was lower ($P = 0.02$) for low BC (50%) vs. moderate BC (73%) cows. Percentage of cows detected in estrus was decreased ($P = 0.05$) for cows in low BC compared with moderate BC cows with cows in low BC having decreased ($P < 0.01$) intensity of estrus. Body condition may influence estrous behavior in postpartum Brahman-influenced cows, and bST may increase reproductive performance of thin, Brahman-influenced cows.

Introduction

Energy intake regulates ovarian function in beef cattle (Wettemann et al., 2003), and greater BCS at calving improves reproductive performance of beef cows (Lake et al., 2005). Growth hormone (GH) serves as an endocrine mediator of nutritional status on reproduction (Hess et al., 2005), and treatment with bovine somatotropin (bST) increases insulin-like growth factor-I (IGF-I) in beef cattle (Bilby et al., 1999). Nutritionally induced changes in GH and IGF-I may partially explain the infertility and anestrus in undernourished cattle (Chase et al., 1998). Nutrient restriction uncouples the positive relationship of the GH-IGF-I axis with increased concentrations of GH and reduced IGF-I (Butler et al., 2003); IGF-I may be involved in informing the reproductive axis of the nutritional status in cattle (Meikle et al., 2004). Effects of bST on reproductive performance of dairy cattle have been reported (Santos et al., 2004); however, less is known of the effects of body condition (BC) and bST on estrous characteristics and reproductive performance in beef cattle, especially Brahman-influenced cows. Objectives were to evaluate the effects of BC and bST on estrous characteristics and reproductive performance in postpartum Brahman-influenced cows.

Experimental Procedures

All cows were managed as described in a companion report (Flores et al., 2006). Spring-calving crossbred (1/4 to 3/8) multiparous Brahman-influenced cows were managed to achieve low or moderate BC at parturition. Cows grazed stockpiled and spring-growth, endophyte-infected tall fescue (*Festuca arundinacea* Schreb.) pastures to obtain desired BC at a stocking rate of either 1 cow/0.8 acres (low BC) or 1 cow/2 acres (moderate BC) for approximately 162 d prior to initiation of treatment. Mean BCS of low (n = 50; mean BW = 931.0 ± 34.8 lb) and moderate (n = 49; mean BW = 1,168.9 ± 35.3 lb) BC cows was 4.3 ± 0.1 and 6.1 ± 0.1 (1 = emaciated to 9 = obese), respectively.

Beginning 32 ± 2 d postpartum, cows within each BC were randomly assigned to treatment with or without bST in a 2 x 2 factorial arrangement. Control cows received no treatment, and treated cows were administered bST (500 mg, s.c.; Posilac, St. Louis, Mo.) on d -35, -21, and -7. On d -7, estrus was synchronized utilizing CIDR-$PGF_{2\alpha}$ as previously described (Flores et al., 2006). On d 0 (start of 70-d breeding season), all cows were fitted with a radiotelemetry (Heatwatch, HW; DDx Inc., Denver, Colo.) transmitter, and estrous activity was recorded during the first 30 d of the 70-d breeding season. Cows that lost their HW transmitter following initiation of estrus were removed from the statistical analyses for synchronization rate and estrous characteristics but were included in analyses determining the proportion of cows in estrus and interval to estrus after treatment. Cows were exposed to bulls (1 bull/21 cows) during a 70-d breeding season. Ultrasound (Aloka SSD 500 V ultrasound scanner equipped with a 7.5 MHz linear array transrectal transducer; Aloka Co. Ltd., Wallingford, Conn.) was performed on d 70 to determine pregnancy.

Synchronization rate was defined as the number of cows that exhibited behavioral estrus as detected by HW during the first 3 d of the breeding season following treatment, divided by the total number of cows in each group. First service conception rate was defined as the number of cows detected in estrus via HW that became pregnant, divided by the total number of cows with a HW-

[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.

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detected estrus during the first 3 and 30 d of the breeding season. Date of first service conception was determined by subtracting 285 d from calf birthdate. Pregnancy rate was defined as the number of cows that became pregnant during the first 3 d and the entire 70-d breeding season divided by the total number of cows in each group.

Data were analyzed by ANOVA as a 2 x 2 factorial arrangement of treatments within a completely randomized design and cow being the experimental unit. The effect of treatment, BC, and the interaction on mean interval to estrus, duration of estrus, number of mounts received, quiescence between mounts, and interval to conception was analyzed with the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Categorical data were analyzed with the CATMOD procedure of SAS.

Results and Discussion

Percentage Detected in Estrus and Interval to Estrus. Treatment and (or) BC did not influence ($P > 0.10$) the percentage of cows detected in estrus during the first 3 d of the breeding season (Table 1). Cows in estrus during the first 3 d of the breeding season were assumed to be synchronized in response to CIDR-$PGF_{2\alpha}$ treatment. Synchronization rate averaged 51% (50/99). During the first 30 d of the breeding season, BC influenced ($P = 0.05$) the percentage of cows detected in estrus (Table 2). A greater percentage of moderate BC cows (82%) were detected in estrus during the first 30 d of the breeding season compared with low BC cows (64%). Interval to first detected estrus was not ($P > 0.10$) influenced by treatment and (or) BC and mean interval to first detected estrus was 7.0 ± 2.0 d.

Estrous Characteristics. Mean duration of estrus was not influenced by treatment and (or) BC ($P > 0.10$) and duration of estrus was 6.4 ± 1.2 h. However, cows in low BC had decreased ($P = 0.01$) mean number of mounts received (11.6 ± 4.1 vs. 22.0 ± 3.6) and increased ($P = 0.001$) mean quiescence between mounts (0.8 ± 0.1 vs. 0.4 ± 0.1 h) than moderate BC cows during estrus.

First-service Conception and Pregnancy Rates and Interval to Conception. First-service conception rate during the first 3 d of the breeding season was influenced ($P = 0.02$) by treatment (Table 1). Low (43%) and moderate (69%) BC cows treated with bST had greater first-service conception rates than low (40%) and moderate (15%) BC control cows. Similarly, pregnancy rate during the first 3 d of the breeding season was influenced ($P = 0.04$) by treatment (Table 1). Pregnancy rates were greater for moderate (36%) and low (24%) BC cows treated with bST than low (16%) or moderate (8%) BC control cows during the first 3 d of the breeding season. The improved fertility of low and moderate BC cows treated with bST may be attributed to enhanced follicular growth (Flores et al., 2006). Furthermore, concentrations of GH and IGF-I were increased in bST-treated cows, suggesting the GH:IGF-I axis was re-coupled in low BC cows treated with bST (Flores et al., 2006). An interaction ($P = 0.01$) between treatment and BC was detected for first-service conception rate during the first 30 d of the breeding season (Table 2). First-service conception rates were greater for bST-moderate BC cows (67%) compared with control-moderate BC cows (21%), with no differences among bST-low BC cows (38%) and control-low BC cows (38%). More ($P = 0.02$) cows in moderate BC became pregnant (73%) than cows in low BC (50%) during the breeding season. Interval to conception following CIDR-$PGF_{2\alpha}$ was influenced by a treatment x BC interaction ($P = 0.04$). Interval to conception was lower for bST-moderate BC (12.0 ± 3.1 d), control-low BC (16.8 ± 3.7 d), and bST-control (17.1 ± 4.0 d) cows, compared with moderate BC-control (25.9 ± 3.0 d) cows.

Implications

Body condition influenced estrous behavior in postpartum Brahman-influenced cows, and bST increased reproductive performance of thin, Brahman-influenced cows. Treatment of low and moderate BC Brahman-influenced cows with bST prior to initiation of the breeding season may aid in maintaining a yearly calving interval.

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Table 1. Influence of body condition (BC) and bovine somatotropin (bST) on synchronization rate, first-service conception rate, and pregnancy rate of Brahman-influenced cows during the first 3 d of the breeding season[1].

	Treatment						
	Control		bST		P value		
Variables	Low BC[2]	Moderate BC[3]	Low BC	Moderate BC	Trt[4]	BC	Trt x BC
No. of cows	25	24	25	25	-	-	-
Synchronization rate[5], %	40 (10/25)	54 (13/24)	56 (14/25)	52 (13/25)	0.31	0.29	0.13
First-service conception rate[5], %	40 (4/10)	15 (2/13)	43 (6/14)	69 (9/13)	0.02	0.33	0.16
Pregnancy rate[5], %	16 (4/25)	8 (2/24)	24 (6/25)	36 (9/25)	0.04	0.88	0.24

[1]Cows were treated with or without bST (500 mg s.q.) every 2 wk for 6 wk prior to the initiation of the breeding season.
[2]Low BC (BCS = 4.2 ± 0.1)
[3]Moderate BC (BCS = 6.1 ± 0.1)
[4]Trt = Control (no bST) vs. bST
[5]Number of observations in parentheses

Table 2. Influence of body condition (BC) and bovine somatotropin (bST) on the percentage of Brahman-influenced cows detected in estrus, cumulative first-service conception rate during the first 30 d of the breeding season, and cumulative 70-d breeding season pregnancy rate[1].

	Treatment						
	Control		bST		P value		
Variables	Low BC[2]	Moderate BC[3]	Low BC	Moderate BC	Trt[4]	BC	Trt x BC
No. of cows	25	24	25	25	-	-	-
Estrus[5], %	64 (16/25)	79 (19/24)	64 (16/25)	84 (21/25)	0.73	0.05	0.73
First-service conception rate[5], %	38 (6/16)	21 (4/19)	38 (6/16)	67 (14/21)	0.02	0.75	0.01
Pregnancy rate[5], %	48 (12/25)	79 (19/24)	52 (13/25)	68 (17/25)	0.63	0.02	0.39

[1]Cows were treated with or without bST (500 mg s.q.) every 2 wk for 6 wk prior to the initiation of the breeding season.
[2]Low BC (BCS = 4.2 ± 0.1)
[3]Moderate BC (BCS = 6.1 ± 0.1)
[4]Trt = Control (no bST) vs. bST
[5]Number of observations in parentheses

Associations Between Cattle Breed and Heat Shock Protein 70 Gene[1]

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Story in Brief

Heat shock proteins (HSPs) are induced by various stressors such as heat, cold, toxins, and oxygen deprivation. Our objective was to determine the genetic diversity in a segment of the *HSP-70* gene of cattle. Genomic DNA was collected from 157 cows. The cows were *Bos taurus* (Angus; n = 42), *Bos indicus* (Brahman; n = 41), and *Bos taurus*/*Bos indicus* crosses (n = 74). Specific primers for the bovine *HSP-70* were used for amplification of a 523 base segment using polymerase chain reaction. The amplified gene products were sequenced, and 8 single nucleotide polymorphisms (SNPs) were identified. The SNPs were located at DNA base position 1851 (n = 7; 4.5%), 1899 (n = 1; 0.64%), 1902 (n = 6; 3.8%), 1917 (n = 6; 3.8%), 1926 (n = 6; 3.8%), 2033 (n = 22; 14%), 2087 (n = 10; 6.4%), and 2098 (n = 6; 3.8%). Two SNPs resulted in altered peptide sequences, also known as mis-sense mutations (1926, aspartic acid to glutamic acid, and 2033, glycine to alanine). The occurrence of SNP 2033 was not affected ($P > 0.5$) by breed. Brahman ancestry tended to be related ($P < 0.11$) to the presence of SNPs at positions 1902, 1917, 1926, 2087, and 2098; whereas, SNP 1851 tended to be associated ($P < 0.11$) with Angus. These results indicate that the *HSP-70* gene in cattle is polymorphic, and most of the SNPs identified follow breed lineages.

Introduction

Heat shock proteins (HSPs) are present in all cells of the body but increase in numbers when an animal is subjected to various stressors such as heat, cold, and oxygen deprivation. Heat shock proteins play vital roles in normal cell function by directing other proteins into their right shape, which is essential for function, and then escorting them to the right place at the right time. It has been found in numerous studies that tropically adapted breeds of cattle such as Brahman perform better than some temperate breeds such as Angus in warmer climates. Due to the role of heat shock proteins in the protection of cells against heat stress, and the apparent ability of some breeds to function and perform better than others in heat stress conditions, the possibility of a direct connection between the two is plausible. Therefore, the objective of this study was to determine the genetic diversity of an *HSP-70* gene segment of cattle, and determine if the polymorphisms were associated with breed composition.

Experimental Procedures

Animals. The cows were part of a long-term breeding program at the USDA-ARS Dale Bumpers Small Farms Research Center. Blood samples were collected and the plasma was harvested. Buffy coats were then stored at -112°F to await genomic analysis. Genetic data was successfully collected on 157 cows. The breed composition of the cows and the number of each breed were as follows: *Bos taurus* (Angus; n = 42), *Bos indicus* (Brahman; n = 41), and *Bos taurus*/*Bos indicus* crosses (n = 74). The crossbred cows were distributed as follows: 38 Angus sired Brahman dams, 36 Brahman sired Angus dams.

Polymerase Chain Reaction (PCR). A Peltier thermal cycler 225 (MJ Research, Waltham, Mass.) was used for amplification. The thermocycler conditions began with a denaturation temperature of 201°F for 2 minutes and then cycled at 201°F for 30 seconds, 131°F for one minute and 154°F for 1 minute. After cycling 35 times, a final extension occurred at 154°F for 10 minutes. Samples were held at 46°F until sequenced.

Primers. Three primers were designed for PCR amplification and sequencing (Sigma-Genosys, Saint Louis, Mo.). Those primers were based on the National Center for Biotechnology Information (NCBI) sequence accession number U09861 of *Bos taurus HSP-70*. Primers HSP1778F (CGCTGGAGTCGTACGCCTTC) and HSP2326R (CTTGGAAGTAAACAGAAACGGG) were used for amplification of a 548 base pair fragment from positions 1778 to 2326. After amplification, HSP1803F (GAAGAGCGCCGTGGAGGATG) and HSP2326R were used to sequence a 523 base pair fragment within the amplified region from positions 1803 to 2326.

DNA Sequencing. Sequencing was performed by the DNA Core Lab using either the 3100 Genetic Analyzer (Applied Biosystems, Foster City, Calif.) or the CEQ 8000 Genetic Analysis System (Beckman Coulter, Fullerton, Calif.). The primers used for sequencing were the 1803F and 2326R primers. Sequences were analyzed using the DNA Star software.

Statistical Analysis. Breed associations with each single nucleotide polymorphism (SNP) was determined using Chi-square analyses.

Results and Discussion

The bovine *HSP-70* gene was amplified from base 1778 to base 2326. By comparing the region of interest from our samples to the NCBI published sequence (accession number U09861), 8 SNPs

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were identified with 4 of the 8 resulting in an altered peptide sequence. The SNPs were identified at the following base positions on the *HSP-70* gene: 1851, 1899, 1902, 1917, 1926, 2033, 2087, and 2098.

The frequency and breed composition of each of the 8 SNPs are summarized in Table 1. The base change, location, and effect on the amino acid are summarized in Table 2. The presence of SNP 2033 was not affected ($P > 0.5$) by breed. Brahman ancestry tended to be related ($P < 0.11$) to the occurrence of SNPs at positions 1902, 1917, 1926, 2087, and 2098; whereas, the presence of SNP 1851 tended to be associated ($P < 0.11$) with Angus lineage.

The SNP at position 1851 was found in 7 cows, 4.5% of the total population. Two were Angus purebred and 5 were Brahman-Angus crosses. The base change was from guanine to adenine and displayed the "wobble" effect because it was located in the third position of one of the codons for alanine and resulted in a silent mutation. Only one Brahman/Angus cow, 0.64% of the population, exhibited a SNP at position 1899. Like SNP 1851 the base change was from guanine to adenine in the last base of a codon for leucine and resulted in no amino acid change.

One Angus/Brahman cross, 1 Brahman/Angus cross, and 4 Brahman purebreds, 3.8% of the population, exhibited the same 4 SNP's. A SNP at base 1902 resulted in a base change from cytosine to thymine which occurred in the third position of aspartic acid's codon. A SNP at base 1917 resulted in a guanine to thymine which occurred in the third position of an alanine codon. At base 1926 the SNP resulted in a cytosine to guanine change in the third position of an aspartic acid codon and resulted in an amino acid change to glutamic acid. A base change from thymine to adenine occurred at position 2098. The base change occurred in the first position of the codon would have resulted in an amino acid change of leucine to methionine but occurs after the stop codon.

An SNP at the 2033 position occurred in 22 cows, 14% of the total population, 8 purebred Angus, 5 Angus/Brahman crosses, 3 Brahman/Angus crosses, and 6 purebred Brahman. The base change occurred in the second codon of glycine, guanine to cytosine, and resulted in an amino acid change to alanine. One animal (3002) was found to be homozygous (CC) for the SNP at this position. This was the only animal and only position found to display a homozygous SNP.

An SNP at 2087 occurred in 10 cows, 6.4% of the population. Two of the animals were Angus/Brahman crosses, 2 were Brahman/Angus crosses, and 6 were purebred Brahman. The base changed is cytosine to guanine. The change takes place at the second position of the codon and would have resulted in a change of serine to cysteine. However, the polymorphism occurred after the stop codon which begins at position 2079.

The SNP's at positions 1902, 1917, 1926, and 2098 appeared to be related. If one was present, they all were present suggesting genetic linkage. That was observed in the genotype of 6 cows; 4 purebred Brahman, 1 Brahman/Angus, and 1 Angus Brahman. The primary objective of this study was to determine the genetic diversity, if any, of the *HSP-70* gene between 2 different species/subspecies of bovine. Our results indicate that the bovine *HSP-70* is polymorphic and breed linage impacts the occurrence of those genetic differences.

Implications

The national database sequence that these samples were compared to represented the sequence for a *Bos taurus* breed; therefore, the SNPs associated with our *Bos indicus* samples may represent subtle species differences in genetic coding and possibly give rise to future advances in the understanding of the ability of one breed to perform better in heat stress situations than another breed within a genus. Genomic DNA evaluations allow producers to evaluate the genetic potential of animals and, in the future, will increase the accuracy of selecting breeding stock.

Table 1. Effects of breed composition[1] on single nucleotide polymorphisms (SNP) occurrence.

SNP	Sequence position	Frequency[2]	Breed			
			AA	AB	BA	BB
1	1851	0.045	2	0	5	0
2	1899	0.006	0	0	1	0
3	1902	0.038	0	1	1	4
4	1917	0.038	0	1	1	4
5	1926	0.038	0	1	1	4
6	2033	0.140	8	5	3	6
7	2087	0.064	0	2	2	6
8	2098	0.038	0	1	1	4

[1] The number of animals with the detected SNP by breed; AA-purebred Angus; AB-Angus sire; BA-Angus dam; BB-purebred Brahman

[2] Percentage of cows with that SNP in our population of 157 cows

Table 2. Relationship of single nucleotide polymorphisms (SNP) to potential codon position and translational products.

SNP	Base change[1]	Codon position[2]	Amino acid change[3]
1 (1851)	G to A	3	Ala (no change)
2 (1899)	G to A	3	Leu (no change)
3 (1902)	C to T	3	Asp (no change)
4 (1917)	G to T	3	Ala (no change)
5 (1926)	C to G	3	Asp to Glu
6 (2033)	G to C	2	Gly to Ala
7 (2087)	C to G	-	Post-translational
8 (2098)	T to A	-	Post-translational

[1] G-Guanine; A-Adenine; C-Cytosine; T-Thymine

[2] 1-first base in codon; 2-second base in codon; 3-third base in codon

[3] Ala-alanine; Asp-aspartic acid; Glu-glutamic acid; Gly-glycine; Leu-leucine