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# Arkansas Animal Science Department Report 2003

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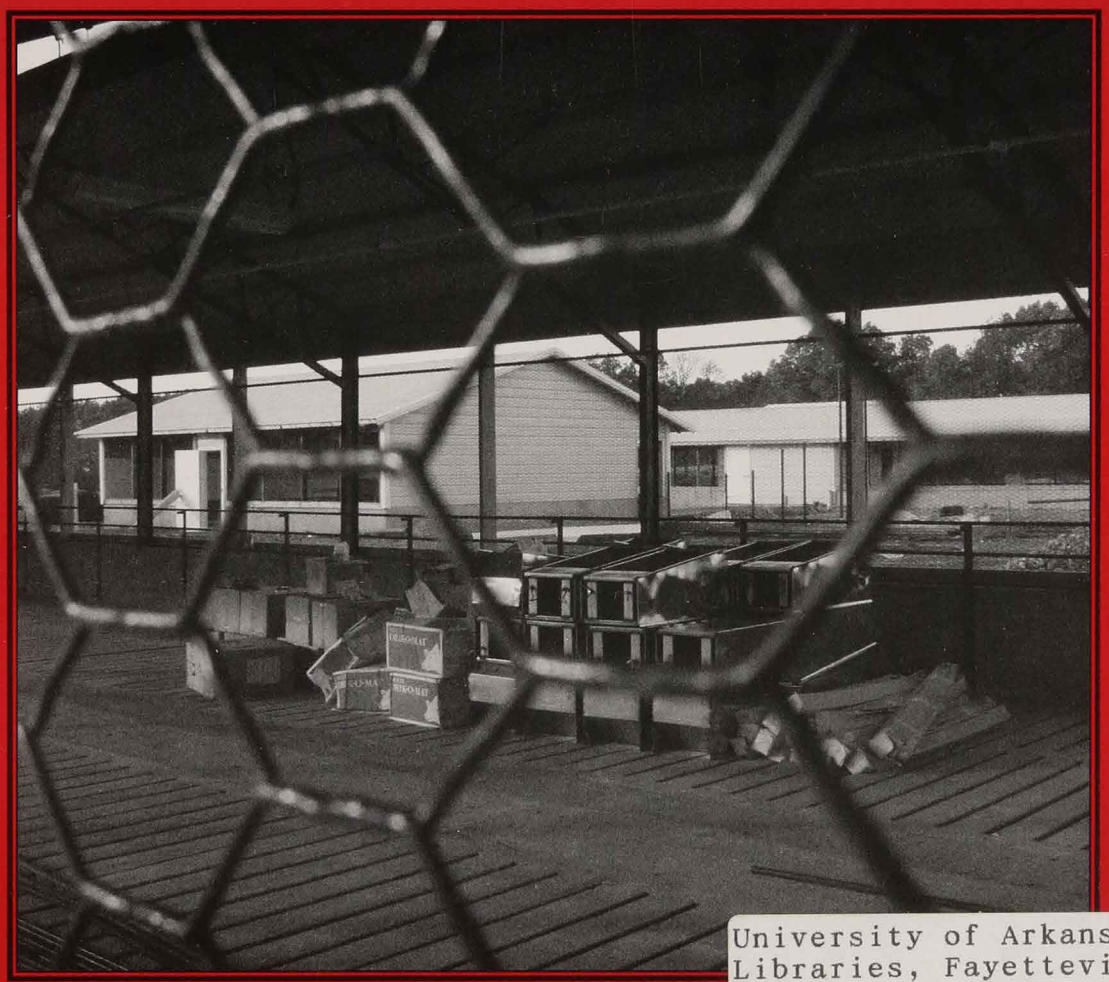
# *Arkansas*
# Animal Science
## Department Report • 2003



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Cover photo by Fred Miller of the new Department of Animal Science Wean-to-Finish Swine Unit (Savoy, Ark.), which contains both state-of-the-art and experimental CAFO waste-management technologies

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# ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT 2003

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# INTRODUCTION

The faculty and staff of the Animal Science Program are pleased to present the sixth edition of the Arkansas Animal Science Report. As with virtually all programs in the country, budget constraints presented serious challenges to teaching, research, and extension programming. However, the faculty and staff responded with innovation, good management, and hard work to maintain a productive program designed to benefit the students of the University and the citizens of the state. We are committed to remaining faithful to our Land-Grant mission. A sincere thank you is owed to Dr. Zelpha Johnson and Dr. Wayne Kellogg for editing this publication.

We are proud that *Meat and Poultry* magazine ranked the animal and poultry programs at the University of Arkansas among the top four in the United States for 2003. This is a tribute to the dedicated and talented faculty in the Departments of Animal Science, Poultry Science, and Food Science and to their high level of cooperation.

We want to commend Laurie Harris, departmental secretary, for remodeling our departmental website. The new version has a modern look and is much more visually attractive, informative, and user friendly. The address is http://www.uark.edu/depts/animals/.

The Animal Science Program uses a multi-disciplinary approach to collaboratively address many of the most challenging issues facing the Arkansas livestock industry. The extension programs provide a critical bridge between evolving research and issues faced by Arkansas producers. Research-based solutions in the areas of beef, dairy, and horse production; forage and grazing management; waste management and many other livestock-related areas were delivered to our industry stakeholders. On any given day, you will find Department of Animal Science extension faculty taking forage samples, weighing cattle, presenting educational programs, serving on state, regional and national committees, teaching the youth of Arkansas, or visiting a ranch to help solve a problem.

Finally, we want to thank the many supporters of our teaching, research, and extension programs. Whether providing grants to fund research or funds for scholarships, educational programs, extension programs, facilities or donating horses and livestock, these friends are essential to maintaining a quality educational program. We thank each and every one of you on behalf of our faculty, staff, students, and clientele.

Sincerely,
**Keith Lusby**
Department Head

**Tom Troxel**
Section Leader

# INTERPRETING STATISTICS

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

Most data will be presented as means or averages of a specific group (usually the treatment). Statements of probability that treatment means differ will be found in most papers in this publication, in tables as well as in the text. These will look like ($P < 0.05$); ($P < 0.01$); or ($P < 0.001$) and mean that the probability (P) that any two treatment means differ entirely due to chance is less than 5, 1, or .1%, respectively. Using the example of $P < 0.05$, there is less than a 5% chance that the differences between the two treatment averages are really the same. Statistical differences among means are often indicated in tables by use of superscript letters. Treatments with any letter in common are not different, while treatments with no common letters are. Another way to report means is as mean ± standard error (e.g. 9.1 ± 1.2). The standard error of the mean (designated SE or SEM) is a measure of how much variation is present in the data – the larger the SE, the more variation. If the difference between two means is less than two times the SE, then the treatments are usually not statistically different from one another. 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 |
|---|---|
| ADFI | Average daily feed intake |
| ADG | Average daily gain |
| avg | Average |
| BW | Body weight |
| cc | Cubic centimeter |
| cm | Centimeter |
| CP | Crude protein |
| CV | Coefficient of variation |
| cwt | 100 pounds |
| d | Day(s) |
| DM | Dry matter |
| DNA | Deoxyribonucleic acid |
| °C | Degrees Celsius |
| °F | Degrees Fahrenheit |
| EPD | Expected progeny difference |
| F/G | Feed:gain ratio |
| FSH | Follicle stimulating hormone |
| ft | Foot or feet |
| g | Gram(s) |
| gal | Gallon(s) |
| h | Hour(s) |
| in | Inch(es) |
| IU | International units |
| kcal | Kilocalorie(s) |
| kg | Kilogram(s) |
| lb | Pound(s) |
| L | Liter(s) |
| LH | Lutenizing hormone |
| m | Meter(s) |
| mg | Milligram(s) |
| Meq | Milliequivalent(s) |
| Mcg | Microgram(s) |
| min | Minute(s) |
| mm | Millimeter(s) |
| mo | Month(s) |
| N | Nitrogen |
| NS | Not Significant |
| ng | Nanogram(s) |
| ppb | Parts per billion |
| ppm | Parts per million |
| r | Correlation coefficient |
| $r^2$ | Simple coefficient of determination |
| $R^2$ | Multiple coefficient of determination |
| s | Second(s) |
| SD | Standard deviation |
| SE | Standard error |
| SEM | Standard error of the mean |
| TDN | Total digestible nutrients |
| wk | Week(s) |
| wt | Weight |
| yr | Year(s) |

# TABLE OF CONTENTS

# Carcass and Color Characteristics of Three Biological Types of Cattle Grazing Cool-Season Forages Supplemented with Soyhulls

*R.T. Baublits[1], A.H. Brown, Jr.[1], F.W. Pohlman[1], Z.B. Johnson[1], B.A. Sandelin[1], and D.O. Onks[2]*


## Story in Brief

Soyhull supplementation to divergent biological types of cattle on forage-based systems was studied to determine the impact on carcass and color characteristics. Weaned calves (n = 107) biologically classified as large-, medium-, or small-framed and intermediate maturing rates were allocated to three cool season grazing systems consisting of either orchardgrass pasture or fescue pasture, each with soyhull supplementation, or fescue pasture with no supplementation for a control. Supplementing cattle with soyhulls allowed for heavier ($P < 0.05$) live and carcass weights; larger ($P < 0.05$) loin eyes; increased ($P < 0.05$) backfat; kidney, pelvic and heart fat, and yield grades; and increased ($P < 0.05$) marbling scores, and quality grades. Utilizing cattle biologically classified as large- or medium-framed allowed for heavier ($P < 0.05$) carcass weights without reducing ($P > 0.05$) marbling scores or quality grades when compared to small-framed cattle. Instrumental color analysis of lean and adipose tissue revealed improved ($P < 0.05$) lightness (L*) in lean color for supplemented carcasses as compared to the control. There were no differences ($P > 0.05$) between dietary treatments for L*, a* or b* values of adipose tissue. Other than adipose b* values being lower ($P < 0.05$) for medium-framed cattle, there were no differences ($P > 0.05$) between biological types for instrumental color values. These results indicate that supplementing forage-grazing cattle with soyhulls can improve carcass merit, and utilizing large- or medium-framed cattle can allow for increased carcass weights without decreasing carcass quality. Both of these factors could be beneficial in forage-based finishing systems.


## Introduction

Retaining cattle after weaning and even up to a finished weight, and allocating different types of beef cattle to specific forages can allow for increased productivity and profit to producers. However, on a similar time scale, forage-fed cattle typically do not have the same degree of finish as grain-fed cattle due to the decreased energy available in the forage. Although typical forage-fed beef is lean and warrants an acceptable USDA yield grade, it is often inferior to traditional grain-fed beef in terms of both USDA quality grade and forage-fed beef's darker lean and more yellow fat color. The color of the lean and external fat of cuts of meat has been shown to be influential on the purchasing ability and visual acceptability by the consumer (Dikeman, 1990; Kropf, 1980)

Supplementing cattle on forage can provide sufficient additional energy to obtain a desirable degree of finish. However, concentrate supplementation can cause decreased forage utilization, and because the objective of forage-feeding cattle is to maximize utilization of available forages, alternative forms of supplementation could be considered to achieve a desirable production system. Utilization of appropriate biological types of cattle with the proper dietary regimen could allow for superior end product either in carcass weight or carcass quality. Therefore, the objectives of this study were to determine the effects of the supplementation of soyhulls, a highly digestible fiber source, to different biological types of forage-fed cattle on carcass quality and adipose and lean color.

## Experimental Procedures

*Animals.* British and British x Continental fall- and spring-born beef steers and heifers from two consecutive years (n = 108) of small (SI), medium (MI), or large (LI) frame size and intermediate maturing rate were selected from a commercial cow herd at the University of Tennessee Experiment Station, Springhill, TN, to be utilized in this study. Biological types were estimated using the equation set forth by McCurley et al. (1980). This study was replicated over two consecutive years consisting of 54 animals utilized each year. One small-framed intermediate maturing heifer was removed from the first year's study due to chronic illness.

After weaning in October of each year, all calves chosen for the study were backgrounded for 2 weeks, receiving orchardgrass hay ad libitum and were started on pelleted soyhulls before being allocated to the trial. The randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture with pelleted soyhull supplementation (Fescue), or tall fescue pasture with no supplementation (Control). A commercial salt and mineral mix was available to all animals throughout the study.

Six animals (two from each biological type) were allocated to each paddock. There were three paddocks of each forage allowing for three replications each year (n = 36 per treatment). Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring and 1 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 days when the cattle were reweighed. Grazing continued into the summer months (mean days of age = 555) until forage availability started to diminish and cattle had attained a relative degree of finish determined by visual appraisal, whereupon all cattle, within a year, were sent to a commercial slaughtering facility.

*Carcass.* Carcasses were chilled for 48 h before carcass data were obtained by a USDA Grader. Carcass data obtained included 12th rib backfat, maturity score, hot carcass weight, marbling score, percent kidney, pelvic and heart fat (KPH), loin eye area, quality grade and yield grade.

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*Instrumental color.* Instrumental color data were obtained by a qualified technician using a Minolta chromatographer (Model CR-300; Minolta Corp., Ramsey, NJ). Instrumental color data included lean and adipose CIE L*, a* and b* values. The lean values were obtained at the central, medial and lateral areas of the exposed longissimus at the 12th rib. Adipose values were obtained at the external fat located between the 10th and 12th rib region.

*Statistical analysis.* The experiment was set up as a split-plot design with random effects of year and replicate within year, and fixed effects of treatment and biological type. The whole plot consisted of treatment and the sub-plot consisted of biological type. The three-way interaction of year x replicate x treatment was the error term for the whole plot, and the four-way interaction year x replicate x treatment x biological type was the error term for the sub-plot and for the interaction of treatment x biological type. Although year is generally considered to have a significant effect on performance, it is likely due to temporary environmental effects causing pasture conditions to vary between years (Vallentine, 1990). Due to this, and that year was considered a random effect, no interactions pertaining to year were included in the final model. Days of age of individual animals was included in the final model as a covariate for all traits analyzed. Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC.). Means were generated using the LSMEANS option and separation was performed using the PDIFF option.

## Results and Discussion

Main effect results for carcass traits, by treatment and biological type, are reported in Table 1. The live weights prior to slaughter and the carcass weights of the cattle supplemented with soyhulls were heavier ($P < 0.05$) than cattle without supplementation, although there were no differences ($P > 0.05$) between the Orchard and Fescue supplemented cattle. Similarly, loin eye area was larger ($P < 0.05$), and KPH, marbling score and quality grade were greater ($P < 0.05$) for the soyhull supplemented cattle than the Control, although the soyhull supplemented treatments did not differ ($P > 0.05$). Soyhull supplementation of cattle grazing fescue and orchardgrass allowed carcasses to obtain USDA Choice quality grades compared to USDA Standard quality grades for traditional grazing cattle. The LI cattle had heavier ($P < 0.05$) live and carcass weights and larger ($P < 0.05$) loin eye areas than SI, whereas there were no differences ($P > 0.05$) between the biological types for marbling score or quality grade.

The treatment x biological type interaction ($P < 0.05$) on carcass backfat means is reported in Table 2. Carcasses from the three biological types within the Control treatment had less ($P < 0.05$) backfat than biological types within either the Fescue or Orchard treatments. Excluding Fescue-MI carcasses, the LI carcasses within the Orchard treatment had more ($P < 0.05$) backfat than all other biological types represented within each treatment. There were no differences ($P > 0.05$) for backfat between the LI, MI and SI carcasses within the Fescue treatment and MI and SI within the Orchard treatment. An interaction of treatment x biological type was also found to be significant for yield grade of the carcasses (Table 3). Similar to backfat, Control carcasses from the three biological types did not differ ($P > 0.05$) in numerical values for yield grade, but were lower ($P < 0.05$) than carcasses from the three biological types within both soyhull-supplemented treatments. There were no differences ($P > 0.05$) for yield grade between biological types within the Fescue treatment, and the LI carcasses from the Orchard treatment had a higher ($P < 0.05$) yield grade than all other biological types within treatments except the MI carcasses within the Fescue treatment.

Typically, increased forage ingestion allows for carcasses with a darker lean appearance or fat that is yellow in appearance. The darker lean can be attributed to increased myoglobin, decreased muscle glycogen, or both, and the yellow fat is due to forages having increased carotenoids compared to concentrates (Priolo et al., 2001). The instrumental color results from the present study are reported in Table 4. The lean L* values, corresponding to degrees of lightness or darkness, resulted in the Control carcasses having a lower ($P < 0.05$) L* value, indicating a darker lean than the soyhull supplemented treatments. The lean b* values, indicating degree of yellow appearance, revealed the Control carcasses had a lower lean b* value ($P < 0.05$), indicating a less yellow appearance than the Fescue or Orchard carcasses. However, the lean b* values reported did not reveal a drastically yellow appearance, as the values were below the mean values from a survey from 1,000 carcasses evaluated at commercial processing plants (Page et al., 2001). There were no differences ($P > 0.05$) between feeding treatments for adipose instrumental values. Instrumental color results for biological type revealed no differences ($P > 0.05$) for lean characteristics, but MI carcasses had lower ($P < 0.05$) adipose b* values than LI or SI carcasses. Even though the mean b* values between biological types were statistically different, the numerical difference was not drastic

**Table 1. Least-squares means for carcass traits by treatment and biological type (n = 107).**

| | Treatment | | | Biological type[a] | | |
|---|---|---|---|---|---|---|
| Trait | Control | Fescue | Orchard | LI | MI | SI |
| Live weight (lb) | 847 ± 13$^{x}$ | 1192 ± 13$^{w}$ | 1203 ± 13$^{w}$ | 1144 ± 13$^{w}$ | 1065 ± 13$^{x}$ | 1034 ± 13$^{x}$ |
| Hot carcass weight (lb) | 438 ± 11$^{x}$ | 671 ± 11$^{w}$ | 680 ± 11$^{w}$ | 629 ± 11$^{w}$ | 596 ± 11$^{x}$ | 561 ± 5$^{y}$ |
| Loin eye area (in$^2$) | 9.63 ± 0.25$^{x}$ | 11.81 ± 0.25$^{w}$ | 11.79 ± 0.26$^{w}$ | 11.69 ± 0.26$^{w}$ | 11.09 ± 0.25$^{wx}$ | 10.46 ± 0.27$^{x}$ |
| KPH | 1.52 ± 0.06$^{x}$ | 2.26 ± 0.06$^{w}$ | 2.32 ± 0.06$^{w}$ | 2.06 ± 0.06 | 2.01 ± 0.06 | 2.03 ± 0.06 |
| Maturity[b] | 164.72 ± 3.67 | 157.49 ± 3.65 | 156.70 ± 3.72 | 159.41 ± 3.79 | 162.01 ± 3.65 | 157.48 ± 3.83 |
| Marbling score[c] | 178.62 ± 16.07$^{x}$ | 473.85 ± 15.99$^{w}$ | 446.94 ± 16.27$^{w}$ | 367.34 ± 16.59 | 368.77 ± 15.98 | 363.30 ± 16.78 |
| Quality grade[d] | 535.02 ± 8.51$^{x}$ | 718.03 ± 8.46$^{w}$ | 704.26 ± 8.61$^{w}$ | 653.06 ± 8.78 | 657.05 ± 8.46 | 647.20 ± 8.89 |

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

[b] 100 to199 = A maturity

[c] PD = 100 to 199, Tr = 200 to 299, SI = 300 to 399, Sm = 400 to 499, Mt = 500 to 599, Md = 600 to 699

[d] Standard = 500 to 599, Select = 600 to 699, Choice = 700 to 799

[wxy] Within treatment or biological type, within a row, means without a common superscript letter differ ($P < 0.05$)

and probably would not have been visually influential in terms of the degree of yellowness. Therefore, supplementing soyhulls to cattle on forage may slightly improve lean color, but overall does not seem to largely affect lean or adipose color. Biological type within these feeding conditions does not seem to be an influential source of variation in lean or adipose color as well.

## Implications

These results illustrate that supplementing forage-fed cattle with soyhulls can improve carcass merit in terms of increased weights and quality grade values, but can negatively affect leanness due to higher yield grades. Utilizing cattle with potential for a larger mature size could allow for increased carcass weights without negatively impacting quality. Future studies utilizing different supplementation rates and cattle types might be necessary to achieve maximal production and carcass merit.

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**Table 2. Least-squares means for the treatment x biological type interaction on 12th rib backfat (in).**

| | Biological Type[a] | | |
|---|---|---|---|
| Treatment | LI | MI | SI |
| Control | 0.11 ± 0.04$^{z}$ | 0.10 ± 0.04$^{z}$ | 0.08 ± 0.04$^{z}$ |
| Fescue | 0.35 ± 0.04$^{xy}$ | 0.42 ± 0.04$^{wx}$ | 0.39 ± 0.04$^{x}$ |
| Orchard | 0.51 ± 0.04$^{w}$ | 0.36 ± 0.04$^{xy}$ | 0.26 ± 0.04$^{y}$ |

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

$^{wxyz}$ Means without a common superscript letter differ (P < 0.05)

**Table 3. Least squares means for the treatment x biological type interaction on yield grade.**

| | Biological type[a] | | |
|---|---|---|---|
| Treatment | LI | MI | SI |
| Control | 1.52 ± 0.12$^{z}$ | 1.62 ± 0.11$^{z}$ | 1.65 ± 0.11$^{z}$ |
| Fescue | 2.60 ± 0.11$^{xy}$ | 2.85 ± 0.11$^{wx}$ | 2.61 ± 0.11$^{xy}$ |
| Orchard | 3.01 ± 0.11$^{w}$ | 2.52 ± 0.11$^{y}$ | 2.58 ± 0.12$^{xy}$ |

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

$^{wxyz}$ Means without a common superscript letter differ (P < 0.05)

**Table 4. Least-squares means for carcass instrumental color by treatment and biological type (n = 107).**

| | Treatment | | | Biological type[a] | | |
|---|---|---|---|---|---|---|
| Item | Control | Fescue | Orchard | LI | MI | SI |
| Lean | | | | | | |
| L * | 30.51 ± 0.47$^{x}$ | 32.98 ± 0.47$^{w}$ | 32.58 ± 0.47$^{w}$ | 32.03 ± 0.48 | 32.00 ± 0.47 | 32.03 ± 0.49 |
| a * | 19.34 ± 0.35 | 20.47 ± 0.35 | 19.92 ± 0.35 | 19.80 ± 0.36 | 19.91 ± 0.35 | 20.03 ± 0.36 |
| b * | 7.71 ± 0.35$^{x}$ | 9.65 ± 0.35$^{w}$ | 9.47 ± 0.35$^{w}$ | 8.77 ± 0.36 | 9.03 ± 0.35 | 9.01 ± 0.36 |
| Adipose | | | | | | |
| L* | 73.83 ± 1.08 | 70.12 ± 1.07 | 71.56 ± 1.08 | 72.35 ± 0.84 | 71.49 ± 0.81 | 71.68 ± 0.85 |
| a * | 1.36 ± 0.55 | 2.80 ± 0.54 | 2.56 ± 0.53 | 1.83 ± 0.43 | 2.55 ± 0.42 | 2.34 ± 0.43 |
| b * | 18.37 ± 0.77 | 20.97 ± 0.77 | 18.94 ± 0.64 | 21.37 ± 1.05$^{w}$ | 19.44 ± 0.63$^{x}$ | 21.10 ± 0.62$^{w}$ |

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

$^{wx}$ Within treatment or biological type, within a row, means without a common superscript letter differ (P < 0..05).

# Chemical, Fatty Acid and Sensory Characteristics of Beef from Cattle Grazing Forages Supplemented with Soyhulls vs. USDA Choice and Select Beef

*R.T. Baublits[1], F.W. Pohlman[1], A.H. Brown, Jr.[1], Z.B. Johnson[1], B.A. Sandelin[1], and D.O. Onks[2]*


## Story in Brief

Increased concerns for a healthier diet have spurred interests in forage-fed beef due to proportions of fatty acids that have exhibited a healthy impact when incorporated into a dietary regimen. Supplementing concentrates to cattle on a forage ration can improve palatability, but can negatively impact the healthier fatty acid profile associated with a forage ration. Therefore, over two consecutive years, steaks from cattle (n = 107) grazing three cool season grazing systems consisting of either orchardgrass pasture or fescue pasture, each with soyhull supplementation, or fescue pasture with no supplementation for a control were compared with USDA Choice and Select steaks obtained from area supermarkets for chemical, fatty acid and sensory characteristics. Steaks from all three forage treatments had more ($P < 0.05$) longissimus conjugated linoleic acid (CLA; 18:2*cis*-9, trans-11) and lower ($P < 0.05$) n-6 to n-3 fatty acid ratios than USDA Choice or Select steaks. Supplementing soyhulls did not decrease ($P > 0.05$) longissimus CLA, and sensory evaluation revealed that the supplemented treatments had improved ($P < 0.05$) beef/brothy and reduced ($P < 0.05$) grassy characteristics when compared to the control. These results suggest supplementing soyhulls to cattle on forage can improve the sensory characteristics of the beef without dramatically hindering the fatty acid profile associated with forage-fed beef.


## Introduction

Forage-fed beef has taken a "healthy" role as a marketing strategy due to an increased awareness for a healthier human diet. Typically, beef from cattle on a forage diet has been considered healthy due to either its leanness or a healthier fatty acid profile. In human health, certain fatty acid interests are increased levels of conjugated linoleic acid (CLA), which has exhibited anticarcinogenic properties, and lowering the ratio of n-6 to n-3 fatty acids, which can aid in cardiovascular health (Lee et al., 1989; Whigham et al., 2000). However, forage-fed beef can experience decreased consumer acceptance due to differences in juiciness or tenderness (Muir et al., 1998), and most commonly differing flavor characteristics when compared to grain-fed beef (Melton et al., 1983). Increasing the portion of grain in the diet can allow for improved flavor desirability (Smith et al., 1983).

Supplementation of forage-fed beef can allow for increased gains, enhanced carcass quality, and improved palatability; however, increased incorporation of concentrates in the diet can decrease forage utilization and deleteriously affect the fatty acid profile associated with the healthier aspects of forage-fed beef (French et al., 2000; Griebenow et al., 1997). Therefore, the objectives of this study were to determine if supplementation of soyhulls, a highly digestible fiber source, could allow for improved sensory characteristics without negatively affecting the perceived healthier fatty acid profile commonly present in forage-fed beef.

## Experimental Procedures

*Animals.* For this study, British and British x Continental fall- and spring-born beef steers and heifers (n = 107) were selected from a commercial cowherd at the University of Tennessee Experiment Station, Springhill, TN. Cattle were assessed and chosen based on three divergent biological types for a separate trial. This study was replicated over two consecutive years consisting of 54 animals utilized each year. One heifer was removed from the first year's study due to chronic illness.

After weaning, the randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture (n = 35) supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture (n =36) with soyhull supplementation (Fescue), or fescue pasture (n = 36) with no supplementation (Control). Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring, and 1 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 days when the cattle were reweighed. Grazing continued into the summer months (mean days of age = 555), until forage availability started to diminish and cattle had attained a relative degree of finish determined by visual appraisal, whereupon all cattle, within a year, were sent to a commercial slaughtering facility.

After carcasses had chilled for 48 h, a three-rib section (10th to 12th ribs) of the wholesale rib from the right side of each carcass was removed, vacuum-sealed, transported back to the University of Arkansas and aged for an additional 5 days before subsequent analyses.

For comparison to the forage-fed beef, USDA Choice (Choice) and Select (Select) ribeye steaks were randomly chosen from area supermarkets or purveyors to be representative of those typically available to consumers. Unless otherwise specified, the number of USDA Choice and Select steaks were equal in number to those from the forage-fed treatments for individual analyses.

*Warner-Bratzler shear force and cooking loss.* For Warner-Bratzler shear force (WBS) analysis, rib steaks (1 in thick) were cooked in a convection oven until the internal temperature of each steak was 158°F. After cooking, steaks were allowed to cool to room temperature for approximately 2 h, and upon cooling, five 0.5-in diameter cores were removed from the longissimus muscle from each steak for WBS. Each core was sheared with a Warner-Bratzler shear (WBS) attachment using an Instron (Canton, MA) Universal Testing Machine.

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Cooking loss of the steaks was determined during the cooking process for WBS. After steaks were removed from the vacuum-sealed pouches, each steak was weighed on a balance prior to cooking. Upon completion of cooking, a final weight was obtained for cooking loss calculations.

*Chemical analyses.* For fatty acid, lipid, and moisture analyses a sub-sample consisting of 14 Choice and 14 Select steaks was utilized. Samples from the forage treatments consisted of the total number of observations in each treatment (n = 36 each).

Percent moisture was obtained by dicing the longissimus muscle of a steak and utilizing approximately a 50-g sample to represent a homogenous portion. Samples were freeze-dried for approximately 96 h. After drying, percentage moisture was calculated, and samples were placed in a commercial blender, ground and stored in a freezer at - 20°F for later determination of total lipids and fatty acid profiles.

Total lipids were obtained using the method as described by Rule (1997). Tissue samples weighing 200 mg were utilized, and lipid extraction was performed with chloroform-methanol, followed by chloroform removal and evaporation to yield the lipid fraction.

For fatty acid analysis, total lipids were extracted by the same method previously described. Fatty acid methyl esters (FAME) were prepared by transmethylation utilizing methanol and HCl as described by Murrieta et al. (2003). Tridecanoic acid (13:0; 1 mg) was used as the internal standard for all samples. Fatty acid methyl esters were analyzed using a Hewlett-Packard 5890 series II gas chromatograph (Hewlett-Packard, Avondale, PA) equipped with a flame ionization detector and a 60-m x 0.25-mm fused silica capillary column (SP-2380; Supelco, Bellefonte, PA).

*Taste-panel.* Sensory characteristics of the longissimus steaks were obtained by a professional taste-panel at Texas A & M University, College Station, TX. A sub-sample consisting of 24 steaks per forage treatment and 14 Choice and 14 Select steaks (n = 100) was utilized for determination of sensory characteristics. A six-member taste panel was utilized to determine aromatic, feeling-factor, taste and aftertaste, and textural sensory characteristics. The aromatic, feeling factor, taste and aftertaste sensory characteristics were scored on a 15-point scale (0 = not detected; 15 = extremely intense). Textural sensory characteristics were scored on an 8-point scale (1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense).

*Statistical analysis.* Comparisons of steaks from the three forage treatments and USDA Choice and Select steaks by one-way analysis of variance blocked by year were performed using PROC GLM in SAS (SAS Inst., Inc., Cary, NC.). Mean generation and separation was executed using LSMEANS with the PDIFF and STDERR options of SAS.

## Results and Discussion

Least squares means for longissimus steak cooking loss, percentage lipid and moisture, and WBS are reported in Table 1. Choice steaks had the highest ($P < 0.05$) lipid percentage and the lowest ($P < 0.05$) moisture percentage compared to all other treatments. Fescue and Orchard steaks had higher ($P < 0.05$) lipid percentages than Control or Select steaks. Control steaks had lesser ($P < 0.05$) cooking losses than Choice steaks, but did not differ ($P > 0.05$) from the other treatments. The WBS force values for Choice were lowest ($P < 0.05$), indicating improved tenderness; however, steaks from all treatments had less than 13.2 lb (6 kg) shear force, an index of tenderness, indicating all treatments could be classified as tender.

Longissimus fatty acid least squares means are reported in Table 2. Choice and Select steaks had increased ($P < 0.05$) 18:2cis- 9,12 percentages, and had decreased ($P < 0.05$) 18:2*cis*- 9, trans-11 (CLA) and 18:3*cis*- 9,12,15 percentages compared to the forage treatments. In fact, forage treatments had greater than twice the CLA content than Choice or Select steaks. There were no differences ($P > 0.05$) between forage treatments for CLA, but the Control steaks did have increased ($P < 0.05$) 18:3*cis*- 9,12,15 percentages. This increase could be due to increased forage ingestion associated with no supplemented feed. Therefore, the increased 18:3*cis*- 9,12,15 percentages in Control lean tissue is probably a result of increased ingestion of fescue forage, which typically has a high percentage of 18:3*cis*-9,12,15. The Control steaks also had higher ($P < 0.05$) percentages of 20:5*cis*- 5,8,11,14,17 and 22:5*cis*- 7,10,13,16,19 than all other treatments; thus allowing the Control steaks to have a lower ($P < 0.05$), more desirable, n-6 to n-3 fatty acid ratio than all other treatments. However, the Fescue and Orchard longissimus steaks did have a lower ($P < 0.05$) n-6 to n-3 ratio than Choice or Select steaks.

Sensory profile characteristics are reported in Table 3. Although Control longissimus steaks had the lowest ($P < 0.05$) beef/brothy sensory characteristic, there were no differences ($P > 0.05$) between Choice, Fescue, Orchard or Select longissimus steaks, indicating an improved beef flavor with soyhull supplementation. Furthermore, longissimus steaks from Fescue and Orchard had lower ($P < 0.05$) grassy sensory values than the Control, and did not differ ($P > 0.05$) from Choice or Select steaks. There were no differences ($P > 0.05$) between treatments for juiciness, and even though longissimus steaks from Choice were rated more tender ($P < 0.05$) for overall tenderness, there were no differences ($P > 0.05$) between forage treatments or Select steaks.

## Implications

Implementing soyhull supplementation on a forage-feeding regimen can allow for improved flavor characteristics to levels similar to Choice steaks while maintaining heightened CLA concentrations and a more acceptable n-3 fatty acid profile compared to typical supermarket steaks available to the consumer.

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**Table 1. Least-squares means for longissimus cooking loss, lipid percentage, moisture percentage and Warner-Bratzler shear force (WBS) by treatment[a].**

| | Treatment | | | | |
|---|---|---|---|---|---|
| Item | Control | Fescue | Orchard | Choice | Select |
| Cooking loss[b] | 27.54 ± 0.77$^{x}$ | 27.13 ± 0.78$^{x}$ | 28.77 ± 0.79$^{wx}$ | 30.14 ± 0.78$^{w}$ | 29.28 ± 0.78$^{wx}$ |
| Lipid %[c] | 2.56 ± 0.27$^{y}$ | 4.72 ± 0.27$^{x}$ | 5.00 ± 0.27$^{x}$ | 6.93 ± 0.42$^{w}$ | 3.29 ± 0.43$^{y}$ |
| Moisture %[d] | 74.43 ± 0.26$^{w}$ | 71.92 ± 0.26$^{x}$ | 71.70 ± 0.27$^{x}$ | 69.38 ± 0.42$^{y}$ | 72.38 ± 0.42$^{x}$ |
| Shear (lb) | 10.23 ± 0.20$^{xy}$ | 11.46 ± 0.20$^{w}$ | 11.42 ± 0.20$^{wx}$ | 8.12 ± 0.44$^{z}$ | 9.88 ± 0.20$^{y}$ |

[a] Cooking loss and WBS: Choice, Control, Fescue, Orchard and Select (n = 36 each; n = 179 total)
Lipid and moisture %: Control, Fescue and Orchard (n = 36 each); Choice and Select (n = 14 each)
Total sample (n = 135)

[b] Cooking loss calculated as: (Fresh weight – Cooked weight) / Fresh weight x 100

[c] Lipid percentage calculated as: Lipid weight / Tissue weight x (100 – percent moisture)

[d] Moisture percentage calculated as: (Wet weight – Dry weight) / Wet weight x 100

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

**Table 2. Least-squares means for individual fatty acids of longissimus muscle by treatment (n = 135)[a].**

| | Treatment | | | | |
|---|---|---|---|---|---|
| Fatty acid[a] | Control | Fescue | Orchard | Choice | Select |
| 12:0 | 0.29 ± 0.05 | 0.30 ± 0.06 | 0.26 ± 0.06 | 0.35 ± 0.08 | 0.28 ± 0.08 |
| 14:0 | 1.20 ± 0.07$^{x}$ | 1.41 ± 0.08$^{wx}$ | 1.33 ± 0.08$^{wx}$ | 1.61 ± 0.13$^{w}$ | 1.56 ± 0.13$_{w}$ |
| 14:1*cis*-9 | 0.54 ± 0.11$^{y}$ | 0.99 ± 0.11$^{w}$ | 0.86 ± 0.11$^{wx}$ | 0.56 ± 0.18$^{xy}$ | 0.45 ± 0.18$^{xy}$ |
| 15:0 | 2.58 ± 0.11$^{w}$ | 1.44 ± 0.11$^{y}$ | 1.83 ± 0.11$^{x}$ | 1.89 ± 0.18$^{x}$ | 2.04 ± 0.18$^{x}$ |
| 15:1*cis*-9 | 0.33 ± 0.02$^{w}$ | 0.18 ± 0.02$^{x}$ | 0.28 ± 0.02$^{w}$ | 0.16 ± 0.03$^{x}$ | 0.18 ± 0.03$^{x}$ |
| 16:0 | 22.80 ± 0.29$^{x}$ | 25.28 ± 0.29$^{w}$ | 24.50 ± 0.30$^{w}$ | 25.09 ± 0.47$^{w}$ | 22.90 ± 0.47$^{x}$ |
| 16:1*cis*-9 | 2.75 ± 0.09 | 3.13 ± 0.09 | 2.97 ± 0.09 | 3.06 ± 0.15 | 2.98 ± 0.15 |
| 16:1*trans*-9 | 0.94 ± 0.03$^{w}$ | 0.68 ± 0.03$^{x}$ | 0.72 ± 0.04$^{x}$ | 0.45 ± 0.06$^{y}$ | 0.50 ± 0.06$^{y}$ |
| 17:0 | 2.00 ± 0.14$^{w}$ | 1.51 ± 0.13$^{x}$ | 2.09 ± 0.14$^{w}$ | 1.76 ± 0.22$^{wx}$ | 1.76 ± 0.22$^{wx}$ |
| 17:1*cis*-9 | 1.01 ± 0.03$^{x}$ | 0.93 ± 0.03$^{xy}$ | 0.84 ± 0.03$^{y}$ | 0.87 ± 0.05$^{y}$ | 1.13 ± 0.05$^{w}$ |
| 18:0 | 13.70 ± 0.23$^{w}$ | 13.01 ± 0.23$^{x}$ | 12.91 ± 0.23$^{x}$ | 11.68 ± 0.37$^{y}$ | 11.49 ± 0.37$^{y}$ |
| 18:1*cis*-9 | 30.97 ± 0.47$^{z}$ | 34.98 ± 0.47$^{w}$ | 34.61 ± 0.47$^{wx}$ | 32.88 ± 0.75$^{xy}$ | 31.90 ± 0.75$^{yz}$ |
| 18:2*cis*-9,12 | 7.15 ± 0.32$^{y}$ | 6.47 ± 0.32$^{y}$ | 6.85 ± 0.32$^{y}$ | 9.85 ± 0.55$^{x}$ | 11.52 ± 0.53$^{w}$ |
| 18:2*cis*-9, *trans*-11 (CLA) | 0.69 ± 0.02$^{w}$ | 0.70 ± 0.02$^{w}$ | 0.63 ± 0.02$^{w}$ | 0.25 ± 0.03$^{x}$ | 0.26 ± 0.03$^{x}$ |
| 18:3*cis*-6,9,12 | 0.04 ± 0.01$^{x}$ | 0.06 ± 0.00$^{w}$ | 0.05 ± 0.01$^{wx}$ | 0.03 ± 0.02$^{x}$ | 0.04 ± 0.01$^{wx}$ |
| 18:3*cis*-9,12,15 | 2.12 ± 0.07$^{w}$ | 1.28 ± 0.07$^{x}$ | 1.17 ± 0.07$^{x}$ | 0.39 ± 0.12$^{y}$ | 0.58 ± 0.12$^{y}$ |
| 20:4*cis*-5,8,11,14 | 3.55 ± 0.15$^{w}$ | 2.54 ± 0.16$^{x}$ | 2.61 ± 0.16$^{x}$ | 3.60 ± 0.26$^{w}$ | 3.79 ± 0.25$^{w}$ |
| 20:5*cis*-5,8,11,14,17 | 1.27 ± 0.04$^{w}$ | 0.38 ± 0.04$^{y}$ | 0.50 ± 0.04$^{x}$ | 0.28 ± 0.06$^{y}$ | 0.61 ± 0.06$^{x}$ |
| 22:0 | 0.98 ± 0.06$^{w}$ | 0.70 ± 0.06$^{x}$ | 0.86 ± 0.06$^{wx}$ | 0.90 ± 0.13$^{wx}$ | 0.92 ± 0.11$^{wx}$ |
| 22:5*cis*-7,10,13,16,19 | 1.53 ± 0.05$^{w}$ | 0.80 ± 0.05$^{yz}$ | 1.01 ± 0.05$^{x}$ | 0.64 ± 0.08$^{z}$ | 0.99 ± 0.08$^{xy}$ |
| 22:6*cis*-4,7,10,13,16,19 | 0.16 ± 0.01$^{w}$ | 0.08 ± 0.01$^{x}$ | 0.09 ± 0.01$^{x}$ | 0.08 ± 0.01$^{x}$ | 0.14 ± 0.01$^{w}$ |
| PUFA | 15.07 ± 0.46$^{w}$ | 10.03 ± 0.46$^{y}$ | 12.95 ± 0.46$^{x}$ | 12.90 ± 0.69$^{x}$ | 14.77 ± 0.69$^{wx}$ |
| SFA | 43.08 ± 0.37 | 43.40 ± 0.37 | 42.95 ± 0.37 | 43.48 ± 0.55 | 42.05 ± 0.55 |
| PUFA / SFA | 0.35 ± 0.01$^{w}$ | 0.23 ± 0.01$^{y}$ | 0.30 ± 0.01$^{x}$ | 0.30 ± 0.02$^{x}$ | 0.35 ± 0.02$^{w}$ |
| n - 3 | 4.90 ± 0.13$^{w}$ | 2.21 ± 0.13$^{y}$ | 2.81 ± 0.13$^{x}$ | 1.46 ± 0.19$^{z}$ | 2.37 ± 0.19$^{xy}$ |
| n - 6 | 9.37 ± 0.41$^{x}$ | 7.03 ± 0.41$^{y}$ | 9.42 ± 0.41$^{x}$ | 11.16 ± 0.62$^{w}$ | 12.09 ± 0.62$^{w}$ |
| n - 6 / n - 3 | 1.92 ± 0.32$^{z}$ | 3.19 ± 0.32$^{y}$ | 3.38 ± 0.32$^{y}$ | 8.24 ± 0.48$^{w}$ | 5.69 ± 0.48$^{x}$ |

[a] Control, Fescue and Orchard (n = 36 each); Choice and Select (n = 14 each)

[b] Fatty acid percents expressed as proportion of all peaks observed by GLC
PUFA = Fatty acids with 2 or more double bonds; SFA = Fatty acids with no double bonds;
n-3 = 18:3*cis*- 9,12,15; 20:5*cis*-5,8,11,14,17; 22:5*cis*-7,10,13,16,19; 22:6*cis*-4,7,10,13,16,19
n-6 = 18:2*cis*-9,12; 18:3*cis*-6,9,12; 20:4*cis*-5,8,11,14

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

**Table 3. Least-squares means for sensory characteristics of longissimus muscle by treatment (n = 100)[a].**

| | Treatment | | | | |
|---|---|---|---|---|---|
| Item | Control | Fescue | Orchard | Choice | Select |
| *Aromatics*[b] | | | | | |
| Beef/brothy | 4.46 ± 0.08$^{x}$ | 4.73 ± 0.08$^{w}$ | 4.80 ± 0.08$^{w}$ | 4.94 ± 0.10$^{w}$ | 4.86 ± 0.10$^{w}$ |
| Beef fat | 1.42 ± 0.06$^{y}$ | 1.58 ± 0.06$^{xy}$ | 1.61 ± 0.06$^{x}$ | 1.82 ± 0.08$^{w}$ | 1.59 ± 0.08$^{xy}$ |
| Serumy/bloody | 1.49 ± 0.09 | 1.61 ± 0.09 | 1.58 ± 0.09 | 1.47 ± 0.12 | 1.51 ± 0.12 |
| Grainy/cowy | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cardboard | 0.11 ± 0.03 | 0.08 ± 0.03 | 0.10 ± 0.03 | 0.06 ± 0.04 | 0.10 ± 0.04 |
| Painty | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fishy | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Liver | 0.27 ± 0.07 | 0.21 ± 0.07 | 0.26 ± 0.07 | 0.47 ± 0.09 | 0.25 ± 0.09 |
| Soured | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Browned/burnt | 0.73 ± 0.10 | 0.83 ± 0.10 | 0.94 ± 0.10 | 0.80 ± 0.13 | 0.89 ± 0.13 |
| Grassy | 1.11 ± 0.08$^{w}$ | 0.80 ± 0.08$^{x}$ | 0.78 ± 0.08$^{x}$ | 0.60 ± 0.11$^{x}$ | 0.71 ± 0.11$^{x}$ |
| Milky/oily | 0.61 ± 0.06 | 0.64 ± 0.06 | 0.69 ± 0.06 | 0.52 ± 0.08 | 0.48 ± 0.08 |
| Old/putrid | 0.10 ± 0.03 | 0.02 ± 0.03 | 0.05 ± 0.03 | 0.04 ± 0.03 | 0.02 ± 0.03 |
| *Feeling factors*[b] | | | | | |
| Metallic | 2.68 ± 0.04 | 2.81 ± 0.04 | 2.76 ± 0.04 | 2.71 ± 0.05 | 2.73 ± 0.05 |
| Astringent | 2.37 ± 0.03$^{wx}$ | 2.45 ± 0.03$^{x}$ | 2.42 ± 0.03$^{x}$ | 2.28 ± 0.04$^{w}$ | 2.39 ± 0.04$^{wx}$ |
| Tastes[b] | | | | | |
| Salt | 1.98 ± 0.02 | 2.03 ± 0.02 | 2.00 ± 0.02 | 2.02 ± 0.02 | 2.01 ± 0.02 |
| Sour | 2.51 ± 0.05 | 2.52 ± 0.05 | 2.60 ± 0.05 | 2.48 ± 0.06 | 2.51 ± 0.06 |
| Bitter | 2.45 ± 0.05 | 2.43 ± 0.05 | 2.39 ± 0.05 | 2.29 ± 0.07 | 2.35 ± 0.07 |
| Sweet | 0.40 ± 0.04 | 0.50 ± 0.04 | 0.43 ± 0.04 | 0.59 ± 0.05 | 0.47 ± 0.05 |
| *Aftertastes*[b] | | | | | |
| Sour | 0.99 ± 0.07 | 0.92 ± 0.07 | 1.00 ± 0.07 | 1.08 ± 0.09 | 1.09 ± 0.09 |
| Acid | 1.27 ± 0.10 | 1.28 ± 0.10 | 1.19 ± 0.10 | 1.09 ± 0.14 | 1.26 ± 0.14 |
| Bitter | 0.90 ± 0.08 | 0.94 ± 0.08 | 0.82 ± 0.08 | 0.68 ± 0.11 | 0.83 ± 0.11 |
| Liver | 0.09 ± 0.03 | 0.03 ± 0.03 | 0.07 ± 0.03 | 0.14 ± 0.04 | 0.06 ± 0.04 |
| Browned/burnt | 0.14 ± 0.07 | 0.14 ± 0.07 | 0.20 ± 0.07 | 0.18 ± 0.08 | 0.25 ± 0.08 |
| Metallic | 1.72 ± 0.06$^{x}$ | 1.89 ± 0.06$^{wx}$ | 1.91 ± 0.06$^{w}$ | 1.79 ± 0.08$^{wx}$ | 2.02 ± 0.08$^{w}$ |
| Grassy | 0.26 ± 0.05$^{w}$ | 0.11 ± 0.05$^{x}$ | 0.10 ± 0.05$^{x}$ | 0.04 ± 0.06$^{x}$ | 0.13 ± 0.06$^{x}$ |
| Milky/oily | 0.30 ± 0.06 | 0.38 ± 0.06 | 0.37 ± 0.06 | 0.24 ± 0.08 | 0.23 ± 0.08 |
| Lipburn | 0.38 ± 0.03 | 0.33 ± 0.03 | 0.30 ± 0.03 | 0.34 ± 0.04 | 0.36 ± 0.03 |
| Chemical | 0.01 ± 0.02 | 0.03 ± 0.02 | 0.0 | 0.04 ± 0.02 | 0.01 ± 0.02 |
| Serumy/bloody | 0.25 ± 0.06 | 0.25 ± 0.06 | 0.25 ± 0.06 | 0.18 ± 0.07 | 0.13 ± 0.07 |
| Sweet | 0.01 ± 0.02 | 0.07 ± 0.02 | 0.0 | 0.04 ± 0.03 | 0.01 ± 0.03 |
| Old/putrid | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Textures*[c] | | | | | |
| Juiciness | 4.95 ± 0.11 | 5.05 ± 0.11 | 5.02 ± 0.11 | 5.26 ± 0.15 | 5.10 ± 0.15 |
| Myofibrillar tenderness | 5.35 ± 0.17$^{x}$ | 5.36 ± 0.17$^{x}$ | 5.37 ± 0.17$^{x}$ | 6.49 ± 0.22$^{w}$ | 5.80 ± 0.22$^{x}$ |
| Connective tissue | 6.19 ± 0.17$^{xy}$ | 6.23 ± 0.17$^{xy}$ | 6.01 ± 0.17$^{y}$ | 7.14 ± 0.22 $^{w}$ | 6.60 ± 0.22$^{wy}$ |
| Overall tenderness | 5.36 ± 0.17$^{x}$ | 5.36 ± 0.17$^{x}$ | 5.35 ± 0.17$^{x}$ | 6.51 ± 0.22$^{w}$ | 5.79 ± 0.22$^{x}$ |

[a] Sample consisted of sub-sample: Control, Fescue and Orchard (n = 24 each); Choice and Select (n = 14 each)

[b] 0 to 15: 0 = absent, 15 = extremely intense

[c] 1 to 8: 1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense

[wxy] Within treatment or biological type, within a row, means with different superscripts differ (P < 0.05)

# Effects of Treadmill Exercise on Stress Physiology and the Incidence of Dark-Cutting Longissimus Muscle in Holstein Steers

*J.K. Apple[1], E.B. Kegley[1], C.B. Boger[1], D. Galloway[1], L.K. Rakes[1], and J.W. Roberts[2]*


## Story in Brief

Holstein steers (n = 25) were used to evaluate the influence of treadmill exercise (TME) on meat quality and formation of dark-cutting beef. Calves were blocked by weight and assigned within blocks to one of five treatments of a 2 x 2 factorial design with an unexercised control (NS). Calves were exercised at either 2.5 or 5.0 mph for either 10 or 15 min, then immediately harvested. Blood samples were collected via indwelling jugular catheters at 10 and 2 min pre-exercise, at initiation of exercise (0-min), and at 2.5-min intervals during exercise for quantification of serum cortisol and plasma glucose, lactate, and non-esterified fatty acids (NEFA). Upon completion of TME, calves were harvested, and longissimus muscle (LM) samples were removed from right sides at 0, 1.5, 3, 6, 12, 24, and 48 h post-exsanguination for pH determinations. After a 48-h chill at 34°F, subjective and objective color measurements of the LM were obtained, and samples of LM were used to measure bound and expressible moistures using the Carver press methodology. Serum cortisol levels increased ($P < 0.01$) during the movement of calves from home stanchions to the treadmill, and cortisol concentrations were higher ($P < 0.01$) during TME in calves exercised at 5.0 mph for 10 min compared to calves exercised at 2.5 mph, regardless of duration, and NS. Additonally, TME caused increases in plasma lactate and NEFA concentrations; however, TME did not affect ($P = 0.30$) postmortem pH decline, and had no ($P \geq 0.29$) effect on LM color or moisture content. Even though TME elicited a noticeable stress response, this physical stressor failed to produce dark-cutting beef.


## Introduction

Dark-cutting beef is a persistent quality defect characterized by an elevated muscle pH (≥ 6.0), high water-holding capacity, dry, firm, and "sticky" lean, and a dark-red to almost-black lean color, and is associated with depletion of muscle glycogen reserves prior to harvest. More importantly, the dark-cutting condition (DCC) costs the U.S. beef industry between $132 and $170 million annually (Smith et al., 1995).

Glycogen degradation prior to harvest can occur during heavy exercise or in response to catecholamines in the absence of physical exertion. The aggressive activity associated with mixing unfamiliar bulls or heifers in estrus elicits pre-harvest muscle glycogen depletion and formation of dark-cutting beef (Kenny and Tarrant, 1988; Schaefer et al., 1990). Furthermore, chasing sheep to exhaustion also resulted in dark-cutting meat (Chrystall et al., 1982). Because cattle are quite lethargic and normally expend little energy moving, it is reasonable to suspect that muscular activity could lead to depletion of muscle glycogen reserves and lead to the development of dark-cutting beef. Therefore, the objective of this experiment was to determine the effects of treadmill exercise on blood metabolites associated with energy metabolism and the stress response, and meat quality. The ultimate aim of this study was to evaluate treadmill exercise as a potential animal-model that could repeatedly produce dark-cutting meat.

## Experimental Procedures

Twenty-five Holstein calves, weighing approximately 300 lb, were purchased from a local supplier and blocked by weight into five blocks. Within blocks, calves were assigned randomly to one of five treatments arranged in a 2 x 2 factorial design with an unexercised control, with two treadmill speeds (2.5 or 5.0 mph) and two exercise durations (10 or 15 min). Calves had ad libitum access to a high-concentrate diet and water for a minimum of 4 weeks before each replicate. Seven days before exercise treatments, each block of calves was moved from the University of Arkansas Beef Cattle Research Unit to the University of Arkansas Calf Research Facility, and subjected to a single, 10-min training/screening session where all calves were exercised at 1.25 mph for approximately 10 min. Afterwards, calves were stanchioned in individual metabolic crates, and individually fed the high-concentrate diet at a rate of 2.5% of their individual body weight. Calves had ad libitum access to water via automated bowl-waterers attached to each crate.

Calves were fitted with indwelling jugular catheters 24 h before stressor treatment to facilitate repeated blood sampling. On the morning of exercise treatment, a sample of blood was collected 10 min before moving the calf from its home stanchion to the treadmill. After a 4-min acclimation period on the treadmill, a blood sample was collected (designated –2 min) and the treadmill speed was gradually increased from 0 to the appropriate speed (2.5 or 5.0 mph) in a 2-min period of time. When the treatment speed was achieved, a sample of blood was collected (designated as the 0-min sample) and the calf was exercised for either 10 or 15 min (additional blood samples were collected at 2-min intervals until completion of exercise). Unexercised control calves were placed upon the treadmill, but were not subjected to exercise. Samples of blood were collected at 2-min intervals for the duration of each treatment, and assayed for serum cortisol (by direct RIA), and plasma glucose, lactate, and non-esterified fatty acids (NEFA; by commercially-available diagnostic kits). Upon completion of the specified exercise treatment, calves were moved approximately 100 yards to the University of Arkansas Red Meat Abattoir, and harvested according to industry-accepted procedures. Immediately following non-penetrating, captive bolt stunning and exsanguination, samples of the longissimus muscle (LM) were excised from the right side of each carcass. Subsequently, LM samples were removed at 45 min, 1.5, 3, 6, 12, and 24 h after stunning. Approximately 2 g of LM was used for pH determinations, whereas

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the remainder of the sample was frozen immediately in liquid nitrogen for determination of muscle glycogen and lactate concentrations at a later date.

After a 48-h chilling period at 34°F, left sides were ribbed between the 12th and 13th ribs, and the wholesale rib was fabricated from the forequarter. Three 1.0-in thick LM steaks were removed from each rib, and subjective and objective color measurements were collected on two steaks; whereas, the third LM steak was used to measure moisture content and water-holding capacity. Longissimus muscle color was subjectively evaluated using the Japanese color standards for pork (Nakai et al., 1975) by a three-person panel after a 30-min bloom period at 38°F. The Japanese color scoring system, consisting of six plastic disks with meat-like texture, is widely used as the standards for visual appraisal of veal color (E. D. Mills, personal communication). Additionally, L* (a measure of darkness to lightness; a larger number indicates a lighter color), a* (a measure of redness; a larger number indicates a redder color), and b* (a measure of yellowness; a larger number indicates a more yellow color) values of LM steaks were determined from a mean of four random readings with a Hunter MiniScan XE (Hunter Associates Laboratory, Reston, VA) using illuminant C. After color measurements were collected, both 1.0-in thick steaks were paper-wrapped and stored at -20°F for determination of cooking loss percentage and Warner-Bratzler shear force (WBSF) analyses.

*Muscle pH and Water-Holding Capacity.* Approximately 1 g of excised muscle at each sampling time was homogenized with 10 mL of 5 mM sodium iodoacetate in 150 mN of potassium chloride. The pH of the homogenate was measured with a temperature-compensating, combination electrode attached to a pH/Ion/FET-meter (Denver Instrument Co., Arvada, CO). Moisture content of the LM was determined according to the freeze-drying procedure of Apple et al. (2001). Additionally, the amount of free and bound moisture was measured using the Carver press/compensating planar planimeter method of Urbin et al. (1962).

*Warner-Bratzler Shear Force Determination.* Rib steaks were thawed for 16 h at 36°F, deboned, weighed, and then cooked to an internal temperature of 174°F in a commercial convection oven (Zephaire E; Blodgett Oven Co., Burlington, VT) preheated to 365°F. Internal temperature was monitored with Teflon-coated thermocouple wires (Type T; Omega Engineering, Inc., Stamford, CT) placed in the geometric center of each steak and attached to a multichannel data logger (model 245A; VAS Engineering, Inc., San Diego, CA). Immediately after removal from the oven, steaks were blotted dry, weighed, and the difference between pre- and post-cooked weights was used to calculate cooking loss percentage. Then, steaks were chilled overnight at 38°F, and at least five 0.5-in diameter cores were removed parallel with the muscle fiber orientation, and each core was sheared once through the center with a Warner-Bratzler shear force device attached to an Instron Universal Testing Machine (model 4466; Instron Corp., Canton, MA) equipped with a 110-lb tension/compression load cell and a crosshead speed setting of 10 in/min.

*Statistical Analyses.* All data were analyzed as a randomized complete block design with calf as the experimental unit. Blood data, as well as postmortem pH decline data, were analyzed as a repeated measure using PROC MIXED (SAS Inst., Inc., Cary, NC) with sampling time as the repeated variable, calf as the subject, and stressor treatment and treatment x sampling time included in the model as fixed effects (random effects included block and block x treatment x calf). PROC MIXED was also used to generate the analysis of variance for all beef quality data. The lone fixed effect was exercise treatment, whereas block and block x treatment were the random effects included in the model. Least squares means were computed for all main and interactive effects, and separated statistically using pair-wise t-tests (PDIFF option of SAS).

## Results and Discussion

*Physiological Responses.* Serum cortisol concentrations were similar ($P > 0.10$) among treatments before exercise (-10 and –2 min), and during the first 2 min of exercise (Fig. 1). However, after 4 min of exercise, serum cortisol levels were higher ($P < 0.01$) in calves exercised for 10 min at 5.0 mph than unstressed controls (treatment x time interaction; $P < 0.0001$). Additionally, after 6 and 8 min of exercise, calves exercised for 10 min at 5.0 mph had higher ($P < 0.01$) serum cortisol levels than unexercised calves and calves exercised for 10 min at 2.5 mph, and, after 10 min of exercise, calves exercised at 5.0 mph, regardless of the duration of exercise, had greater ($P < 0.01$) circulating cortisol levels than control calves. Thus, exercise at 5.0 mph appeared to have effectively elicited a stress response.

Even though there was no exercise treatment x time interaction ($P = 0.35$) for plasma glucose (Fig. 2), plasma lactate (Fig. 3) levels increased sharply during the 2-min period where treadmill speed was gradually increased to the appropriate treatment speed (treatment x time interaction; $P < 0.0001$). In 0-min samples, calves exercised for 10 min at 5.0 mph had higher ($P < 0.01$) plasma lactate concentrations than calves exercised at 2.5 mph, regardless of length of exercise, and unexercised controls. Moreover, calves exercised at a treadmill speed of 5.0 mph had higher ($P < 0.01$) circulating lactate levels than either unstressed controls or calves exercised at a speed of 2.5 mph after, 2, 4, 6, 8, and 10 min of exercise.

Plasma NEFA levels were similar ($P > 0.10$) before exercise and before treatment speeds had been achieved (Fig. 4); however, after 2 and 4 min of exercise, unexercised calves had higher ($P < 0.01$) plasma NEFA concentrations than calves exercised for 10 min at either 2.5 or 5.0 mph (treatment x time interaction; $P = 0.008$). Moreover, control calves continued to have higher circulating NEFA levels than exercised calves after 6 min of exercise. Plasma NEFA levels began to rebound in exercised calves after 8 min of exercise, when NEFA levels of controls were only higher ($P < 0.01$) than calves exercised at 5.0 mph (regardless of exercise duration); thereafter, there was no effect ($P > 0.10$) of exercise on plasma NEFA concentrations.

Even though plasma glucose levels were not affected by exercise, the increase in plasma lactate would indicate increased metabolism of muscle and liver glycogen, as well as available glucose. However, similar to the results of Apple et al. (1994) with sheep, circulating lactate levels declined as duration of exercise was extended which implies that calves never reached the anaerobic threshold where muscle metabolism shifts from aerobic metabolism and beta-oxidation of fatty (supported by the plasma NEFA results) acids to anaerobic metabolism of muscle glycogen.

*pH decline and LM Quality Attributes.* Postmortem pH decline in the LM is presented in Fig. 5. In the LM, pH values were similar among treatment groups at all sample times, and mean ultimate (48-h) pH values ranged from 5.67 to 5.73 (which is within the pH range of normal meat). There was no difference ($P > 0.10$) in visual color scores or instrumental measures of lightness (L*), redness (a*), and yellowness (b*) among treatments. Moreover, exercise did not ($P > 0.10$) impact the moisture content and water-holding capacity of the LM, or WBSF values of cooked steaks.

## Implications

Treadmill exercise resulted in elevations in circulating cortisol, lactate, and non-esterified fatty acids, but failed to alter postmortem metabolism or produce dark-cutting carcasses. Therefore, subjecting lightweight calves to treadmill exercise, under these experimental conditions, would not be a suitable animal-model to study the dark-cutting condition in a controlled laboratory setting.

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**Table 1. Effect of treadmill exercise on beef quality attributes of Holstein calves.**

| | | 2.5 mph | | 5.0 mph | | |
|---|---|---|---|---|---|---|
| Quality trait | Control | 10 min | 15 min | 10 min | 15 min | SE |
| Color score[a] | 4.9 | 4.8 | 4.6 | 5.0 | 4.5 | 0.19 |
| Lightness (L*)[b] | 40.04 | 40.40 | 41.71 | 39.73 | 41.95 | 0.773 |
| Redness (a*)[b] | 11.80 | 11.78 | 11.93 | 11.51 | 10.86 | 0.544 |
| Yellowness (b*)[b] | 13.50 | 13.72 | 14.03 | 13.30 | 13.70 | 0.324 |
| Moisture content, % | 76.6 | 76.3 | 77.1 | 76.6 | 76.7 | 0.26 |
| Bound water, % | 56.7 | 57.0 | 54.3 | 58.5 | 56.6 | 1.90 |
| Free water, % | 43.3 | 43.0 | 45.7 | 41.5 | 43.4 | 1.90 |
| Cooking loss, % | 29.2 | 32.3 | 33.2 | 29.5 | 27.8 | 1.85 |
| Shear force, lb | 24.2 | 24.2 | 26.4 | 25.1 | 23.4 | 2.97 |

[a] Color score: 1 = pale gray to 6 = dark purple (Nakai et al., 1975).
[b] L* values are a measure of lightness to darkness (lower number indicates a darker color); a* values area measure of redness (larger number indicates redder color); and b* values are a measure of yellowness (larger number indicates more yellow color).

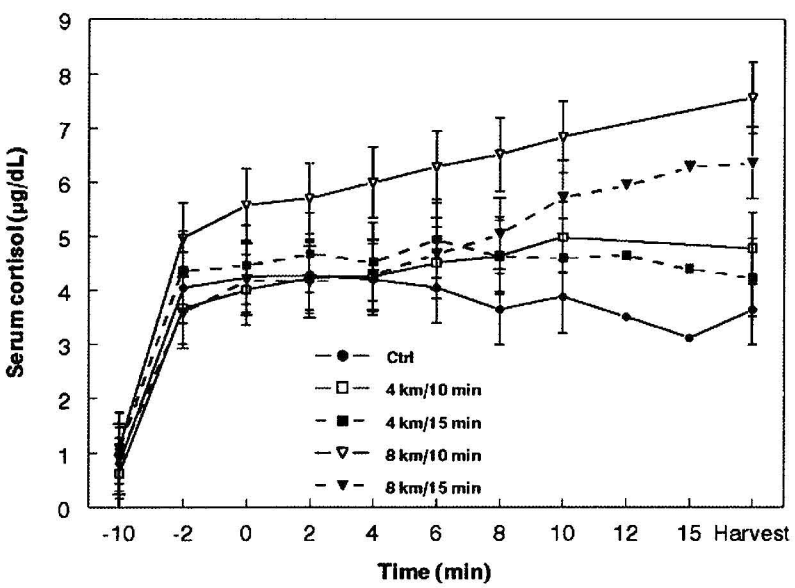


**Fig. 1. Effect of treadmill exercise speed and duration on serum cortisol concentrations (treatment x time interaction; P < 0.0001).**

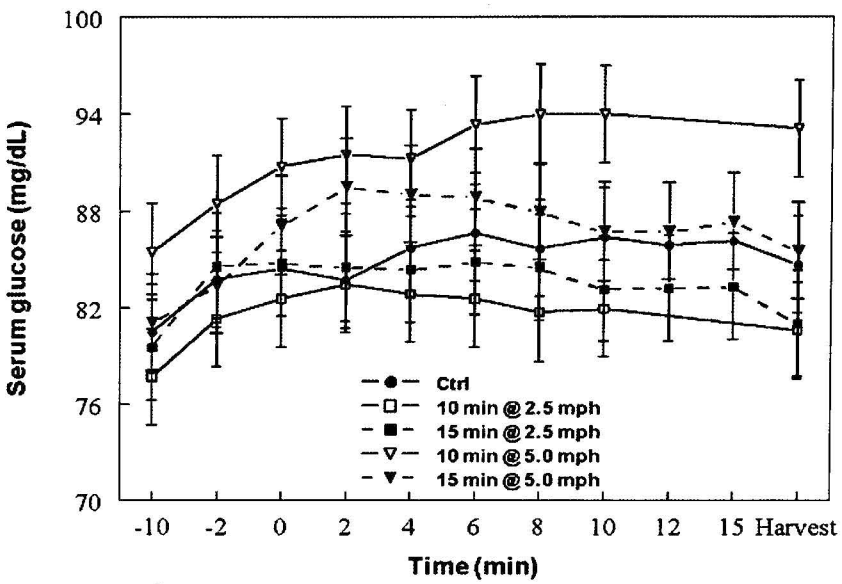


**Fig. 2. Effect of treadmill exercise speed and duration on plasma glucose concentrations (treatment x time interaction; P = 0.35).**

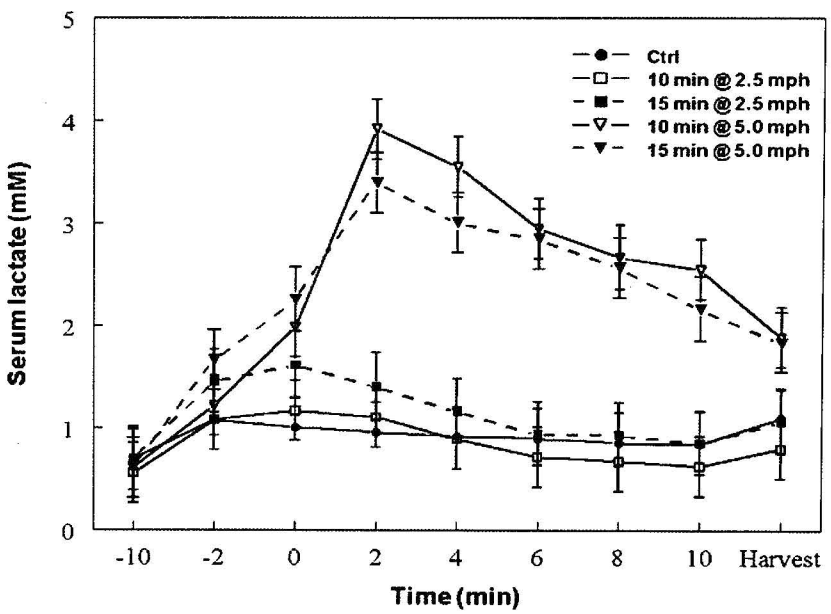


**Fig. 3. Effect of treadmill exercise speed and duration on plasma lactate concentrations (treatment x time interaction; P < 0.0001).**

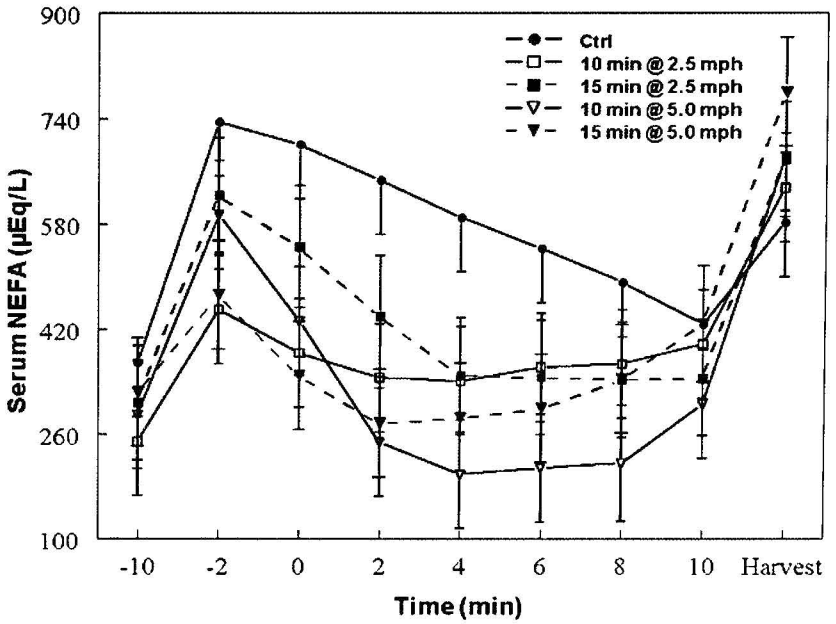


**Fig. 4. Effect of treadmill exercise speed and duration on plasma NEFA concentrations (treatment x time interaction; P = 0.008).**

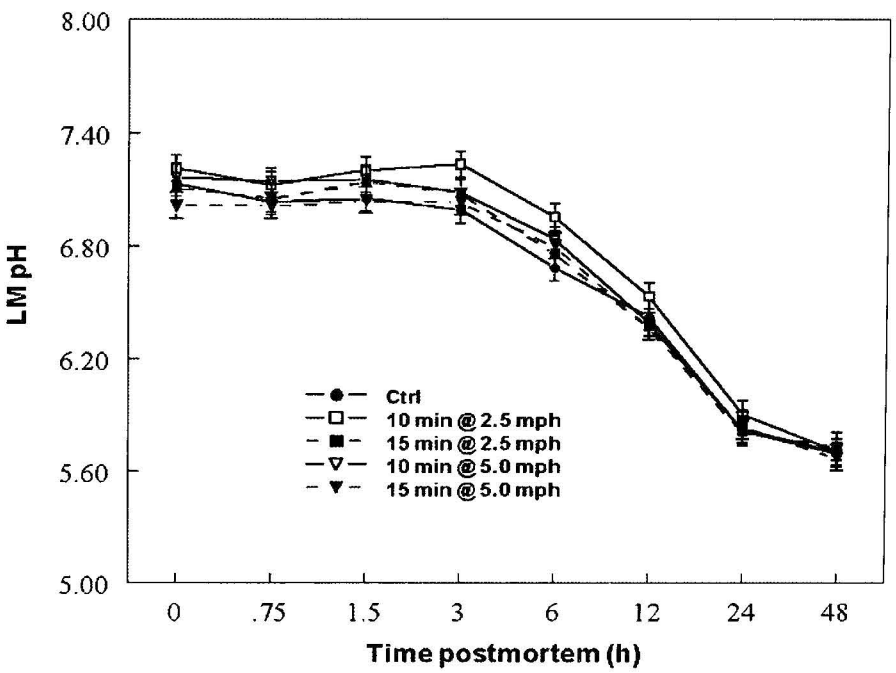


**Fig.5. Postmortem pH decline in the longissimus muscle (LM) as affected by speed and duration of treadmill exercise (treatment x time interaction; P = 0.92).**

# Feeding Feedlot Steers Fish Oil Differentially Enhances the Fatty Acid Composition of Muscle Tissue[1]

*T.J. Wistuba[2,3], E.B. Kegley[2], J.K. Apple[2], and D.C. Rule[4]*


## Story in Brief

Inclusion of fish oil, a source of omega-3 fatty acids, in ruminant diets may fortify the fatty acid composition of meats. Therefore, a 70-day study using 16 crossbred steers (970 ± 69.7 lb initial BW; four calves/pen; two pens/dietary treatment) was conducted. Dietary treatments consisted of: 1) control (75% corn, 11% soybean meal, and 10% cottonseed hull diet); and 2) the control diet with 3% fish oil replacing a portion of the corn. Calves were harvested on days 71 and 72. Collected tissue samples included the longissimus dorsi from the 6th to 7th rib section and ground tissue from the 10th to 12th rib. Total saturated fatty acids in both of the muscle tissue locations were increased ($P < 0.01$) with the inclusion of fish oil in the diet. The proportion of monounsaturated fatty acids in muscle tissue was decreased ($P < 0.01$) in the calves fed fish oil. Fish oil addition to the diet resulted in increased ($P < 0.03$) proportions of total polyunsaturated fatty acids in the ground rib sections, however fish oil supplementation had no effect ($P > 0.10$) on the proportion of total polyunsaturated fatty acids in the longissimus dorsi. Calves that consumed the fish oil diet had higher ($P < 0.01$) levels of omega-3 fatty acids in both muscle tissues, resulting in the fish oil supplemented calves having a lower ($P < 0.01$) omega-6:omega-3 ratio. Results indicate that fish oil may have a place in beef rations and a role in the niche marketing of beef provided there are no deleterious effects on consumer satisfaction.


## Introduction

In the future, there will be considerable emphasis on modification of fatty acid composition of beef. Recently, the dietary recommendation for humans of the highly unsaturated omega-3 fatty acids, specifically eicosapentaenoic acid (20:5) and docosahexanoic acid (22:6), was increased from 0.15 to 0.65 g/d. It has been demonstrated that intestinal supply and muscle tissue composition of fatty acids in beef cattle were affected by the fatty acid composition of the diet. Feeding lipids high in long chain polyunsaturated lipids can enhance the fatty acid concentrations found in meat from beef cattle and milk from dairy cattle. Limited research, however, is available regarding the effects of dietary manipulation on ruminant muscle and adipose tissue composition of long chain polyunsaturated fatty acids. Therefore, our objectives were to determine the effects of fish oil supplementation in the finishing diet on the fatty acid composition of muscle and adipose tissue of beef.

## Experimental Procedures

*Animals and feed.* Sixteen Angus crossbred steers (970 ± 69.7 lb initial BW) from the same maternal herd were obtained from the University of Arkansas Livestock and Forestry Branch Station in Batesville. Steers were blocked by weight and randomly assigned to pens with covered bunks and bunk aprons, such that four steers were maintained in each of four pens, for a total of 8 steers per dietary treatment. Dietary treatments (Table 1) consisted of: 1) control and 2) the control diet with 3% fish oil replacing corn on an equal weight basis. The diets were mixed at approximately weekly intervals. Steers were allowed ad libitum access to their respective diets and water for 70 d starting on October 24, 2000. Growth performance data are reported in Wistuba et al. (2002). Feed samples were taken on weigh days and analyzed.

*Tissue collection and sample preparation.* The cattle were stratified by treatment and harvested on d 71 and 72. Steers were stunned via captive bolt pistol and exsanguinated. After routine processing, carcasses were hung and chilled at 36°F for 24 h, at which time they were ribbed at the 12th rib. Left primal ribs from each carcass were removed and cut into three sections including the 6th to 7th, 8th to 9th, and 10th to 12th ribs at 96 h postmortem. The 6th to 12th rib sections were vacuum packaged in barrier bags. The vacuum-packaged muscles and carcasses were aged until 14 d postmortem in a cooler at 36 to 39°F. The muscles were removed from the vacuum bags after aging for the removal of two steaks that were 1-in-thick from the longissimus dorsi of the 6th to 7th rib section. The steaks were stripped of surrounding epimysium for the fatty acid analysis of the longissimus dorsi. Longissimus muscle from the 10th to 12th ribs was removed from the bone and ground for the determination of ground muscle fatty acid composition. Tissue samples were stored in airtight Whirl-Pak bags (Nasco) at –4°F. Prior to analysis, duplicate 30 g samples were pulverized in liquid nitrogen in a Waring blender, freeze dried, and stored at –4°F until fatty acid analysis.

*Fatty acid analysis.* Triplicate 150-mg muscle tissue samples were subjected to direct transesterification by incubating in 2.0 mL of 0.2 M methanolic KOH according to the methods of Murrieta et al. (2003). Fatty acid methyl esters were transferred to gas liquid chromatograph vials that contained a 1.0-mm bed of anhydrous sodium sulfate. Separation of fatty acid methyl esters was achieved by gas liquid chromatography with a 100-m capillary column. Identification of peaks was accomplished using purified standards.

*Statistical analysis.* Tissue fatty acid data were subjected to analysis of variance using a general linear model (SAS Inst. Inc., Cary, NC). Data are presented as least-squares means. Separate analyses were conducted within each type of sampled tissue. The model included weight block and dietary treatment and calf was the experimental unit.

[1] Research was funded in part by a grant from the Arkansas Beef Council.

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## Results and Discussion

In ruminants as in other species, the degree of unsaturation of fat depends on anatomical location. In general, subcutaneous sites are most unsaturated followed by inter- and intramuscular fat and internal organ fat being most saturated. In addition, within subcutaneous locations, the most external layers of fat are the most unsaturated with saturation increasing with depth or distance from the exterior. Patterns of unsaturation are inversely related to temperature of the depot location, a concept that applies across many species.

*Fatty Acid Composition of Longissimus dorsi Muscle and Ground Rib Tissue.* Steers fed the fish oil diet had higher ($P < 0.01$) levels of total saturated fatty acids and individual proportions of saturated fatty acids, except for the proportion of 18:0 which was not different ($P > 0.10$) than the control calves in both ground rib and LD tissues (Tables 2 and 3). The findings in longissimus dorsi muscle and ground rib tissue are similar to others that reported that fish oil supplementation had no effect on the proportion of 18:0 in muscle phospholipids and triacylglycerol (Ashes et al., 1992). However, Scollan et al. (2001) reported that fish oil fed in a diet that was 60% forage and 40% grain reduced the proportion of 18:0 in muscle phospholipids and had no effect in neutral lipids and phospholipids in adipose tissue when compared to the control group. Rule et al. (1994) reported that increasing the proportion of 18:0 would be beneficial to the beef industry because this FA is hypocholesteremic in humans. Fish oil fed calves had greater ($P < 0.01$) levels of 14:0, 15:0, 16:0, and 17:0 than the control fed calves. Because palmitic acid (16:0) is thought to be hyperlipidemic and may contribute to increasing serum cholesterol (Lough et al., 1992), increasing its proportion in beef would not be desired. In contrast to the current study, the proportion of 16:0 in muscle triacylglycerol and phospholipids was not affected by feeding fish oil in other studies (Ashes et al., 1992; Scollan et al., 2001).

Total monounsaturated fatty acids in the LD and ground rib were lower ($P < 0.01$) in the fish oil fed calves, with the majority of this resulting from a decrease ($P < 0.01$) in the proportion of $18:1^{cis-9}$. However, fish oil supplemented calves had greater ($P < 0.08$) quantities of $18:1^{cis-11}$. Bolte et al. (2002) reported a similar reduction in $18:1^{cis-9}$ with supplemental fish oil.

In the current study, fish oil addition to the diet had no effect ($P > 0.10$) on the total proportion of PUFA in the longissimus dorsi. Although, in the ground muscle tissue, total proportions of PUFA in fish oil fed calves were greater ($P < 0.01$). Fish oil fed calves did have higher ($P < 0.09$) levels of $18:2^{cis-9, trans-11}$, 20:2, 20:4, and 22:5 in both tissues. However, in the current study the control supplemented calves had greater ($P < 0.09$) concentrations of 18:2 in the LD and ground rib. Ashes et al. (1992) reported similar results in muscle phospholipids when feeding ruminally protected fish oil at 30% of the diet. However, fish oil had no effect on the proportions of 18:2 or 18:3 when it was fed at 20% of the diet. Ashes et al. (1992) also reported that fish oil supplementation increased the proportions of 20:3, 20:4, 20:5, and 22:6 in muscle when compared to control calves. In contrast, Scollan et al. (2001) suggested that fish oil supplementation increased the proportions of 20:3, 20:5, 22:5, and 22:6 but reduced the proportion of 20:4.

Calves that consumed the fish oil diet had greater ($P < 0.01$) levels of omega-3 fatty acids in the LD and ground rib tissues. However, there was no effect ($P > 0.10$) due to dietary treatment on the level of omega-6 fatty acids. These findings resulted in the fish oil supplemented calves having a lower ($P < 0.01$), more desirable, omega-6:omega-3 ratio. The significance of omega-3 fatty acids, particularly 20:5 and 22:6, to human health has been discovered within the past two decades (Ponnampalam et al., 2001). The recommended level of consumption of 20:5 and 22:6 for adults ranges from 0.3 to 0.65 g/d. Based on the recommended levels, the weight percentages of 20:5 and 22:6 in longissimus dorsi muscle and ground rib tissue locations could supply an adult eating a 100 g portion of meat a day with a portion of their recommended daily allowance. In the current study, there was no difference in the polyunsaturated:saturated fatty acid ratio due to dietary treatment. Scollan et al. (2001) suggested that fish oil supplementation tended to decrease the polyunsaturated:saturated fatty acid ratio.

## Implications

The increase in the proportion of $18:2^{cis-9, trans-11}$, 20:5, and 22:6 that was observed in the tissues of fish oil supplemented steers may not supply adequate quantities of these fatty acids to meet the recommended daily allowances for humans. Inclusion of this beef in a balanced diet will aid in the improvement of the essential fatty acid status in the diet of humans.

## Acknowledgements

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**Table 1. Ingredient and nutrient compositions (as-fed basis) of experimental diets.**

| Item | Control | Fish oil |
|---|---|---|
| Ingredient | % | |
| Corn, cracked | 75.4 | 72.4 |
| Cottonseed hulls | 10 | 10 |
| Soybean meal | 11.2 | 11.2 |
| Cane molasses | 2 | 2 |
| Dicalcium phosphate | 0.4 | 0.4 |
| Limestone, 38% Ca | 0.85 | 0.85 |
| Salt | 0.15 | 0.15 |
| Fish oil | 0 | 3 |
| Rumensin premix[a] | + | + |
| Vitamin premix[b] | + | + |
| Trace mineral premix[c] | + | + |
| Nutrient composition | | |
| Dry matter | 88.3 | 86.8 |
| Crude protein | 13.78 | 13.45 |
| Acid detergent fiber | 7.8 | 7.6 |
| Neutral detergent fiber | 11.5 | 11.4 |
| Fat | 3.44 | 6.66 |
| $NE_m$, Mcal/kg[d] | 2.08 | 2.17 |
| $NE_g$, Mcal/kg[d] | 1.32 | 1.39 |

[a] Premix supplied 22 ppm of monensin.

[b] Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin $D_3$, and 0.15 IU vitamin E.

[c] Premix supplied: 20 ppm of Zn as ZnO, 10 ppm of Mn as MnO, 8 ppm of Cu as $CuSO_4$, 0.10 ppm of Se as $Na_2SeO_3$, and 0.10 ppm of Co as $CoCO_3$.

[d] Calculated.

**Table 2. Influence of fish oil supplementation on the fatty acid composition of longissimus dorsi muscle tissue.**

| Fatty acid[a] | Control | Fish oil | SEM | P< |
|---|---|---|---|---|
| Saturated fatty acids | 45.77 | 51.13 | 0.90 | 0.01 |
| 14:0 | 2.72 | 3.67 | 0.21 | 0.01 |
| 15:0 | 0.33 | 0.55 | 0.03 | 0.01 |
| 16:0 | 26.02 | 30.05 | 0.51 | 0.01 |
| 17:0 | 1.11 | 1.62 | 0.05 | 0.01 |
| 18:0 | 15.55 | 14.99 | 0.58 | 0.51 |
| 22:0 | 0.02 | 0.18 | 0.02 | 0.01 |
| Monounsaturated fatty acids | 47.2 | 38.98 | 0.85 | 0.01 |
| $14:1^{cis-9}$ | 0.43 | 0.42 | 0.06 | 0.88 |
| 16:1 | 2.98 | 2.62 | 0.18 | 0.18 |
| 17:1 | 0.7 | 0.62 | 0.04 | 0.21 |
| $18:1^{cis-9}$ | 39.01 | 25.93 | 0.83 | 0.01 |
| $18:1^{cis-11}$ | 1.42 | 1.81 | 0.07 | 0.01 |
| $18:1^{trans-9}$ | 0.11 | 0.10 | 0.02 | 0.70 |
| $18:1^{trans-11}$ | 2.55 | 7.48 | 0.31 | 0.01 |
| Polyunsaturated fatty acids | 3.71 | 4.01 | 0.39 | 0.60 |
| 18:2 | 2.54 | 1.93 | 0.24 | 0.09 |
| $18:2^{cis-9,\ trans-11}$ | 0.21 | 0.26 | 0.02 | 0.03 |
| 18:3 | 0.19 | 0.32 | 0.02 | 0.01 |
| 20:2 | 0.17 | 0.28 | 0.03 | 0.04 |
| 20:3 | 0.41 | 0.49 | 0.11 | 0.63 |
| 20:4 | 0.04 | 0.35 | 0.05 | 0.01 |
| 20:5 | 0.15 | 0.24 | 0.04 | 0.18 |
| 22:5 | 0.00 | 0.15 | 0.03 | 0.01 |
| 22:6 | 0.00 | 0.003 | 0.002 | 0.36 |
| Omega-3[b] | 0.34 | 0.71 | 0.06 | 0.01 |
| Omega-6[c] | 3.00 | 2.76 | 0.33 | 0.63 |
| Omega-6:omega-3 | 9.81 | 3.92 | 1.15 | 0.01 |
| Polyunsaturated:saturated | 0.08 | 0.08 | 0.008 | 0.86 |

[a] Weight percentage values are relative proportions of all peaks observed by gas liquid chromatography.
[b] Omega-3 fatty acids included $18:3^{cis-9,12,15}$, $20:5^{cis-5,8,11,14,17}$, $22:5^{cis-7,10,13,16,19}$, and $22:6^{cis-4,7,10,13,16,19}$.
[c] Omega-6 fatty acids included $18:2^{cis-9,12}$, $20:3^{cis-8,11,14}$, and $20:4^{cis-5,8,11,14}$.

**Table 3. Influence of fish oil supplementation on the fatty acid composition of ground muscle tissue.**

| Fatty acid[a] | Control | Fish oil | SEM | P< |
|---|---|---|---|---|
| Saturated fatty acids | 45.85 | 53.88 | 1.04 | 0.01 |
| 14:0 | 2.80 | 4.40 | 0.16 | 0.01 |
| 15:0 | 0.41 | 0.68 | 0.02 | 0.01 |
| 16:0 | 25.26 | 30.83 | 0.66 | 0.01 |
| 17:0 | 1.18 | 1.59 | 0.04 | 0.01 |
| 18:0 | 16.15 | 16.28 | 0.69 | 0.90 |
| 22:0 | 0.01 | 0.04 | 0.005 | 0.01 |
| Monounsaturated fatty acids | 48.09 | 36.69 | 0.86 | 0.01 |
| 14:1$^{cis-9}$ | 0.54 | 0.54 | 0.06 | 0.94 |
| 16:1 | 3.00 | 2.74 | 0.16 | 0.27 |
| 17:1 | 0.74 | 0.58 | 0.03 | 0.01 |
| 18:1$^{cis-9}$ | 38.75 | 21.81 | 0.59 | 0.01 |
| 18:1$^{cis-11}$ | 1.40 | 1.59 | 0.07 | 0.08 |
| 18:1$^{trans-9}$ | 3.54 | 9.29 | 0.38 | 0.01 |
| Polyunsaturated fatty acids | 2.31 | 2.69 | 0.09 | 0.01 |
| 18:2 | 1.60 | 1.13 | 0.05 | 0.01 |
| 18:2$^{cis-9,\ trans-11}$ | 0.025 | 0.052 | 0.002 | 0.01 |
| 18:3 | 0.42 | 0.39 | 0.03 | 0.46 |
| 20:2 | 0.04 | 0.09 | 0.005 | 0.01 |
| 20:3 | 0.08 | 0.25 | 0.02 | 0.01 |
| 20:4 | 0.07 | 0.42 | 0.02 | 0.01 |
| 20:5 | 0.03 | 0.25 | 0.016 | 0.01 |
| 22:5 | 0.04 | 0.09 | 0.01 | 0.01 |
| 22:6 | 0.00 | 0.01 | 0.003 | 0.03 |
| Omega-3[b] | 0.48 | 0.75 | 0.04 | 0.01 |
| Omega-6[c] | 1.76 | 1.80 | 0.07 | 0.69 |
| Omega-6:omega-3 | 3.71 | 2.45 | 0.19 | 0.01 |
| Polyunsaturated:saturated | 0.05 | 0.05 | 0.003 | 0.98 |

[a] Weight percentage values are relative proportions of all peaks observed by gas liquid chromatography.
[b] Omega-3 fatty acids included 18:3$^{cis-9,12,15}$, 20:5$^{cis-5,8,11,14,17}$, 22:5$^{cis-7,10,13,16,19}$, and 22:6$^{cis-4,7,10,13,16,19}$.
[c] Omega-6 fatty acids included 18:2$^{cis-9,12}$, 20:3$^{cis-8,11,14}$, and 20:4$^{cis-5,8,11,14}$.

# Influence of Fish Oil Addition to Finishing Diets on the Professional Descriptor Sensory Analysis of Steaks from Cattle[1]

*T.J. Wistuba[2], E.B. Kegley[3], and J.K. Apple[3]*


## Story in Brief

Inclusion of fish oil, a source of omega-3 fatty acids, in ruminant diets will fortify the fatty acid composition of meat and may modify the sensory perceptions of meat taste and tenderness. Therefore, a 70-day study using 16 crossbred steers (970 ± 69.7 lb initial BW; four calves/pen; two pens/dietary treatment) consuming a high concentrate ration was conducted. Dietary treatments consisted of: 1) control (75% corn, 11% soybean meal, and 10% cottonseed hull based diet); and 2) the control diet with 3% fish oil replacing a portion of the corn. Calves were stratified by treatment and harvested on days 71 and 72. In addition, a commercially available longissimus muscle steak product was purchased to add to the sensory evaluation session as a reference point. A professional descriptor panel was able to detect differences in the aromatic taste of degraded protein/fishy and the aroma of degraded protein/fishy between steaks from calves that had been supplemented with fish oil, a commercially available product, and steaks from control calves. The panel also detected differences between steaks from fish oil supplemented calves and the control and commercially available product for the texture profile characteristics: hardness of mass and number of chews. In summary, supplementation with fish oil increased ($P < 0.05$) the detection of degraded protein/fishy flavors in the meat by a professional descriptor panel; however, it is unknown if the typical consumer would find the flavors and aromas discerned unacceptable.


## Introduction

Typically fat is limited to < 5% of the diet of cattle in order to minimize negative effects on ruminal fiber digestion. In the rumen, most triglycerides are broken down and the fatty acids are hydrogenated; however, research indicates that increasing the proportion of omega-3 fatty acids in ruminant diets may modify the fatty acid composition of meat and milk (Ashes et al., 1992).

In the future, there will be considerable emphasis on modification of fatty acid composition of beef. Recently, the dietary recommendation for humans of the highly unsaturated omega-3 fatty acids, specifically eicosapentaenoic acid and docosahexanoic acid, has increased from 0.15 to 0.65 g/d (Kris-Etherton et al., 2000). However, feeding diets that alter the fatty acid content of meat may also affect other aspects of beef production including sensory and consumer perceptions about dining satisfaction. Previous research indicated that fish oil addition to the finishing diet did not alter ADG, feed/gain, or carcass quality; however, carcass weight was reduced (Wistuba et al., 2002). Dietary fish oil did fortify the omega-3 fatty acid composition of beef (Wistuba et al., 2003). The objective of this study was to determine the effects of fish oil addition on sensory characteristics of beef.

## Experimental Procedures

*Animals and feed.* Sixteen Angus crossbred steers (970 ± 69.7 lb initial BW) from the same maternal herd were obtained from the University of Arkansas Livestock and Forestry Branch Station in Batesville. Calves were blocked by weight and randomly assigned to pens with covered bunks and bunk aprons, such that four steers were maintained in each of four pens, for a total of eight steers per dietary treatment. Dietary treatments (Table 1) consisted of: 1) a control diet, and 2) the control diet with 3% fish oil replacing corn on an equal weight basis. The fish oil was produced from freshly caught menhaden (Omega Protein, Morgan City, LA). The diets were mixed at approximately weekly intervals. Steers were allowed ad libitum access to their respective diets and water for 70 d starting on October 24, 2000.

*Animal harvest and tissue collection.* Two calves/pen were harvested on d 71 and 72. Steers were stunned via captive bolt pistol and exsanguinated by severing the jugular veins on both the right and left sides. Left primal ribs from each carcass were removed and subsequently cut into three sections including the 6th to 7th, 8th to 9th, and 10th to 12th ribs at 96 h postmortem. The 6th to 9th rib sections were then vacuum packaged in barrier bags and aged until 14 d postmortem in a cooler at 36 to 39°F. After the aging period, the 8th to 9th rib section was cut into 1-in-thick steaks, and individually paper packaged, and stored at –4°F for 13 mo until the professional descriptor panel analysis for aromatic and palatability characteristics.

*Descriptive flavor and aroma profile evaluation.* A longissimus muscle steak from each animal was thawed at 39°F for 24 h. Steaks were cooked to an internal temperature of 95°F, turned, and then cooked to an endpoint internal temperature of 160°F on a food service grill preheated to 325°F. Internal temperature was monitored by 30-gauge, type-T thermocouples inserted into the geometric center of the steak and attached to a temperature recorder. A commercially available longissimus muscle steak product was added to the sensory evaluation session for a reference point. Each steak was cut into sample cubes of 0.5 $in^3$. Sensory panel evaluations were conducted in an environmentally controlled room partitioned into booths with a controlled mixture of red and green light. One orientation sample was evaluated and discussed at the beginning of each session. For each session, duplicate samples for each treatment were served warm and evaluated by an eight-member professional descriptor panel. Order of presentation was randomized for each panelist within each session. Flavor characteristics that were evaluated included:

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1) basic tastes: sweet, salt, sour, and bitter; and 2) aromatics: cooked beef, beef fat, blood serum/metallic, browned/caramelized/roasted, degraded protein/fishy, and other flavors. Aroma characteristics that were evaluated included cooked beef, beef fat, blood serum/metallic, browned/caramelized/roasted, and degraded protein/fishy. Sweet was defined as the basic taste, perceived on the tongue, stimulated by sugars and high potency sweeteners. Salt was defined as the basic taste, perceived on the tongue, stimulated by sodium salt, especially sodium chloride. The basic taste sour was perceived on the tongue and defined as the taste stimulated by acids, such as citric acid. Bitter was defined as the basic taste, perceived on the tongue, stimulated by substances such as quinine, caffeine, and certain other alkaloids. Cooked beef was defined as the aromatic associated with cooked beef muscle. Beef fat was defined as the aromatic associated with cooked beef fat. Blood serum/metallic was defined as the aromatic taste sensation associated with raw/rare meat, cooked blood and blood serum. Browned/caramelized/roasted was defined as a sweet aromatic characteristic of browned sugars and other carbohydrates. Degraded protein/fishy was defined as the aromatic associated with trimethylamine and old fish. The characteristics were scored to the nearest 0.5 on a scale ranging from 0 (least intense) to 15 (most intense). Aftertaste was defined as the taste that was perceived after the product had been tasted, chewed, and then expelled.

*Texture-attribute evaluation.* A trained, descriptive-attribute panel was utilized for determining the effects of fish oil supplementation during the finishing period on texture characteristics. The texture characteristics that were evaluated included: 1) first bite: hardness, cohesiveness, and moisture release; and 2) chewdown: cohesiveness of mass, hardness of mass, fibrousness, and number of chews. The procedures for this panel were in accordance with the guidelines set by the American Meat Science Association (1995). Duplicate 1 x 0.5 x 0.5-in. samples from each steak were provided to panelists. Hardness was defined as the force required to compress the sample. Cohesiveness was defined as the amount the sample deformed rather than split apart, cracked or broke. Moisture release was defined as the amount of wetness or moistness felt in the mouth after one bite or chew. Cohesiveness of mass was defined as the amount the chewed sample held together. Hardness of mass was defined as the force required to compress the sample/bolus after chewing. Fibrousness was defined as the amount of grinding of fibers required to chew through the sample.

*Statistical analysis.* The descriptive flavor and aroma profile data and the texture attribute data were analyzed using the general linear model procedure of SAS (SAS Inst., Inc., Cary, NC). The model included replication, steak source, and panelist. The experimental unit for the descriptive flavor and aroma profile data and the texture attribute data were sampled and least-squares means are reported. If steak source was significant ($P < 0.10$) then an *F*-protected t-test was used to separate the means.

## Results and Discussion

*Descriptive flavor profile.* Cooked longissimus muscle steaks from the fish oil supplemented steers did not differ in the basic tastes (sweet, salt, sour, and bitter) from the control or retail products in this study (Table 2, $P > 0.10$). When the aromatics were considered, the steaks from the fish oil supplemented steers did not differ in cooked beef, beef fat, blood serum/metallic, or browned/caramelized/roasted flavors ($P > 0.10$). However, fish oil supplementation did increase the aromatic sensation of degraded protein/fishy flavor ($P < 0.05$) compared to the control and retail products.

*Descriptive aroma profile.* The panel was able to detect the effect of fish oil supplementation on cooked beef and found that steaks from the fish oil supplemented steers had less cooked beef aroma than did the control and retail products (Table 3; $P < 0.05$). The panel also detected that steaks from fish oil supplemented steers had a greater ($P < 0.05$) degraded protein/fishy aroma than did the steaks from the control or the retail. However, no differences were detected between treatment for the beef fat, blood serum/metallic, or browned/caramelized/roasted aromas.

*Descriptive aftertaste profile.* Panelists were able to determine that steaks from fish oil supplemented steers had less cooked beef aftertaste than the retail (Table 4; $P < 0.05$). However, panelists did not distinguish a difference for the cooked beef aftertaste between the control and fish oil products ($P > 0.10$). Panelists did not detect differences between the three products in aftertaste for the flavors beef fat, blood serum/metallic, browned/caramelized/roasted, salt or bitter ($P > 0.10$). However, panelists did detect an increase in the aftertaste of degraded protein/fishy, where the retail product had the least flavor, the control product was intermediate ($P < 0.05$) and the fish oil product had the greatest amount of the flavor ($P < 0.05$).

*Descriptive texture-attribute profile.* The panel was not able to distinguish any differences for any of the three first bite attributes: hardness, cohesiveness of mass, or moisture release (Table 5; $P > 0.10$). However, during the chew-down portion of the descriptive texture attribute session, panelists did determine that the fish oil product had a higher hardness of mass and required more chews to swallow than did the control or retail products ($P < 0.05$). Fish oil supplementation also resulted in an increase in fibrousness between fish oil and retail ($P < 0.05$), but not between the control and fish oil ($P > 0.10$).

Ramaswamy et al. (2001) concluded that milk from dairy cows supplemented with 2% fish oil had no oxidized flavors when compared to a control. However, this conclusion was based on four experienced panelists and not a professional taste panel. Ponnampalam et al. (2002) utilized lambs in two experiments to determine the effect of diet on the fatty acid composition of the meat and the meats subsequent sensory characteristics. The authors concluded that fish meal and fish oil supplementation had no effect on flavor, flavor strength, aroma, aroma strength, or overall palatability; however, fish meal supplementation decreased the juiciness of the product when compared to the control.

## Implications

Fish oil supplementation, at the 3% level employed in this 70-day finishing study, did not have an effect on most of the meat characteristics studied. However, fish oil supplementation increased the aromatic sensation of degraded protein/fishy characteristics that were detected by the professional descriptor panel. It is unknown whether the typical consumer would be able to detect this negative characteristic.

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**Table 1. Ingredient and nutrient composition (as-fed basis) of experimental diets.**

| Item | Control | Fish oil |
|---|---|---|
| | % | |
| Ingredient | | |
| Corn, cracked | 75.4 | 72.4 |
| Cottonseed hulls | 10 | 10 |
| Soybean meal | 11.2 | 11.2 |
| Cane molasses | 2 | 2 |
| Dicalcium phosphate | 0.4 | 0.4 |
| Limestone, 38% | 0.85 | 0.85 |
| Salt | 0.15 | 0.15 |
| Fish oil | 0 | 3 |
| Rumensin premix[a] | + | + |
| Vitamin premix[b] | + | + |
| Trace mineral premix[c] | + | + |
| Nutrient | | |
| Dry matter | 88.3 | 86.8 |
| Crude protein | 13.78 | 13.45 |
| Acid detergent fiber | 7.8 | 7.6 |
| Neutral detergent fiber | 11.5 | 11.4 |
| Fat | 3.44 | 6.66 |
| $NE_m$, Mcal/kg[d] | 2.08 | 2.17 |
| $NE_g$, Mcal/kg[d] | 1.32 | 1.39 |

[a] Premix supplied 22 ppm of monensin.
[b] Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin $D_3$, and 0.15 IU vitamin E.
[c] Premix supplied: 20 ppm of Zn as ZnO, 10 ppm of Mn as MnO, 8 ppm of Cu as $CuSO_4$, 0.10 ppm of Se as $Na_2SeO_3$, and 0.10 ppm of Co as $CoCO_3$.
[d] Calculated.

**Table 2. Influence of fish oil supplementation on the descriptive taste profile of cooked longissimus dorsi steaks determined by a trained professional sensory panel[a].**

| Item | Retail | Control | Fish oil |
|---|---|---|---|
| Basic tastes | | | |
| Sweet | 0.57 ± 0.13 | 0.77 ± 0.13 | 0.57 ± 0.13 |
| Salt | 1.59 ± 0.10 | 1.53 ± 0.10 | 1.67 ± 0.10 |
| Sour | 0.80 ± 0.08 | 1.02 ± 0.08 | 1.04 ± 0.09 |
| Bitter | nd[b] | nd | nd |
| Aromatics | | | |
| Cooked beef | 4.91 ± 0.13 | 5.05 ± 0.17 | 4.98 ± 0.21 |
| Beef fat | 3.33 ± 0.25 | 3.42 ± 0.25 | 2.83 ± 0.25 |
| Blood serum/metallic | 4.41 ± 0.16 | 4.43 ± 0.18 | 4.56 ± 0.17 |
| Browned/caramelized/roasted | 3.52 ± 0.32 | 4.14 ± 0.32 | 3.16 ± 0.32 |
| Degraded protein/fishy | 0.06 ± 0.35[x] | 2.97 ± 0.48[y] | 6.56 ± 0.40[z] |

[a] Characteristics scored to the nearest 0.5 on a scale ranging from 0 (least intense) to 15 (most intense).
[b] Nondetectable
[x,y,z] Within a row, means without a common superscript letter differ ($P < 0.05$).

**Table 3. Influence of fish oil supplementation on the descriptive aroma profile of cooked longissimus dorsi steaks determined by a trained professional sensory panel[a].**

| Item | Retail | Control | Fish oil |
|---|---|---|---|
| Cooked beef | 4.59 ± 0.23[x] | 4.68 ± 0.23[x] | 3.57 ± 0.23[y] |
| Beef fat | 3.22 ± 0.28 | 3.61 ± 0.28 | 3.26 ± 0.28 |
| Blood serum/metallic | 3.93 ± 0.28 | 3.58 ± 0.32 | 4.16 ± 0.30 |
| Browned/caramelized/roasted | 4.08 ± 0.32 | 3.98 ± 0.32 | 3.53 ± 0.32 |
| Degraded protein/fishy | 0.68 ± 0.40[y] | 1.74 ± 0.42[y] | 4.96 ± 0.47[x] |

[a] Characteristics scored to the nearest 0.5 on a scale ranging from 0 (least intense) to 15 (most intense).
[x,y] Within a row, means without a common superscript letter differ ($P < 0.05$).

**Table 4. Influence of fish oil supplementation on the descriptive aftertaste profile of cooked longissimus dorsi steaks determined by a trained professional sensory panel[a].**

| Item | Retail | Control | Fish oil |
|---|---|---|---|
| Cooked beef | 3.41 ± 0.16[x] | 3.21 ± 0.19[xy] | 2.78 ± 0.21[y] |
| Beef fat | 2.24 ± 0.27 | 2.03 ± 0.27 | 1.60 ± 0.27 |
| Blood serum/metallic | 3.53 ± 0.12 | 3.78 ± 0.12 | 3.86 ± 0.12 |
| Browned/caramelized/roasted | 1.49 ± 0.29 | 1.47 ± 0.29 | 1.39 ± 0.29 |
| Degraded protein/fishy | 0.07 ± 0.26[x] | 1.97 ± 0.35[y] | 4.09 ± 0.29[z] |
| Salt | 0.88 ± 0.09 | 1.03 ± 0.09 | 1.10 ± 0.09 |
| Bitter | nd[b] | nd | nd |

[a] Characteristics scored to the nearest 0.5 on a scale ranging from 0 (least intense) to 15 (most intense).
[b] Nondetectable
[x,y,z] Within a row, means without a common superscript letter differ ($P < 0.05$).

**Table 5. Influence of fish oil supplementation on the descriptive texture profile of cooked longissimus dorsi steaks determined by a trained professional sensory panel.**

| Item | Retail | Control | Fish oil |
|---|---|---|---|
| First bite | | | |
| Hardness[a] | 7.93 ± 0.25 | 8.03 ± 0.25 | 8.21 ± 0.25 |
| Cohesiveness[a] | 9.35 ± 0.26 | 9.39 ± 0.26 | 9.65 ± 0.26 |
| Moisture release[a] | 5.18 ± 0.34 | 5.06 ± 0.34 | 5.67 ± 0.34 |
| Chewdown | | | |
| Cohesiveness of mass[a] | 7.70 ± 0.12 | 7.93 ± 0.12 | 7.78 ± 0.12 |
| Hardness of mass[a] | 6.70 ± 0.19[x] | 7.01 ± 0.19[x] | 7.56 ± 0.19[y] |
| Fibrousness[a] | 7.30 ± 0.23[x] | 8.14 ± 0.26[y] | 8.48 ± 0.30[y] |
| Number of chews | 24.56 ± 0.70[x] | 25.18 ± 0.70[x] | 28.44 ± 0.70[y] |

[a] Characteristics scored to the nearest 0.5 on a scale ranging from 0 (least intense) to 15 (most intense).
[x,y] Within a row, means without a common superscript letter differ ($P < 0.05$).

# Impact of Ham and Brine Temperatures on Processing Characteristics of Cured Ham

*J.N. Leach*[1] *and F.W. Pohlman*[1]


## Story in Brief

The effects of brine temperature and ham temperature during curing on injection and yield characteristics of cured hams were studied. Ham temperature and brine temperature were standardized to yield the following treatments: 1) 29°F ham and 29°F brine (CC), 2) 29°F ham and 34.5°F brine (IC) 3), 29°F ham and 39°F brine (CW) 4) 39°F ham and 29°F brine (WC), 5) 39°F ham and 34.5°F brine (WI) and 6) 39°F ham and 39°F brine (WW). Hams cured with the 29°F brine had less ($P < 0.05$) total weight loss from green weight to chill weight. Hams cured with the cold 29°F brine had less chill loss and cook loss than that of the warm brine. There were no differences in the mean losses and gains of the different ham temperatures in injection uptake, tumble loss, cook loss, chill loss, total gain, or loss from green to chill weight, and moisture. There were no differences in the mean values of the brine temperature for injection uptake, tumble loss, and moisture.


## Introduction

Hams are generally cured at the temperature of the individual cooling or processing room. Brine is often mixed at tap water temperatures and ice may or may not be added to lower brine temperatures, thus causing substantial variation in brine temperatures through the curing process. Brine retention is important to meat processors for yield improvement, brine distribution and color development. This is also important since purchasing decisions by consumers are influenced by product color (Dineen, 2000). Curing brine contains sodium nitrite thus making brine uptake an important factor in color and flavor stability in cured meats (Tichivangana et al., 1984). Although some knowledge exists about how brine or marinades affect yield, color, and tenderness characteristics of muscle foods, little is known regarding the impact of brine and ham temperature effects on these attributes. Therefore, the objective of this study was to determine what impact ham and brine temperatures have on injection and yield characteristics of cured hams.

## Experimental Procedures

*Processing.* For this experiment, hams were divided into two temperature groups; 29°F and 39°F. A commercial brine was mixed and brine temperatures were standardized into three groups; 29°F, 34.5°F and 39°F. Each treatment group consisted of ten hams that resulted in the following treatment combinations 1) 29°F ham and 29°F brine (CC); 2) 29°F ham and 34.5°F brine (CI); 3) 29°F ham and 39°F brine (CW); 4) 39°F ham and 29°F brine (WC); 5) 39°F ham and 34.5°F brine (WI); and 6) 39°F ham and 39°F brine (WW). Brine used for each treatment was made from ingredients originating from the same production lot to avoid lot to lot ingredient variation.

Fresh hams were placed on a perforated wire rack in a cooler operating at 29°F or 39°F 1 to 2 days prior to use to temper ham internal temperature. After mixing, the brine was placed in commercial brine chiller (Admix) and chilled to either 29°F, 34.5°F or 39°F. Internal ham temperatures were checked and recorded prior to the curing process. When hams reached either 29°F or 39°F internal temperature, samples of the psoas major and gluteous profundis muscles were removed from each ham and placed in whirl pack bags for moisture determination. Before injection, hams were weighed for fresh (green) weight and recorded. Each ham was then injected with a multiple needle automatic pickle injector (Fomaco FGM 40/20, Denmark). The injector was set for an injection rate of 40%. The injection parameters used were 3 bar pressure and 35 strokes per minute. The head speed was adjusted accordingly to yield a 40% injection rate. During injection, brine was continuously circulated through the brine chiller to maintain target brine temperatures.

After injection, hams were reweighed to determine injection rate, and internal ham temperatures were rechecked. The hams were then placed on a perforated wire screen and drained for 30 minutes. Hams were weighed for dry weight and then tumbled for 8 hours. During the tumbling process, each treatment tumbled for 1 hour, rested for 30 minutes, then tumbled again for a total of 8 hours. The hams were removed from the tumbler, placed in ham stockings, and weighed to determine tumble losses. The hams were next placed in a computer-controlled smokehouse (Alkar Model 1000 Smokehouse, USA) and cooked to an internal temperature of 157°F. The smoke cycle is shown in Table 1. Five thermocouples were placed in hams on top, bottom and center of the smokehouse to record temperatures during cooking and cooling. After 5 hours, hams were reweighed and internal temperatures recorded. Next, hams were placed in a cooler for chilling (34°F) for 24 hours then reweighed again to obtain ultimate chilled ham yield. After curing and chilling, ham center slices were removed from each ham. A portion of the *semimembranousus* muscle was removed from each ham for moisture analysis.

*Moisture analysis.* Moisture content was determined by freeze vacuum drying on fresh gluteous profundis muscles and on cured semimembranousus muscles obtained from hams. For this, duplicate samples of approximately 3 grams were weighed and placed in 30-mL beakers then weighed again. The beakers were placed in a vacuum-flask and frozen completely. Next, the vacuum-flasks were placed on a Labconco freeze dryer (model 4.5, Labconco Corp., Kansas City, MO) and dehydrated at a vacuum of < 10 um mercury

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(Hg). Samples remained on the freeze dryer for a minimum of 48 hours. The samples were re-weighed and the difference between the initial and dried beaker weights was divided by the sample weight and multiplied by 100 to calculate the percentage moisture.

*Statistical analysis*. The experiment was analyzed as a completely randomized factorial design. Data were analyzed by using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). For analysis, the main effects of ham and brine temperature as well as their interaction were placed in the model. Since there were no ham x brine temperature interactions for processing characteristics, least-squares means were generated for all dependent variables for each main effect and separated using the PDIFF option of SAS.

## Results and Discussion

The impact of ham temperature during curing on injection uptake, processing yields and moisture content are shown in Table 2. Since injection rate was calibrated, and therefore expected, ham temperature had no effect ($P > 0.05$) on injection uptake. Likewise, ham temperature did not affect ($P > 0.05$) ham tumble losses, cook losses, chill losses or final ham yield (total gain/loss %). Since ham temperature did not affect processing yields, cured moisture content did not differ ($P > 0.05$) between ham temperature treatments.

The impact of brine temperature on injection uptake, processing yields and moisture content are shown in Table 3. There were no differences ($P > 0.05$) between mean values for injection uptake percentage, tumble loss percentage and moisture content between brine temperature treatments. However, brine temperature did have an effect on mean cook losses where hams injected with 34.5°F brine had less ($P < 0.05$) cooking losses than those injected with 29°F brine. Futhermore, hams cured with 39°F brine had less cooking losses than those cured with either 29°F or 34.5°F brine. Ham chill losses were lowest ($P < 0.05$) for 34.5°F treatment, intermediate for the 39°F, and highest for the 29°F treatment. Therefore, total losses were affected ($P < 0.05$) by curing brine temperature, and losses declined with the use of progressively warmer brines. Advantages in ham cook yields when cured with warmer brines, therefore, also translated into greater final product ham yields and would lead to greater quantities of finished product to be sold. While Gillet et al. (1982) found that in boneless fresh hams that pump level had no effect on yield of intermittently massaged hams when the pump level exceed 30%, results from our study indicate that cook losses can be reduced and, therefore, yield increased by curing hams with warmer brines.

**Table 1. Ham cook and smoke cycle.**

| Step | Time, Min | Cycle | Dry Bulb | Wet Bulb | Relative Humidity, % |
|---|---|---|---|---|---|
| 1 | 10 | cook | 120 | 0 | 0 |
| 2 | 120 | cook | 150 | 90 | 12 |
| | | smoke, | | | |
| 3 | 180 | cook | 160 | 120 | 30 |
| 4 | 60 | cook | 170 | 130 | 32 |
| 5[a] | 60 | cook | 190 | 175 | 71 |

## Implications

Discovering a way to increase brine retention is important for producing higher quality hams with greater yields. The use of warmer brine curing temperatures can improve both cooked as well as chilled finished product yields and have an economic advantage by allowing increased quantities of product sold and therefore greater profitability.

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**Table 2. Least-squares means for injection uptake, tumble loss, cook loss, chill loss, total gain or loss, and moisture content as influenced by ham curing temperature.**

| | Ham temperature | |
|---|---|---|
| Trait | Cold (29°F) | Warm (39°F) |
| *Processing* | | |
| Injection uptake, % | 41.03 ± 1.25 | 41.92 ± 1.30 |
| Tumble loss, % | 3.54 ± 0.57 | 3.45 ± 0.53 |
| Cook loss, % | 22.39 ± 0.62 | 23.24 ± 0.59 |
| Chill loss, % | 8.01 ± 0.51 | 7.61 ± 0.51 |
| Total gain/loss, % | 9.70 ± 1.13 | 10.08 ± 1.13 |
| Moisture, % | 72.31 ± 0.80 | 71.28 ± 0.97 |

Means within a row do not differ ($P > 0.05$).

**Table 3. Least-squares means for injection uptake, tumble loss, cook loss, chill loss, total gain or loss, and moisture content as influenced by brine curing temperature.**

| | Brine temperature | | |
|---|---|---|---|
| | Cold | Intermediate | Warm |
| Trait | (29°F) | (34.5°F) | (39°F) |
| *Processing* | | | |
| Injection uptake, % | 42.66 ± 1.58 | 38.57 ± 1.58 | 43.19 ± 1.54 |
| Tumble loss, % | 3.66 ± 0.65 | 3.30 ± 0.63 | 3.38 ± 0.73 |
| Cook loss, % | 25.96 ± 0.71[x] | 21.82 ± 0.71[y] | 20.67 ± 0.80[z] |
| Chill loss, % | 15.84 ± 3.66[x] | 7.52 ± 3.66 [z] | 9.11 ± 3.78[y] |
| Total gain/loss, % | 14.59 ± 1.37[x] | 9.27 ± 1.37[y] | 5.80 ± 34.51[z] |
| Moisture, % | 73.09 ± 1.21 | 71.51 ± 1.05 | 70.79 ± 1.00 |

[xyz]Least-squares means within a row with no letters in common differ ($P < 0.05$).

# Evaluation of the Electronic Nose for Rapid Determination of Meat Freshness

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## Story in Brief

The Electronic Nose was used to determine changes in lipid oxidation and microbial load of ground beef throughout simulated retail display. Aerobic, vacuum and $CO_2$ mixing treatments were also evaluated to determine their impact on Electronic Nose, lipid oxidation and microbial characteristics. Beef trim and ground beef were mixed in a commercial mixer with treatments Air-None, (AN), Vacuum-None, (VN), $CO_2$-None, (CN), Air-Air, (AA), Air-Vacuum, (AV), and Air-$CO_2$, (AC) where the first designation indicates beef trimming mixing conditions and the second designates ground beef mixing conditions. After grinding and mixing, ground beef was stored under simulated retail display, and analyzed at days 0, 1, 2, 3, 6, and 10. Analyses included Thiobarbituric Acid Reactive Substances (TBARS), Aerobic Plate Count (APC), and Electronic Nose characteristics. The Electronic Nose detected changes ($P < 0.05$) in ground beef lipid and microbial stability as did conventional TBARS and APC measures. Therefore, the Electronic nose may hold promise for rapid detection of meat freshness and safety.


## Introduction

The challenges retail marketers encounter maintaining the shelf life of ground beef are due to color, lipid, and microbial stability. Increases in lipid oxidation have been observed in ground beef through retail display (Insausti et al., 1999). Likewise, the reduction of microorganisms in ground beef is critical to the Food Industry (Cutter and Siragusa, 1995) for safety and quality concerns. For lipid stability, thiobarbituric acid reactive substances (TBARS) testing has been used for the detection of malonaldehyde to estimate lipid oxidation of meat. While this procedure has been widely used, it is cumbersome and subject to error through lipid extraction procedures necessary to conduct the test. Therefore, it would be advantageous to have a rapid, nondestructive test that could indicate lipid and microbial characteristics of meat in real time. The Electronic Nose may provide a rapid means for assessing meat quality characteristics (Winquist et al., 1993). Therefore, an experiment was designed to determine the relationship between Electronic Nose response to TBARS values and aerobic bacterial counts in ground beef. Additionally, the Electronic Nose was evaluated to determine the impact of meat mixing treatments on volatile responses.

## Experimental Procedures

*Ground beef processing and display.* Beef trim meat was obtained in 300 lb lots. Each lot consisted of 6 (50.0 lb) batches. Six treatments were used to test the impact of aerobic, vacuum, and $CO_2$ mixing of beef trimmings and ground beef on Electronic Nose responses using a commercial mixer (Food Processing Equipment Co, Springdale, AR.). Beef trim followed by ground beef mixing treatments included Air-None (AN), Vacuum-none (VN), $CO_2$-none (CN), Air-Air (AA), Air-Vacuum (AV), and Air-$CO_2$ (AC).

For the first three treatments, beef trimmings were tumbled once, under the appropriate atmosphere, ground twice (Hobart Grinder, Model 310, Hobart Inc, Troy Ohio, USA) with a 3.2 mm plate, and packaged. For the remaining treatments, both beef trimmings and ground beef were mixed under the appropriate atmosphere. The first three treatments were mixed for 6 min and the last three treatments were mixed for 12 min (6 min for each half of the treatments). Liquid Food Grade $CO_2$ (P G Walker, Springdale, AR) was injected into the mixing chamber every 1 1/2 min during the $CO_2$ treatments. Vacuum treatments had vacuum applied to 15 mm mercury (Hg) with vacuum repeated as needed during a 6-min tumble to retain pressure.

All treatments of ground beef were packaged (1 lb) on styrofoam trays with absorbent paper diapers, over-wrapped with polyvinyl chloride film (oxygen transmission rate of 1400 cu/m$^2$/24 h/1 atm; Borden Inc., Dallas, TX), and stored under simulated retail conditions (39°F; deluxe Phillips warm white fluorescent lighting, 1630 lux, Phillips Inc., Somerset, N.J.). Multiple trays of ground beef were stored at 3°F and sampled on days 0, 1, 2, 3, 6, and 10 for Electronic Nose and TBARS characteristics and aerobic plate count (APC). For each treatment, fat content was standardized to 10% (Hobart Fat Analyzer, Model F101, Hobart Inc., Troy, OH.). The pH was also measured by homogenizing 0.24 oz of ground beef in 2.4 oz of Millipore water with an Orion pH meter (Orion pH Meter, Orion Research, Inc., Beverly, MS).

*Thiobarbituric acid reactive substances analysis.* The TBARS assays were performed on ground beef using a modified procedure of Witte et al. (1970). The samples were stored in simulated retail conditions then frozen (-4°F) on days 0, 1, 2, 3, 6, and 10 of display. For TBARS analysis, three replicates from each treatment were sampled. A standard curve was made using TEP (1,1,3,3 tetraethoxypropane with concentrations from 0.088 ug/ml to 4.4 ug/ml in standard curve). For analysis, ground beef samples (0.07 oz) were mixed with 8 ml cold phosphate buffer (50 Mm phosphate buffer, 0.1% EDTA, 0.1% N-Propyl Gallate; Sigma Scientific, St. Louis, MO.) and homogenized using a Pro 250 Homogenizer (ProScientific, Monroe, CT.) Two ml 30% Trichloroacetic acid (Sigma Scientific, St. Louis, MO.) were added to each test tube and vortexed (Vortex Genie II Scientific Industries, Bohemia, NY). Samples were centrifuged (Beckman Tabletop Centrifuge GS-6, Palo Alto, CA) at 75°F and 4,000 rpm for 5 min. The supernatants were removed and added to 10 ml screw cap tubes. Two ml of TBARS reagent were added to each test tube. The samples were vortexed again. The standard curve and sample tubes were placed into a

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boiling water bath (General Signal, Blue Island, IL.) for 20 min. Tubes were next removed from the water bath and placed in an ice bath for 5 min. After removal from ice bath, tubes were stored in a refrigerator (Westinghouse, N.Y.) at 28°F for 30 min then centrifuged again at the same force. Absorbances at 533 nm were recorded in duplicate using a UV/VIS Spectrophotometer (Hewlett Packard, Vectra XM, Series 3, 5/75, Ponca City, OK.). The absorbance was multiplied by 12.21 and reported as TBARS in mg/kg sample (Mei et al., 1998.).

*Microbial analyses*. Ground beef packages were tested during simulated retail display at days 0, 3, and 10 for aerobic bacterial plate counts. Each 0.88 oz sample of ground beef was aseptically removed from the packages and placed in a sterile whirlpak bag (NASCO, Ft. Atkinson, WI) with 8.7 oz of 0.1% buffered peptone water. Samples were stomached (Stomacher, Model 400 Lab Stomacher, Seward, London, U.K.) for 60 sec. Next, samples were serial diluted and plated in duplicate on Aerobic Plate Count plates (Petrifilm, 3M Microbiologicals, St. Paul, Mn, USA). Plates were placed in an incubator (VWR Scientific Products Model 5015 Incubator, West Chester, Pa. USA) at 98.6°F for 48 ± 2 hr then read. Microbial counts were initially recorded as CFU/gram then converted to Log CFU/gram of sample.

*Electronic Nose*. On days 0, 1, 2, 3, 6 and 10 of display, ground beef packages were opened, sampled and evaluated for Electronic Nose (Electronic Nose Fox 4000, Alpha Moss Toulouse, France) characteristics in triplicate. Data were averaged to one data point. For evaluation, a 0.14 oz sample was aseptically removed from each package and placed in clean, volatile free 3.05 oz vials and sealed. Vials were placed in the Electronic Nose auto sampling tray and analyzed within each tray as one set of triplicate to help offset any baseline drift. The heating unit of the Electronic Nose heated samples to 122°F while agitating the sample vial to liberate volatiles. The gas-sampling syringe was heated to 41.0°F above sample temperature. Vapor generated in headspace of each sample vial was drawn out by the gas syringe and injected into the instrument for analysis by 12 sensors (Fox Sensor System, Toulous, France). Heating syringes avoided condensation and possible sample contamination. The gas syringe was flushed by a carrier gas (20% oxygen, 80% Nitrogen; Hydrocarbon and water free) for avoidance of cross-contamination of samples.

*Statistical analyses*. The experiment was replicated three times. Treatments were blocked by replication and analyzed for the main effects of mixing treatment and days of display and their interaction using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Any variables involved in interactions were separated using the PDIFF option of PROC GLM and subsequently plotted. Least squares means for all other variables were generated and separated using the PDIFF option.

## Results and Discussion

*Effects of day and mixing treatments on Electronic Nose characterizations*. We hypothesized that the Electronic Nose is capable of rancidity detection in ground beef in industrial applications for the retail shelf life estimation of ground beef. The Electronic Nose was able to detect increases or decreases in aromatic compounds (hydrocarbons, aldehydes, polar compounds) during the duration of simulated retail display ($P < 0.05$). Sensor 11 (T70/2) is commonly used for the detection of natural food aromas and volatiles. During display the Sensor 11 readings rose ($P < 0.05$) over a period of days of display (Table 1) in conjunction with the TBARS surface and APC results (Table 2). Our findings are in agreement with those reported by Winquist et al. (1993), Spanier et al. (1999), and Grigioni et al. (2000) indicating the Electronic Nose is capable of detecting meat volatile changes over a period of days of simulated display.

Sensor 2 (SY/g) is commonly used for the detection of meat and fish freshness. Response to Sensor 2 declined ($P < 0.05$) indicating a meat freshness decline with advancing duration of display (Table 1). The negative numbers suggest a volatile shift and change in detection. Likewise, the change in Sensor 2 response relates to changes in TBARS and APC values going up over the same period.

Mixing treatments did not produce any negative effects nor were there any differences ($P > 0.05$) among treatments shown for the first six sensors of the Electronic Nose (Table 3). However, the CN treatment tended to have the lowest odor detection for sensors 7 to 12 compared to all other treatments and control (AN). Furthermore, the data suggest that, although not significant at $P < 0.05$, volatiles detected by sensors 7 to 12 (Table 3) tended to be numerically reduced by adding $CO_2$ ground beef mixing after aerobic trim mixing (AC treatment) compared with AA or AV treatments. Sensors 7 to 12 cover the range of food aromas, cooking and roasting hydrocarbons, and alcohols. Our findings suggest it is possible to add Liquid Food Grade $CO_2$ prior to grinding beef trimmings to obtain better shelf life at the retail level as detected by the Electronic Nose.

*Impact of mixing treatments on TBARS and microbial populations*. TBARS and APC showed no significant differences ($P > 0.05$) between beef trim and ground beef mixing treatments (Table 4). The TBARS values showed that little lipid oxidation occurred in all treatments on ground beef surfaces, subsurfaces and a composite average of these two locations.

## Implications

Data suggest the Electronic Nose has potential for the rapid detection of beef lipid stability and freshness determination in industrial applications. Utilizing technology such as this might aid in the exclusion of meat products with depressed quality and perhaps safety from consumer consumption.

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**Table 1. Impact of duration of ground beef simulated retail display on Electronic Nose sensor response.**

| | Sensor | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 1[a] | 2[b] | 3[c] | 4[d] | 5[e] | 6[f] | 7[g] | 8[h] | 9[i] | 10[j] | 11[k] | 12[l] |
| 0 | 0.0016[z] | 0.0009[x] | -0.000[x] | 0.0006[x] | 0.0013[x] | 0.0012[x] | 0.0109[z] | 0.0111[z] | 0.0062[z] | 0.0101[z] | 0.0125[z] | 0.0129[z] |
| 1 | 0.0017[z] | 0.0009[x] | -0.000[x] | 0.0004[x] | 0.0013[x] | 0.0013[x] | 0.0120[z] | 0.0130[z] | 0.0064[z] | 0.0118[z] | 0.0143[z] | 0.0153[z] |
| 2 | 0.0016[z] | 0.0006[x] | -0.000[x] | 0.0003[x] | 0.0013[x] | 0.0012[x] | 0.0192[z] | 0.0236[z] | 0.0095[z] | 0.0216[z] | 0.0231[z] | 0.0265[z] |
| 3 | 0.0025[z] | -0.001[x] | -0.001[x] | -0.001[x] | -0.000[x] | -0.000[x] | 0.0548[z] | 0.0757[z] | 0.0265[z] | 0.0693[z] | 0.0683[z] | 0.0821[z] |
| 6 | 0.0145[y] | -0.017[y] | -0.024[y] | -0.017[y] | -0.018[y] | -0.015[y] | 0.4619[y] | 0.5569[y] | 0.3667[y] | 0.5393[y] | 0.4946[y] | 0.5830[y] |
| 10 | 0.0262[x] | -0.037[z] | -0.046[z] | -0.036[z] | -0.036[z] | -0.031[z] | 0.5833[x] | 0.6776[x] | 0.4907[x] | 0.6594[x] | 0.6194[x] | 0.7038[x] |
| SE | 0.0029 | 0.0033 | 0.0043 | 0.0032 | 0.0027 | 0.0020 | 0.0259 | 0.0281 | 0.0266 | 0.0277 | 0.0206 | 0.0291 |

[a] Sensor 1: Senses fluorinated, chlorinated, and aldehyde compounds.
[b] Sensor 2: Senses meat and fish freshness.
[c] Sensor 3: Senses hydrocarbon, methane, and propane.
[d] Sensor 4: Senses paint, polymers, smoke.
[e] Sensor 5: Senses alcoholic beverages, perfumes, fermentations.
[f] Sensor 6: Senses cooking, roasting coffee, petrochemistries.
[g] Sensor 7: Senses polar compounds, ethanols.
[h] Sensor 8: Senses petrochemistries.
[i] Sensor 9: Senses cooking and roasting hydrocarbons.
[j] Sensor 10: Same as sensor 1.
[k] Sensor 11: Senses food aromas and volatiles.
[l] Sensor 12: Senses alcohols, solvents.
[xyz] Least-squares means within a column bearing different superscripts differ ($P < 0.05$).

**Table 2. Impact of duration of ground beef simulated retail display on thiobarbituric acid reactive substances (TBARS) and log aerobic plate count (APC) colony forming units per gram (CFU/g).**

| | TBARS (mg/kg) | | | |
|---|---|---|---|---|
| Day | Surface | Subsurface | Average | APC (log CFU/g) |
| 0 | 0.76[y] | 1.01[xy] | 0.89[xy] | 2.92[z] |
| 1 | 0.83[y] | 0.69[y] | 0.76[x] | |
| 2 | 0.92[xy] | 1.02[xy] | 0.97[xy] | |
| 3 | 0.96[xy] | 0.93[xy] | 0.94[xy] | 4.80[y] |
| 6 | 1.01[xy] | 1.16[x] | 1.08[x] | |
| 10 | 1.14[x] | 0.94[xy] | 1.04[x] | 7.28[x] |
| SE | 0.09 | 0.13 | 0.09 | 0.01 |

[xyz]Least-squares means within a column bearing different superscripts differ ($P < 0.05$).

**Table 3. Impact of ground beef mixing treatments on Electronic Nose sensor response.**

| | Sensor[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| AN[b] | 0.01 | -0.01 | -0.02 | -0.01 | -0.01 | -0.01 | 0.21 | 0.25$^{xy}$ | 0.18 | 0.24$^{xy}$ | 0.23 | 0.26$^{xy}$ |
| VN[c] | 0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | 0.20 | 0.25$^{xy}$ | 0.17 | 0.24$^{xy}$ | 0.22 | 0.26$^{xy}$ |
| CN[d] | 0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | 0.15 | 0.17$^{y}$ | 0.11 | 0.17$^{y}$ | 0.16 | 0.18$^{y}$ |
| AA[e] | 0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | 0.19 | 0.23$^{xy}$ | 0.15 | 0.22$^{xy}$ | 0.21 | 0.24$^{xy}$ |
| AV[f] | 0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | 0.22 | 0.25$^{x}$ | 0.18 | 0.25$^{x}$ | 0.23 | 0.27$^{x}$ |
| AC[g] | 0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | 0.17 | 0.20$^{xy}$ | 0.13 | 0.19$^{xy}$ | 0.18 | 0.21$^{xy}$ |

[a] See Table 1 for description of sensors.
[b] Beef trimmings mixed aerobically, no ground beef mixing.
[c] Beef trimmings mixed under vacuum, no ground beef mixing.
[d] Beef trimmings mixed under carbon dioxide, no ground beef mixing.
[e] Beef trimmings mixed aerobically, ground beef mixed aerobically.
[f] Beef trimmings mixed aerobically, ground beef mixed under vacuum.
[g] Beef trimmings mixed aerobically, ground beef mixed under carbon dioxide.
[xyz] Least-squares means within a column bearing different superscripts differ ($P < 0.05$).

**Table 4. Impact of ground beef mixing treatments on thiobarbituric acid reactive substances (TBARS) and log aerobic plate count (APC) colony forming units per gram (CFU/g).**

| | TBARS (mg/kg)[a] | | | |
|---|---|---|---|---|
| Treatment | Surface | Subsurface | Average | APC (log CFU/g)[b] |
| AN[c] | 0.93 | 0.84 | 0.88 | 5.04 |
| VN[d] | 1.03 | 1.05 | 1.04 | 5.01 |
| CN[e] | 0.97 | 0.99 | 0.98 | 4.97 |
| AA[f] | 0.78 | 0.94 | 0.86 | 4.92 |
| AV[g] | 0.91 | 0.91 | 0.91 | 5.00 |
| AC[h] | 0.98 | 1.02 | 1.00 | 5.05 |

[ab] Least-squares means for TBARS values and APC did not differ ($P < 0.05$) among mixing treatments.
[c] Beef trimmings mixed aerobically, not ground beef mixing.
[d] Beef trimmings mixed aerobically, ground beef mixed aerobically.
[e] Beef trimmings mixed aerobically, ground beef mixed under vacuum.
[f] Beef trimmings mixed aerobically, ground beef mixed under carbon dioxide.
[g] Beef trimmings mixed aerobically, ground beef mixed under vacuum.
[h] Beef trimmings mixed aerobically, ground beef mixed under carbon dioxide.

# Arkansas Feedout Program
# 2001-2002

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## Story in Brief

The objective of the Arkansas Feedout Program is to provide cow-calf producers information about the postweaning performance and carcass characteristics of their calves. For the 2001 – 2002 feedout, hot carcass weight, days on feed, medicine cost, quality grade, dressing percentage, yield grade, feed cost of gain and average daily gain were significant factors that affected return over specified cost. With the information gained from this program, cow-calf producers can better evaluate their cattle breeding programs.


## Introduction

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

## Experimental Procedures

On November 8, 2001, 350 calves (30 heifers and 320 steers) from 37 Arkansas producers representing 18 counties, were placed on feed at Oklahoma Feeders Inc., Coyle, Oklahoma. Upon arrival, steers were eartagged, weighed, and processed (Ivomec, Ralgro (heifers), Synovex-S (steers), Covexin, and *pasteurella bacterin*). An Arkansas Livestock Market Reporter placed an arrival value on all calves. Steers and heifers were sorted into five pens based upon weight, frame, and condition. Management factors such as processing, medical treatments, and diets were the same as the other cattle in the feedyard. The feedyard manager selected animals for slaughter when they reached the weight and condition regarded as acceptable for the industry and market conditions. Calves were slaughtered in three groups (April 16, April 30 and May 7, 2002). The cattle were sold on a carcass weight basis with premiums and discounts for quality grade, yield grade, and carcass weight. Feed, processing, medicine costs and other feedyard expenses were financed by the feedyard. All expenses were deducted from the carcass income, and proceeds were sent to the owner. Steer and heifer carcass value for Choice-Yield Grade 2 carcasses was $111.49 and $110.97, $107.46 (no heifers were harvested), and $114.46 and $111.07 for April 16, April 30 and May 2 harvest dates, respectively.

Descriptive statistics were computed to describe general program results. Because there were only 29 heifers (1 heifer died), the heifer data were not used in the statistical analysis. Of the 320 steers that started in the fall, eight died (2.5% death loss) and six carcasses were used by IBP (Iowa Beef Processors) for quality control checks; therefore, carcass data were not obtained from these animals. These steers were not included in the statistical analyses. The final data set analyzed consisted of feedlot and carcass data from 306 steers.

Carcasses of steers were also grouped according to whether or not they fit an industry standard for carcass merit (at least Choice, yield grade $\leq 3.5$, with a hot carcass weight between 550 and 950 lb). Steers either fit the industry standard or they did not, which resulted into two groups. The group main effect and interaction on the dependent variables carcass value, ADG and net return were determined using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Least-squares means were computed and reported.

Calves were sorted into the top or bottom 25% category based upon their feedlot return (income minus feedlot direct expenses). Factors affecting feedlot return for the top 25% steers and the bottom 25% steers were determined using the Stepwise method of PROC REG (SAS Inst., Inc., Cary, NC). Independent variables included arrival weight; percentage Brahman, percentage English, and percentage Continental breeding; ADG; yield grade; quality grade; feed cost per lb of gain; hot carcass weight; days on feed; medicine cost; ribeye area; ribeye area/hot carcass cwt.; and dressing percentage.

## Results and Discussion

The steer and heifer financial reports are summarized in Tables 1 and 2, respectively. Average steer and heifer gross income per head was $757.50 (range = $384 to $1,020) and $672.22 (range = $403 to $911), respectively. The feedlot returns for steers and heifers averaged $470.70 and $394.44, respectively, whereas the calculated returns (accounted for the initial value of the calf at arrival) averaged $-5.00 (range = $-418 to $244) and $-29.17 ($-222 to $156), respectively.

The sick rate was very high with 71 calves (22.8%) treated for sickness. It is not known what caused this high sick rate, but the weather during November and December was thought to have contributed. The average medicine cost per sick calf was $47.80. The medicine cost for the entire group averaged $13.25 per head. The health status of cattle in the feedyard usually has a major impact on performance and profit. Healthy steers had higher feedlot returns ($489) than steers that became sick ($413; $P < 0.001$). In addition, healthy steers had higher final weights (1,154 vs. 1,114 lb; $P < 0.01$), average daily gains (3.30 vs. 3.14; $P < 0.02$), lower total cost of gain ($0.51 vs. $0.61: $P < 0.001$), higher carcass value per cwt. ($105.09 vs. $103.47: $P < 0.06$) and higher carcass weights (729 vs. 701 lb; $P < 0.001$) than steers that became sick (62.0%; $P < 0.001$). Sickness

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also impacted the calves' ability to grade Choice. More healthy steers graded Choice (35%) than steers that were treated for sickness (24%; P = 0.08). Less than 1% of the calves were classified as Dark Cutters and there were no differences in the Dark Cutters between healthy steers and those steers that were treated for sickness. This vividly points out the need to adhere to a sound health management plan. Implementing a sound vaccination program at the farm of origin, and thus keeping calves healthy, will play an important role in allowing calves to express their genetic potential.

The steer and heifer average off-the-truck arrival weights were 600 (range = 397 to 860) and 557 lb (range = 428 to 777), respectively. The steer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 3.25 lb (0.97 to 4.67), 168 days (156 to 183), $0.45 ($0.33 to $1.06), and $0.54 ($0.37 to $1.32), respectively. The heifer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 2.82 lb (1.93 to 4.12), 171 days (156 to 177 days), $0.48 ($0.36 to $0.73), and $0.59 ($0.44 to $0.90), respectively.

The average steer carcass weight, ribeye area, dressing percentage, yield grade, and fat thickness were 723 lb (504 to 904), 12.7 $in^2$ (9.3 to 18.4), 63.2%, 2.66 (0.32 to 4.77), and 0.42 in. (0.12 to 0.88), respectively. Thirty-three percent of the carcasses graded Choice whereas 57% and 9% graded Select and Standard, respectively. Only 1% of the carcasses graded Prime.

Listed below are the significant factors that affected the feedlot return over specified costs for the steers in the 2001 - 2002 Feedout Program. Factors are listed from the most important to the least important.

**Factors Affecting Returns Over Specified Cost**

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

1. Hot Carcass Weight – The relationship between hot carcass weight and feedlot returns over specified cost was positive. As hot carcass weight increased so did feedlot returns. Table 3 shows the relationship between hot carcass weight, total cost of gain, average daily gain and feedlot returns over specified costs. Hot carcass weight discounts were observed for carcasses weighing less than 550 lb and greater than 950 lb.

2. Days on Feed – There was a negative relationship between days on feed and returns over specified cost. This means that on the average, the longer that cattle were on feed the lower the returns (Table 4).

A factor that affected the relationship between days on feed and feedlot return over specified costs was the price difference between Choice and Select quality grades on the three slaughter days. For example, early in the spring (April 16, 2002), there was a $3 per carcass cwt. discount between Choice and Select, but on May 7, 2002 the spread was $10 per carcass cwt.

3. Medicine Cost – Healthy steers had higher feedlot returns ($489) than steers that became sick ($413; P < 0.001).

4. Quality Grade – Cattle that graded Choice, Select, Standard and Dark Cutters had feedlot returns of $532, $452, $384 and $258, respectively for the 2001 – 2002 program. Marbling is the main factor that affects a calf's ability to grade Choice. Three main factors that affect marbling are: (1) the genetic ability to marble; (2) the maturity, or the physiological age, not the chronological age; and (3) diet. Some cattle breed associations report marbling EPD's in their sire summary. Carcass traits such as marbling are highly heritable; therefore, selecting high marbling EPD bulls can impact the marbling ability of their progeny. Breed type can also influence a calf's ability to grade Choice.

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

6. Yield Grade – Feedlot return for Yield Grades 1, 2, and 3 was $492, $439, and $466 for yield grades 1, 2, and 3, respectively, in 2001-2002. The cattle that yield graded 3 high a higher percentage grade Choice, which improved carcass value.

7. Feed Cost – Feed cost of gain had a negative relationship to feedlot return over specified costs. As feed cost of gain decreased, return over specified costs increased. The average feed cost of gain for steers with returns in the bottom 25% was $0.45 per pound compared to $0.43 per pound for steers in the top 25% in 2001-2002.

8. Average Daily Gain – Average daily gain is an accumulation of growth genetics, health, feed conversion, plus many other factors. The steers with returns in the bottom 25% averaged 2.98 lb ADG; whereas, the steers with returns in the top 25% averaged 3.53 lb ADG. Steers that gained faster reached their market weight earlier have were fewer days on feed.

Table 5 summarizes the performance and carcass data from the steers that were in the bottom 25% and top 25% (based on returns over specified costs) and the average of all the steers. In summary, the calves in the bottom 25% had high feed and medicine cost, low dressing percentage and failed to grade Choice. The cattle that performed the best were medium to large framed, heavy muscled, gained well, had a high dressing percentage, did not get sick, and graded Choice.

The beef cattle industry has set the standard that quality grade should be Choice, yield grade should be < 3.5, and hot carcass weight between 550 and 950 lb. In the 2001-2002 feedout, 33% of the steer calves fit all these requirements. Forty-five percent of the steers in the 2000 – 2001 Feedout Program met the industry standards. The breed makeup of the steers that met the industry standards were 57% English, 9% Brahman and 34% Continental. Steers that met the industry standards averaged $80 more per head than those that did not fit the industry standards (P < 0.01). They had higher carcass values ($1.10 vs. $1.02) because they graded Choice, were not discounted for yield grades greater than 4.0 and no carcasses were outside the weight range (550 to 950 lb).

## Implications

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

**Table 1. 2001-02 Arkansas feedout summary – steer financial results.**

| Item | Average | Range |
|---|---|---|
| Gross income | $757.50 | $384 to $1,020 |
| Expenses | | |
| Feed | $242.56 | $181 to $346 |
| Medicine | $10.41 | 0 to $208 |
| Freight, processing, yardage, interest, etc | $33.83 | $24 to $124 |
| Total feedlot expenses | $286.80 | $219 to $496 |
| Feedlot return | $470.70 | $48 to $711 |
| Steer calf in value | $475.70 | $340 to $654 |
| Calculated return | $-5.00 | $-418 to $244 |

**Table 2. 2001-02 Arkansas feedout summary – heifer financial results.**

| Item | Average | Range |
|---|---|---|
| Gross income | $672.22 | $403 to $911 |
| Expenses | | |
| Feed | $227.22 | $198 to $289 |
| Medicine | $23.07 | 0 to $147 |
| Freight, processing, yardage, interest, etc | $27.49 | $24 to $34 |
| Total feedlot expenses | $277.78 | $229 to $386 |
| Feedlot return | $394.44 | $174 to $606 |
| Heifer calf in value | $423.61 | $352 to $533 |
| Calculated return | $-29.17 | $-222 to $156 |

**Table 3. Summary of hot carcass weight, total cost of gain, average daily gain, feedlot returns, and calculated returns.**

| Hot carcass weight (lb) | Total cost of gain/lb | ADG (lb) | Feedlot returns | Calculated return |
|---|---|---|---|---|
| <600 | $0.56 | 2.6 | $267 | $-131 |
| 600-699 | $0.53 | 3.1 | $419 | $-28 |
| 700-799 | $0.54 | 3.3 | $491 | $-0.73 |
| 800-899 | $0.51 | 3.6 | $584 | $74 |

**Table 4. Effect of days on feed on average daily gain, total cost of gain, carcass value and feedlot returns.**

| Slaughter dates | Days on feed | ADG (lb) | Total cost of gain/lb | Carcass value (per cwt.) | Feedlot return |
|---|---|---|---|---|---|
| April 16 | 156 | 3.4 | $0.53 | $109 | $524 |
| April 30 | 170 | 3.2 | $0.52 | $101 | $421 |
| May 7 | 177 | 3.2 | $0.55 | $103 | $456 |

**Table 5. The performance of the bottom 25%, average, and top 25% steers based on feedlot returns.**

| Item | Bottom 25% | Average | Top 25% |
|---|---|---|---|
| Number of steers | 78 | 306[a] | 78 |
| In weight, lb | 541[b] | 600 | 622[c] |
| Muscle score | 1.4[b] | 1.3 | 1.3[c] |
| Frame score | | | |
| Large, % | 10[b] | 25 | 29[c] |
| Medium, % | 90[b] | 60 | 42[c] |
| Final weight, lb | 1,056[b] | 1,144 | 1,201[c] |
| Average daily gain, lb | 2.98[b] | 3.33 | 3.66[c] |
| Gross income, $ | 641[b] | 758 | 871[c] |
| Carcass value per lb, $ | 0.99[b] | 1.04 | 1.09[c] |
| In value per head, $ | 437[b] | 476 | 492[c] |
| Hot carcass weight, lb | 645[d] | 723 | 797[e] |
| Dressing percentage | 61.3[d] | 63.2 | 66.6[e] |
| Medicine cost, $ | 23.90[b] | 12.20 | 2.37[c] |
| Total feed cost per head, $ | 230[b] | 243 | 247[c] |
| Total expense, $ | 286 | 287 | 283 |
| Feedlot returns, $ | 355[b] | 471 | 586[c] |
| Calculated returns, $ | -82[b] | -5 | 94[c] |
| Days on feed | 173[b] | 168 | 164[c] |
| Feed cost per lb of gain, $ | 0.45[f] | 0.45 | 0.43[g] |
| Total cost per lb of gain, $ | 0.56[b] | 0.54 | 0.50[c] |
| Ribeye area, $in^2$ | 12.1[d] | 12.7 | 13.2[e] |
| Fat thickness, in | 0.35[d] | 0.42 | 0.46[e] |
| Quality grade | | | |
| Prime, % | 1 | 1 | 1 |
| Choice, % | 4[d] | 33 | 64[e] |

[a] Fourteen calves were not used in this data set. Eight calves died and six were used as IBP quality control checks.
[b,c] Values within rows with unlike superscripts are different ($P < 0.001$).
[d,e] Values within rows with unlike superscripts are different ($P < 0.01$).
[f,g] Values within rows with unlike superscripts are different ($P < 0.03$).

# The Impact of Livestock Auction Location on the Selling Price of Replacement and Market Cows[1]

*T.R. Troxel, M.S. Gadberry, S. Cline, J. Foley, G. Ford, D. Urell, and R. Wiedower*[2]


## Story in Brief

Data were collected from 15 Arkansas livestock auctions to determine if livestock auction location affected the selling price of replacement and market cows. Data were collected on 22,745 cows that included cow type (replacement or market) and selling price. Longitudinal and latitudinal coordinates (livestock auction location) were determined for each livestock auction. Selling prices differed across livestock auctions ($P < 0.001$). The longitude and latitude livestock auction locations were not significantly related ($P > 0.10$) to the overall average selling price. There was a significant relationship ($P < 0.01$) between the selling price and degrees north for replacement cows. This implies that the livestock auctions located in the northern section of Arkansas sold replacement cows for a greater selling price than livestock auctions located in the southern section of Arkansas. For replacement cows, the difference between the livestock auction with the greatest selling price and the livestock auctions with the least selling price was $10.02 per cwt. The selling price difference was not as great with market cows ($4.27 per cwt.). There was a difference in the selling price of replacement and market cows between livestock auctions. Livestock auctions located in the northern section of Arkansas sold replacement cows for a greater selling price than livestock auctions located in the southern section of Arkansas.


## Introduction

The majority of Arkansas cow-calf producers sell replacement and market cows through local livestock auctions. Many cow-calf producers believe that the livestock auction location affects the selling price of replacement and market cows and they are priced inconsistently from one livestock auction to another. Most market reports list the selling prices of replacement and market cows by cow status (replacement or slaughter cows), pregnancy status (open/short-bred or springing) and pairs (small or large calves). Buyers appraise individual characteristics as predictors of quality and animal performance and adjust their bids accordingly. Producers do not understand why some phenotypic characteristics are discounted and others are not.

Therefore, the objective was to determine if livestock auction location affected the selling price of replacement and market cows across weekly Arkansas livestock auctions.

## Experimental Procedures

Five USDA-certified livestock market reporters collected data from 15 weekly livestock auctions in Arkansas from March 1, 2001 to May 31, 2001 and September 1, 2001 to November 30, 2001. The data collected included classifying the cows as either replacement or market cows. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Morrilton, Ola, Ozark, Pocahontas, Ratcliff and Springdale. During the six reporting months in 2001, a total of 52,292 cows were sold through these livestock auctions, and data were randomly collected (every second to third cow) on 22,745 animals (43.5%). Longitudinal and latitudinal coordinates for each livestock auction were used to determine the relationship between location and selling price using a regression analysis. All selling prices reported are in dollars/cwt.

## Results and Discussion

There was a significant difference in the selling price of cows across the weekly livestock auctions ($P < 0.001$; Table 1). For replacement cows, the difference between the livestock auction with the greatest selling price and the livestock auction with the least selling price was $10.02. The selling price difference was not as great with market cows, $4.27. A livestock auction by cow type interaction (replacement vs. market cows) existed ($P < 0.0001$). The interaction occurred because generally speaking the livestock auctions with higher selling prices for replacement cows had lower selling prices for market cows and vice versa (Table 1). The longitude and latitude livestock auction locations were not significantly related ($P > 0.10$) to the overall average cow selling price. There was a significant relationship ($P < 0.01$) between the selling price and degrees north for replacement cows. This implies that the livestock auctions located in the northern section of Arkansas sold replacement cows for a greater selling price than livestock auctions located in the southern section of Arkansas.

## Implications

The majority of cow-calf producers in Arkansas sell replacement and market cows at local livestock auctions. Selling prices for replacement and market cows differ across Arkansas livestock auctions. The selling price of replacement cows was higher in the northern livestock auctions as compared to the southern livestock auctions.

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**Table 1. Selling price of replacement and market cows based on livestock auction location.[a]**

| Replacement cows | | | Market cows | | |
|---|---|---|---|---|---|
| Livestock Auction | n | Selling price[b] | Livestock Auction | n | Selling price[b] |
| 1 | 510 | $53.07 ± 0.34 [c] | 13 | 1,023 | $40.89 ± 0.25 [c] |
| 2 | 1,403 | $52.73 ± 0.21 [c] | 9 | 912 | $40.60 ± 0.28 [cd] |
| 3 | 837 | $49.96 ± 0.27 [d] | 4 | 465 | $40.43 ± 0.91 [cde] |
| 4 | 850 | $49.34 ± 0.36 [d] | 14 | 562 | $39.76 ± 0.33 [de] |
| 5 | 645 | $48.09 ± 0.30 [e] | 8 | 1,418 | $39.64 ± 0.23 [e] |
| 6 | 336 | $48.08 ± 0.42 [ef] | 7 | 1,094 | $39.53 ± 0.24 [e] |
| 7 | 703 | $47.60 ± 0.29 [efg] | 11 | 658 | $39.47 ± 0.34 [e] |
| 8 | 731 | $47.06 ± 0.29 [efg] | 12 | 538 | $39.17 ± 0.35 [e] |
| 9 | 728 | $46.95 ± 0.29 [fgh] | 2 | 2,273 | $38.94 ± 0.17 [e] |
| 10 | 569 | $46.88 ± 0.32 [fgh] | 3 | 1,443 | $38.92 ± 0.21 [e] |
| 11 | 643 | $46.76 ± 0.31 [gh] | 5 | 503 | $38.85 ± 0.34 [e] |
| 12 | 266 | $46.52 ± 0.47 [gh] | 6 | 534 | $38.63 ± 0.36 [e] |
| 13 | 606 | $45.95 ± 0.32 [h] | 15 | 285 | $38.30 ± 0.49 [e] |
| 14 | 543 | $43.82 ± 0.33 [i] | 10 | 913 | $38.35 ± 0.26 [e] |
| 15 | 228 | $43.05 ± 0.51 [i] | 1 | 526 | $36.62 ± 0.36 [f] |

[a] Livestock auction by cow type interaction ($P < 0.0001$).
[b] Least-squares mean ± SE (dollars/cwt.).
[c,d,e,f,g,h,i] Means within columns without a common superscript differ ($P < 0.01$).

# Factors Affecting the Selling Price of Market Cows Sold at Arkansas Livestock Auctions[1]

*T.R. Troxel, M.S. Gadberry, S. Cline, J. Foley, G. Ford, D. Urell, and R. Wiedower*[2]


## Story in Brief

Data were collected from 15 Arkansas livestock auctions (n = 13,147 cows) to determine the factors affecting market cow selling price. Data collected included pregnancy status, breed or breed type, color, horn status, frame score, muscle thickness, fill, USDA quality grade for market cows, number of brands, brand location, health, BW, age, and price. Mean selling price for market cows was \$39.22 ± \$0.08 (dollars/cwt.). Market cows in their first (\$40.19 ± \$0.29), second (\$40.18 ± \$0.27), and third trimesters (\$39.86 ± \$0.68), and not pregnant (\$39.50 ± \$0.13) sold for the same price ($P > 0.10$), and all prices were greater than the price received for market cows not checked for pregnancy (\$38.98 ± \$0.10; $P < 0.01$). Market cow buyers paid more for Continental breeds or breed types than for cows of English, Longhorn, or dairy breeds or breed types. The selling prices of large- (\$40.19 ± \$0.13), medium- (\$39.07 ± \$0.12), and small- (\$35.28 ± \$0.25) frame market cows were different from each other ($P < 0.001$). Results indicate that a number of management and genetic factors affect the selling price of market cows.


## Introduction

The sale of cull cows accounts for 15 to 20% of the yearly gross revenues of cow-calf operations. The NAHMS Beef study (1997) reported that, of the cows culled in 1996, 39.8% were culled because of old age or bad teeth, 25% were sold because of pregnancy status, and 18.5% were sold for economic reasons (drought, herd reduction or market conditions). Only 5.7% of cows were culled for poor production. The 1999 National Market Cow and Bull Quality Audit (1999) reported that producers lose approximately \$68.82 of potential revenues per non-fed animal slaughtered in the United States. Very little information is available to help cow-calf producers implement management practices that might improve the value of market cows sold at livestock auctions. When buyers at a livestock auction view market cows, they must appraise phenotypic characteristics (muscle thickness, frame score, breed composition, etc.) as predictors of quality and adjust their bids accordingly. Many of these factors such as breed or breed type are very subjective. Therefore, the objective was to determine the factors that affect the selling price of market cows in Arkansas weekly livestock auctions.

## Experimental Procedures

Five USDA-certified livestock market reporters collected data from 15 weekly livestock auctions in Arkansas from March 1, 2001 to May 31, 2001 and September 1, 2001 to November 30, 2001. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Morrilton, Ola, Ozark, Pocahontas, Ratcliff, and Springdale. All cows were sold as individuals. During the six reporting months in 2001, data were randomly collected on 13,147 animals

Data collected included pregnancy status (not checked, not pregnant, or first, second or third trimester), breed or breed type, color, horn status (polled or horned), frame score, muscle thickness, fill (gaunt, shrunk, average, full or tanked), USDA quality grade (Canner, Cutter, Utility, or Commercial), number of brands, brand location (ribs, shoulder or hip), health (dead hair, stale, sick, bad eye(s), lame or healthy), BW, age, and price. Cows were classified as market based on visual appraisal and buyer identification. A veterinarian employed by the livestock auction examined cows for pregnancy by rectal palpation. Pregnancy status was either written with a paintstik or a tag glued to the hip. Fame score was defined as large (over 1,100 lb), medium (900 to 1,100 lb) and small (less than 900 lb) frame based on the expected BW when cows were carrying 0.2 cm fat cover at the 12th rib. Muscle scores were determined using the 1, 2 and 3 scale with "1" being the thicker-muscled cows and "3" the thinner-muscled cows. Healthy cows showed no signs of sickness, lameness or any other unhealthy condition. Dead hair cows demonstrated a "lack luster" hair coat that could have indicated a heavy internal parasite load. Cows classified as stale had lost their effervescence and were apathetic in appearance. Sick cows showed signs of a sick condition (coughing, running nose, water eyes, etc.). Cows that had spot(s) in their eyes (bovine ocular squamous cell carcinoma) were noted as well as cows that demonstrated lameness on any leg. A livestock auction employee examined the teeth and estimated the cow's age. When the animal entered the auction ring, the livestock market reporters evaluated each cow just as a buyer must do before determining a bid.

*Data analyses.* Percentage of cows within pregnancy status, breed or breed type, color, horn status, frame score, muscle thickness, fill, USDA quality grade, number of brands, brand location, age and health were determined by the frequency procedure of SAS (SAS Inst., Inc., Cary, NC ). Due to the unbalanced nature of the data, the month, sale barn, and cow characteristics were analyzed as independent variables. The model included week, age, and body weight as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares. When analysis of variance was performed for month of sale, week was excluded as a covariate. The analysis of variance was performed with the General Linear Model procedure of SAS (SAS Inst., Inc., Cary, NC). Least-

[1] This material is based upon work supported by the Cooperative State Research, Education and Extension Service, U. S. Department of Agriculture, and the Cooperative Extension Service, University of Arkansas, under special project number 97-EXCA-2-0513. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U. S. Department of Agriculture.

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squares means were generated and separated using the PDIFF option. Both are reported throughout this discussion. 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 dollars/cwt.

## Results and Discussion

The mean selling price for market cows was \$39.22 ± \$0.08. For market cows, the selling prices for March (\$41.24 ± \$0.22) and April (\$40.87 ± \$0.18) were not different ($P > 0.10$) but the selling prices for the remaining months (May, September, October and November) were different from each other (\$42.97 ± \$0.16, \$39.54 ± \$0.21, \$36.00 ± \$0.16 and \$34.32 ± \$0.18, respectively; $P < 0.01$). As selling BW increased for market cows, price per lb increased ($P < 0.001$). The positive relationship between BW and price per lb for cows is opposite of the relationship between BW and price per lb for feeder cattle (Troxel et al., 2001). Cows that weighed less than 700 lb had an average selling price of \$27.54 ± \$0.73, whereas the selling price for 700 to 899, 900 to 1,099, 1,100 to 1,299, and 1,300 to 1,499 lb was \$33.74 ± \$0.15, \$38.01 ± \$0.11, \$39.85 ± \$0.14 and \$39.91 ± \$0.26, respectively.

Market cows in their first (\$40.19 ± \$0.29), second (\$40.18 ± \$0.27), and third trimesters (\$39.86 ± \$0.68) and not pregnant (\$39.50 ± \$0.13) sold for the same price ($P > 0.10$), and all prices were greater than the price received for cows not checked for pregnancy (\$38.98 ± \$0.10; $P < 0.01$).

Twenty-six breeds or breed types represented 99.0% of the total cows sampled (Table 1). The breed or breed types were based upon common industry perception rather than actual knowledge of the breed composition. This, however, is what a buyer must do before a selling price can be offered. The price spread from the highest to lowest priced breed or breed type for market cows was \$5.09. It was reported that the price spread between the highest to lowest breed or breed type for feeder cattle was \$23.44 (Troxel, et al., 2001). Market cow buyers paid more for the Continental breeds or breed types than they did for cows of English, Longhorn or dairy breeds or breed types. This may be due to increased muscling, frame score, carcass weights and dressing percentages from Continental breeds or breed types compared to English or dairy breeds or breed types.

Eleven colors represented 99% of the total population (Table 2). Many of the cow colors selling prices were very similar with a range of \$2.13 between the highest and lowest prices.

The selling prices of market cows across muscle scores were all different from each other (\$40.23 ± \$0.11, \$38.76 ± \$0.12, and \$36.77 ± \$0.22, for muscle scores 1, 2, and 3, respectively; $P < 0.001$). Muscle thickness is a major pricing concern when cows are purchased for slaughter. The National Market Cow and Bull Quality Audit (1999) reported a loss of \$18.70 per marketed cow due to inadequate muscling. With a \$3.46 difference between muscle score 1 and 3 market cows, a pricing incentive exists to encourage cow-calf producers to increase muscling in the cowherd.

The selling price between polled or horned market cows (Table 3) was not different ($P > 0.10$). At this pricing level for market cows, there is no price incentive to encourage cow-calf producers to eliminate horns. There may, however, be other incentives for producers to eliminate horns (management and safety concerns, etc.).

When buyers were purchasing market cows, large-framed cows received the greatest selling price (Table 3). Selling prices of large-, medium- and small-frame market cows were different from each other ($P < 0.01$).

The selling prices for tanked and shrunk market cows (Table 3) were not different ($P > 0.10$). The selling price for shrunk market cows was not different from the selling price of average fill market cows ($P > 0.10$), but average fill market cows was less than the selling price for tanked market cows ($P < 0.01$). The selling prices for full and gaunt market cows were not different ($P > 0.10$) but were less than the selling prices for tanked, shrunk and average fill market cows.

Most of the market cows (91.7%) were not branded. The selling price of market cows was greater ($P < 0.01$) for cows with one and two or more brands (Table 3) than it was for market cows with no brands. There was no difference in selling price of market cows based on brand location. Branding costs the industry \$3.10 per marketed cow (National Market Cow and Bull Quality Audit. 1999), but during the 2001 study of price structure for brands, there was no financial encouragement for Arkansas producers to change their branding practices.

For market cows, healthy, lumps, lame, sick cows, and bad eyes cow prices were all different from each other ($P < 0.01$; Table 3).

The percentage of market cows that were indicated USDA Commercial, Utility, Cutter and Canner were 11.3, 11.3, 37.8 and 39.6%, respectively. The average BW for USDA Commercial, Utility, Cutter, and Canner was 1,128 ± 233.2, 1,159 ± 169.1, 1,028 ± 151.2, and 887 ± 181.6 lb, respectively. The selling price across USDA Quality grade tended to be significant ($P < 0.06$). The selling price for USDA Utility cows tended to be greater ($P < 0.02$) than the selling price for USDA Commercial, Cutter and Canner (Table 3). The reported selling price by USDA quality grades followed the 26-yr average price trend reported in Arkansas livestock markets (U. S. Department of Agriculture, 2000). The average selling price for market cows decreased with age (Table 4).

## Implications

A number of factors (health, perceived breed or breed type, muscle thickness, frame score, fill, horn status, color, and USDA quality grade) affect the selling price of cows. Once the impact of these factors are identified and understood, cow-calf producers can make cost-effective management changes that can improve cow and total returns.

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**Table 1. Selling price of market cows based on breed or breed type.**

| Breed or Breed Type[a] | n | Selling price[b] |
|---|---|---|
| Lm | 598 | $41.80 ± 0.34 [c] |
| CLm | 156 | $41.24 ± 0.66 [cd] |
| CB | 171 | $40.55 ± 0.62 [cd] |
| ContBq | 206 | $40.38 ± 0.58 [cd] |
| Cont | 166 | $40.32 ± 0.64 [d] |
| AH | 806 | $40.32 ± 0.29 [d] |
| CBq | 294 | $40.27 ± 0.46 [e] |
| HBA | 236 | $40.16 ± 0.57 [f] |
| Bx | 156 | $40.11 ± 0.68 [f] |
| AB | 724 | $40.03 ± 0.31 [f] |
| HB | 390 | $39.93 ± 0.43 [f] |
| C | 807 | $39.90 ± 0.29 [f] |
| B | 390 | $39.91 ± 0.42 [f] |
| AHBq | 142 | $39.81 ± 0.69 [fg] |
| Sm | 609 | $39.65 ± 0.34 [fg] |
| Bq | 1,828 | $39.63 ± 0.20 [fg] |
| EngBq | 575 | $39.60 ± 0.34 [fg] |
| HC | 271 | $39.29 ± 0.50 [fg] |
| ABq | 578 | $39.25 ± 0.34 [fg] |
| HLm | 255 | $39.22 ± 0.53 [fg] |
| AC | 223 | $38.95 ± 0.56 [fg] |
| EngCont | 358 | $38.91 ± 0.43 [fg] |
| A | 927 | $38.18 ± 0.27 [g] |
| Lg | 183 | $38.05 ± 0.65 [gh] |
| H | 1,084 | $36.99 ± 0.26 [gh] |
| Dairyx | 832 | $36.71 ± .36 h |

[a] Breed type = A - Angus, AB - Angus x Brahman, ABq - Brangus, AC - Angus x Charolais, AH - Angus x Hereford, AHBq - Angus x Hereford x 1/4 Brahman, B - Brahman, Bq - 1/4 Brahman x other crosses, Bx - Brahman x other crosses, C - Charolais, CB - Charolais x Brahman, CBq - Charolais x 1/4 Brahman, CLm - Charolais x Limousin, Cont- other Continental breeds, ContBq - other Continental breeds x 1/4 Brahman, Dairyx - Dairy crosses, EngBq - other English breeds x 1/4 Brahman, EngCont - other English x other Continental crosses, H - Hereford, HB - Hereford x Brahman, HBA - Hereford x Brahman x Angus, HC - Hereford x Charolais, HLm - Hereford x Limousin, Lm - Limousin, Lg - Longhorn, Sm – Simmental.

[b] Least-squares mean ± SE (dollars/cwt.).

[c,d,e,f,g,h] Means within columns without a common superscript differ ($P < 0.01$).

**Table 2. Selling price of market cows based on color.**

| Color | n | Selling price[a] |
|---|---|---|
| Brown and brown white face | 164 | $40.51 ± 0.74 [b] |
| Yellow | 720 | $40.26 ± 0.31 [b] |
| White | 766 | $40.14 ± 0.31 [b] |
| Red | 1,869 | $39.84 ± 0.19 [b] |
| Yellow-white face | 540 | $39.78 ± 0.35 [b] |
| Gray | 542 | $39.59 ± 0.35 [bc] |
| Black | 2,870 | $39.29 ± 0.16 [bc] |
| Gray-white face | 231 | $39.11 ± 0.56 [bcd] |
| Black-white face | 1,416 | $38.69 ± 0.23 [cd] |
| Spots or striped | 1,477 | $38.57 ± 0.24 [cd] |
| Red-white face | 2,527 | $38.38 ± 0.17 [d] |

[a] Least-squares mean ± SE (dollars/cwt.)
[b,c,d] Means within columns without a common superscript differ (P < 0.01).

**Table 3. Selling price of market cows based on frame score, body fill, brands and health.**

| Item: | n | Selling price[a] | Item: | n | Selling price[a] |
|---|---|---|---|---|---|
| Frame score: | | | Brands: | | |
| Large | 6,388 | $40.19 ± 0.13[b] | None | 12,057 | $39.11 ± 0.08[b] |
| Medium | 5,251 | $39.07 ± 0.12[c] | One | 858 | $40.32 ± 0.19[c] |
| Small | 1,465 | $35.28 ± 0.25[d] | Two or more | 229 | $40.98 ± 0.54[c] |
| Body fill: | | | Quality Grade: | | |
| Gaunt | 1,449 | $38.29 ± 0.23[b] | Utility | 5,137 | $37.28 ± 0.36[g] |
| Shrunk | 5,320 | $39.50 ± 0.12[cd] | Commercial | 1,458 | $36.33 ± 0.27[h] |
| Average | 4,422 | $39.24 ± 0.13[d] | Cutter | 4,904 | $36.12 ± 0.34[h] |
| Full | 1,593 | $37.42 ± 0.22[b] | Canner | 1,460 | $36.02 ± 0.43[h] |
| Tanked | 359 | $40.65 ± 0.50[c] | | | |
| Health: | | | | | |
| Healthy | 12,144 | $39.86 ± 0.08[b] | | | |
| Lumps | 274 | $34.47 ± 0.48[c] | | | |
| Lame | 234 | $32.89 ± 0.60[d] | | | |
| Sick | 216 | $25.50 ± 0.64[e] | | | |
| Bad eyes | 279 | $25.31 ± 0.55[f] | | | |

[a] Least-squares mean ± SE (dollars/cwt.).
[b,c,d,e,f] Means within columns within item without a common superscript differ (P < 0.01).
[g,h] Means within columns within item without a common superscript differ (P < 0.02).

**Table 4. Selling price of market cows based on age.**

| Age (yr) | n | Selling price[a] |
|---|---|---|
| 2 | 31 | $43.24 ± 1.39[b] |
| 3 | 83 | $41.84 ± 0.85[bc] |
| 4 | 216 | $41.17 ± 0.53[bcd] |
| 5 | 984 | $39.94 ± 0.25[cde] |
| 6 | 1,058 | $39.87 ± 0.24[de] |
| 7 | 1,595 | $39.51 ± 0.20[e] |
| 8 | 3,344 | $38.43 ± 0.13[f] |
| > 8 | 4,035 | $35.69 ± 0.12[g] |

[a] Least-squares mean ± SE (dollars/cwt.).
[b,c,d,e,f,g] Means within columns without a common superscript differ (P < 0.01).

# Factors Affecting the Selling Price of Replacement Cows Sold at Arkansas Livestock Auctions[1]

*T.R. Troxel, M.S. Gadberry, S. Cline, J. Foley, G. Ford, D. Urell, and R. Wiedower*[2]


## Story in Brief

Data were collected from 15 Arkansas livestock auctions to determine the factors affecting replacement cow selling price. Data collected included pregnancy status, breed or breed type, color, horn status, frame score, muscle thickness, fill, number of brands, brand location, health, BW, age, and price. Data were randomly collected on 9,598 cows. The mean selling price for replacement cows was \$48.39 ± \$0.09, and all main effects reported were significant ($P < 0.001$). Replacement cows in their third trimester sold for the highest price (\$50.33 ± \$0.17) followed by cows not checked for pregnancy (\$48.97 ± \$0.17), second trimester (\$47.59 ± \$0.14), first semester (\$45.67 ± \$0.26), and cows not pregnant (\$43.86 ± \$0.25). Buyers who were purchasing replacement cows paid more for English breed types and less for cows that contained dairy, Longhorn or Continental breeds or breed types. The selling prices for large-, medium-, and small-frame replacement cows were \$47.08 ± \$0.15, \$49.46 ± \$0.12, and \$48.11 ± \$0.25, respectively, and were different from each other ($P < 0.001$). A number of management (fill, horn status, and health) and genetic (color, frame score, and muscle thickness) factors affected the selling price of replacement cows.


## Introduction

Nearly one out of every four U.S. beef cows is located in the Southeast. In 2002, the number of beef cows in the Southeast increased by 107,000 head, or a little over 1%. Arkansas experienced an increase in cow number by 22,000 in 2002. Looking forward, beef cow numbers in the Southeast are expected to increase in 2003. Prospects for a profitable calf market over the next 1 to 2 years should result in increased beef cow numbers for this area (CattleFax, 2003). Consequently, there may be immediate opportunities for Arkansas cattle producers to sell replacement stock (cows and/or heifers). Very little information is available that identifies what management and genetic factors improve the value of replacement cows sold at livestock auctions. When buyers at a livestock auction view replacement cows they must appraise phenotypic characteristics (muscle thickness, frame score, breed composition, etc.) as predictors of quality and adjust their bids accordingly. Many of these factors such as breed or breed type are very subjective. Therefore, the objective was to determine the factors that affect the selling price of replacement cows in Arkansas weekly livestock auctions.

## Experimental Procedures

Five USDA-certified livestock market reporters collected data from 15 weekly livestock auctions in Arkansas from March 1, 2001 to May 31, 2001 and September 1, 2001 to November 30, 2001. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Morrilton, Ola, Ozark, Pocahontas, Ratcliff, and Springdale. All cows were sold as individuals. During the six reporting months, data were randomly collected on 9,598 animals (every second to third cow).

The data collected included pregnancy status (not checked, not pregnant, or first, second or third trimester), breed or breed type, color, horn status (polled or horned), frame score, muscle thickness, fill (gaunt, shrunk, average, full or tanked), number of brands, brand location (ribs, shoulder, or hip), health (dead hair, stale, sick, bad eye(s), lame or healthy), BW, age, and selling price. Cows were classified as replacement on visual appraisal and buyer identification. For those cows checked for pregnancy, a veterinarian employed by the livestock auction examined cows by rectal palpation. Pregnancy status was either written with a paintstik or a tag glued to the hip. The frame score was defined as large (over 1,100 lb), medium (900 to 1,100 lb), and small (less than 900 lb) frame based on the expected BW when cows are carrying 0.20 inches fat cover at the 12th rib. Muscle scores were determined using the 1, 2, and 3 scale with "1" being the thicker-muscled cows and "3" the thinner-muscled cows. Healthy cows showed no signs of sickness, lameness or any other unhealthy condition. Dead hair cows demonstrated a "lack luster" hair coat that could have indicated a heavy internal parasite load. Cows classified as stale had lost their effervescence and were apathetic in appearance. Sick cows showed signs of a sick condition (coughing, running nose, water eyes, etc.). Cows that had spot(s) in their eyes (bovine ocular squamous cell carcinoma) were noted, as well as, cows that demonstrated lameness on any leg. A livestock auction employee examined the teeth and estimated each cow's age.

*Data analyses.* The percentage of cows within pregnancy status, breed or breed type, color, horn status, frame score, muscle thickness, fill, number of brands, brand location, age and health were determined by the frequency procedure of SAS (SAS Inst., Inc., Cary, NC). Due to the unbalanced nature of the data, the month, sale barn and cow characteristics were analyzed as independent variables. The model included week, age, and weight as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares. When analysis of variance was performed for month of sale, week was excluded as a covariate. The analysis of variance was performed with the General Linear Model procedure (GLM) of SAS. Least-squares means were generated and separated based on the PDIFF option. Both are reported throughout this discussion. 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 dollars/cwt.

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## Results and Discussion

The mean selling price for replacement cows was $48.39 ± $0.09. There were no differences (P > 0.10) among the selling prices of replacement cows for March ($51.97 ± $0.21), April ($51.98 ± $0.19) or May ($51.60 ± $0.19), but prices for the fall months were different from each other (September: $47.48 ± $0.23, October: $45.01 ± $0.19 and November: $43.11 ± $0.20; P < 0.01). The selling prices from the fall (September, October and November) were lower than the selling prices from the spring (March, April and May; P < 0.01). As selling weight increased for replacement cows, price per cwt. increased (P < 0.001). The positive relationship between weight and price per cwt. for cows is opposite of the relationship between weight and price per cwt. for feeder cattle (Troxel, et. al., 2001).

Replacement cows in their third trimester sold for the greatest price ($50.33 ± $0.17) followed by cows not checked for pregnancy ($48.97 ± $0.17), second trimester ($47.59 ± $0.14), first trimester ($45.67 ± $0.26) and cows not pregnant ($43.86 ± $0.25). All means were different from each other (P < 0.01).

Twenty-six breeds or breed types represented 99.0% of the total cows sampled (Table 1). The breed or breed types were based upon common industry perception rather than actual knowledge of the breed composition. This, however, is what a buyer must do before a selling price can be offered. The price spread from the highest to lowest priced breed or breed type for replacement cows was $5.05. It appeared the buyers who purchased replacement cows paid more for English breeds or breed types and less for cows that contained dairy, Longhorn and Continental breeding.

Eleven colors represented 99% of the total population (Table 2). For replacement cows, black ($49.59 ± $0.16) and gray ($49.42 ± $0.39) cows sold for the greatest prices and white ($47.17 ± $0.38), spots or striped ($47.05 ± $0.34), red-white faced ($47.04 ± $0.21) and brown or brown white-faced ($46.09 ± $0.74) sold for the lowest prices (P < 0.01). As reported for cow breed or breed types, the price spread between the greatest to least priced replacement cows was small ($2.13).

The selling prices of muscle score 1 and 2 replacement cows were not different from each other ($48.72 ± $0.12 and $48.44 ± $0.44, respective; P > 0.05). Replacement cows with muscle scores 1 and 2 had higher selling prices than replacement cows with muscle score 3 ($46.33 ± $0.12; P < 0.01).

The selling price between replacement polled or horned cows was different ($48.63 ± $0.09 and $46.81± $0.81, respectively; P < 0.001). At this pricing level, there is not much of a price incentive to encourage cow-calf producers to eliminate horns. There may, however, be other incentives for producers to eliminate horns (management and safety concerns, etc.).

The selling prices for large-, medium-, and small-frame replacement cows were $47.08 ± $0.15, $49.46 ± $0.12, and $48.11 ± $0.25, respectively, and were different from each other (P < 0.001; Table 3). Buyers interested in purchasing replacement cows paid more for medium- and small-framed replacement cows than for large-framed replacement cows.

The selling price based on body fill is summarized in Table 3. Body fill was rated as gaunt, shrunk, average fill, full, and tanked. All selling prices due to body fill were different from each other (P < 0.01). Cows that were classified as full and tanked were discounted due to potentially high levels of shrink. Very few of the replacement cows had brands (< 8.0%). There were no differences (P > 0.10) between the selling price of replacement cows with one brand ($48.39 ± $0.31; Table 3), with two or more brands ($48.63 ± $0.67) or with no brands ($48.39 ± $09). There was no difference in selling price of replacements due to brand location (side, hip, and/or shoulder).

Over 94% of the cows surveyed were healthy. Selling price of healthy replacement cows ($48.47 ± $0.09), cows with lumps ($47.23 ± $0.58) and bad eyes ($45.31 ± $1.85) were not different (P > 0.10). The selling price for lame ($43.85 ± $1.29) and sick ($40.25 ± $1.80) replacement cows did not differ from those with lumps or bad eyes (P > 0.10).

The average selling price for replacement cows decreased with age (Table 4). All selling prices among ages were different (P < 0.01) from each other except for the selling prices for the 7- and 8- yr old replacement cows.

## Implications

Prospects for a profitable calf market over the next two years may result in increased beef cow numbers in Arkansas. Consequently, there may be opportunities for producers to sell replacement stock for additional income. To improve the value of replacement cows, producers should pay attention to breed or breed type, frame score, muscling, body fill and cow health. Once these factors are identified, producers can make management changes to improve replacement cow returns.

## Literature Cited

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Troxel, T.R., et al., 2001. Prof. Anim. Scientist 18:227.

**Table 1. Selling price of replacement cows based on breed or breed type.**

| Breed or breed type[a] | N | Selling price[b] |
|---|---|---|
| AC | 193 | $50.96 ± 0.56[c] |
| A | 765 | $50.72 ± 0.29[c] |
| Abq | 785 | $50.62 ± 0.28[c] |
| HC | 222 | $50.30 ± 0.54[cd] |
| AH | 549 | $50.29 ± 0.34[cd] |
| Lm | 460 | $49.82 ± 0.38[cd] |
| AHBq | 174 | $49.67 ± 0.61[cde] |
| ContBq | 198 | $48.72 ± 0.58[cde] |
| AB | 709 | $48.52 ± 0.32[de] |
| CLm | 154 | $48.50 ± 0.64[de] |
| B | 205 | $48.23 ± 0.56[de] |
| CBq | 231 | $48.15 ± 0.52[de] |
| HBA | 277 | $47.89 ± 0.50[de] |
| C | 484 | $47.76 ± 0.36[e] |
| Bq | 1,221 | $47.59 ± 0.23[e] |
| HLm | 241 | $47.52 ± 0.53[ef] |
| Cont | 116 | $47.47 ± 0.73[ef] |
| HB | 228 | $47.26 ± 0.54[ef] |
| EngBq | 514 | $47.31 ± 0.35[ef] |
| EngCont | 242 | $47.30 ± 0.51[ef] |
| Lg | 292 | $47.29 ± 0.50[ef] |
| Dairyx | 123 | $46.89 ± 0.73[ef] |
| CB | 109 | $46.35 ± 0.77[ef] |
| H | 513 | $46.32 ± 0.36[f] |
| Bx | 122 | $46.03 ± 0.77[f] |
| Sm | 299 | $45.91 ± 0.46[f] |

[a] Breed type = A - Angus, AB - Angus x Brahman, ABq - Brangus, AC - Angus x Charolais, AH - Angus x Hereford, AHBq - Angus x Hereford x 1/4 Brahman, B - Brahman, Bq - 1/4 Brahman x other crosses, Bx - Brahman x other crosses, C - Charolais, CB - Charolais x Brahman, CBq - Charolais x 1/4 Brahman, CLm - Charolais x Limousin, Cont- other Continental breeds, ContBq - other Continental breeds x 1/4 Brahman, Dairyx - Dairy crosses, EngBq - other English breeds x 1/4 Brahman, EngCont - other English x other Continental crosses, H - Hereford, HB - Hereford x Brahman, HBA - Hereford x Brahman x Angus, HC - Hereford x Charolais, HLm - Hereford x Limousin, Lm - Limousin, Lg - Longhorn, Sm – Simmental.

[b] Least-squares mean ± SE (dollars/cwt.).

[c,d,e,f] Means within columns without a common superscript differ ($P < 0.01$).

**Table 2. Selling price of replacement cows based on color.**

| Color | n | Selling price[a] |
|---|---|---|
| Black | 2,695 | $49.59 ± 0.16[b] |
| Gray | 420 | $49.42 ± 0.39[bc] |
| Black-white face | 1,163 | $48.76 ± 0.24[cd] |
| Yellow-white face | 345 | $48.73 ± 0.43[cd] |
| Red | 1,483 | $48.50 ± 0.21[cd] |
| Yellow | 573 | $47.78 ± 0.34[de] |
| Gray-white face | 166 | $47.56 ± 0.62[de] |
| White | 459 | $47.17 ± 0.38[f] |
| Spots or striped | 592 | $47.05 ± 0.34[f] |
| Red-white face | 1,553 | $47.04 ± 0.21[f] |
| Brown and brown white face | 131 | $46.09 ± 0.74[f] |

[a] Least-squares mean ± SE (dollars/cwt.)
[b,c,d,e,f] Means within columns without a common superscript differ (P < 0.01).

**Table 3. Selling price of replacement cows based on frame score, body fill, brands and health.**

| Item: | | n | Selling price[a] |
|---|---|---|---|
| Frame score: | | | |
| | Large | 3,397 | $47.08 ± 0.15[b] |
| | Medium | 4,857 | $49.46 ± 0.12[c] |
| | Small | 1,343 | $48.11 ± 0.25[d] |
| Body fill: | | | |
| | Gaunt | 1,116 | $47.57 ± 0.27[b] |
| | Shrunk | 2,670 | $49.78 ± 0.16[c] |
| | Average | 4,235 | $48.13 ± 0.13[d] |
| | Full | 1,407 | $46.33 ± 0.22[e] |
| | Tanked | 167 | $44.35 ± 0.66[f] |
| Brands: | | | |
| | None | 8,779 | $48.39 ± 0.09[b] |
| | One | 671 | $48.39 ± 0.31[b] |
| | Two or more | 141 | $48.63 ± 0.67[b] |
| Health: | | | |
| | Healthy | 9,348 | $48.47 ± 0.09[b] |
| | Lumps | 178 | $47.23 ± 0.58[bc] |
| | Lame | 36 | $43.85 ± 1.29[c] |
| | Sick | 18 | $40.25 ± 1.80[c] |
| | Bad eyes | 18 | $45.31 ± 1.85[bc] |

[a] Least-squares mean ± SE (dollars/cwt.).
[b,c,d,e,f] Means within columns within item without a common superscript differ (P < 0.01).

**Table 4. Selling price of replacement cows based on age.**

| Age (yr) | n | Selling price[a] |
|---|---|---|
| 2 | 574 | $59.51 ± 0.33[b] |
| 3 | 609 | $55.78 ± 0.32[c] |
| 4 | 865 | $53.84 ± 0.27[d] |
| 5 | 1,642 | $50.73 ± 0.19[e] |
| 6 | 1,617 | $49.95 ± 0.19[f] |
| 7 | 1,271 | $47.67 ± 0.22[g] |
| 8 | 1,794 | $47.30 ± 0.18[g] |
| > 8 | 717 | $41.71 ± 0.29[h] |

[a] Least-squares mean ± SE (dollars/cwt.).
[b,c,d,e,f,g,h] Means within columns without a common superscript differ (P < 0.01).

# Blood Trace Mineral Concentrations of Cows and Heifers from Farms Enrolled in the Arkansas Beef Improvement Program

*M.S. Gadberry, T.R. Troxel, and G.V. Davis*[1]


## Story in Brief

The objective of this study was to evaluate blood mineral concentration differences of cows and heifers and to determine the occurrence of mineral deficiencies in beef cattle in Arkansas. Blood samples were collected from mature cows on 22 farms and from replacement heifers on five farms. All farms provided a complete, free-choice mineral. Cow and heifer samples were not collected from the same farms. Fifty-nine heifer samples were analyzed for iron (Fe), zinc (Zn), copper (Cu), and selenium (Se), and 106 cow samples were evaluated for all listed minerals except for Cu (n=316) and Se (n=350). Serum Cu averaged 0.72 ± 0.07 and 0.67 ± 0.03 ppm for heifers and cows, respectively (P = 0.50). Blood Se averaged 0.13 ± 0.02 and 0.11 ± 0.01 ppm for heifers and cows, respectively (P = 0.46). The average blood concentration of Cu and Se for both heifers and cows were at the low end of the Michigan State University recommended, adequate range. The percentage of farms with heifers or cows that were adequate (80% and 54.6%) or below adequate (20% and 45.4%) for Cu was not different (P = 0.30). The percentage of farms with heifers or cows adequate (20% and 36.4%) or below adequate (80% and 63.6%) for Se did not differ (P = 0.48). Zinc was adequate for all farms. Producers should provide mineral supplements containing adequate trace mineral concentrations and monitor and adjust intake of supplements to ensure adequate consumption.


## Introduction

Beef cattle producers in Arkansas rely on forages to supply most of the nutrients needed by the herd, including protein, carbohydrates, vitamins, and minerals. Minerals contribute only a small part of the entire diet; however, they are essential for normal growth, reproduction, and immunity.

Mineral composition of forages is affected by many factors including mineral composition of the soil, soil pH, moisture, plant species, and plant stage of maturity. Hay analyses have indicated Arkansas forages are typically deficient in the trace minerals copper, zinc, and selenium (Davis et al., 2002).

The objective of this study was to compare blood trace mineral levels of cows and replacement heifers enrolled in the Arkansas Beef Improvement Program (ABIP) to determine the occurrence of mineral deficiencies in Arkansas beef cattle herds.

## Experimental Procedures

Blood was collected randomly from either cows or heifers enrolled in ABIP projects. Each herd was provided a free choice mineral supplement. Blood samples were collected from mature cows on 22 farms enrolled in either ABIP whole farm projects, breeding and calving season projects, or supplemental feeding projects. Blood samples from heifers were collected from five farms enrolled in the replacement heifer development project.

Blood samples were collected in Vacutainer (366430) red top tubes for iron (Fe) zinc (Zn), and copper (Cu) analysis, and in Vacutainer (266454) lavender top tubes for whole blood selenium (Se) analysis. Samples were analyzed by Schering-Plough Technical Services from 1992 to 1996 for Cu and Se. From 1996 to 2002, samples were sent to Michigan State University. In addition to serum Cu, Michigan State also reported serum calcium, phosphorus, sodium, potassium, magnesium, Fe, and Zn.

An average of 13 cows and 12 heifers were sampled per farm, representing an average of 17% of the total cows and 74% of the total heifers on each farm. A total of 106 samples from cows were analyzed for Fe and Zn, 316 were analyzed for Cu, and 350 were analyzed for Se. Fifty-nine samples from heifers were analyzed for Fe, Cu, Zn, and Se.

Blood levels were analyzed by the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) with farm as the experimental unit and animal within farm as the error term to determine differences in cow farms and heifer farms. Under research conditions, comparing blood levels would be accomplished by exposing both cows and heifers to similar planes of nutrition on the same or similar pastures to reduce environmental variation and experimental error. However, a comparison across environments with field data is justifiable when multiple farms are used and the variation among animals within farm is used as the experimental error realizing that differences seen could be due to factors other than age of the animal. Management or other environmental conditions might make the cow farms different from the heifer farms. Michigan State suggested blood levels were used to categorize samples as below adequate, adequate, or above adequate (Table 1). The percentage of all heifer and cow samples that were below adequate, adequate, or above adequate was determined with the FREQ procedure of SAS. Average Fe, Zn, Cu, and Se concentrations of animals within a farm were used to establish farm blood mineral concentrations. Chi-square analysis of farm blood classifications was used to determine if the percentage of heifer farms that was below adequate, adequate, or above adequate differed from the percentage of cow farms.

## Results and Discussion

Under field conditions across multiple environments, heifer blood mineral concentrations did not differ significantly (P > 0.10) from cow blood mineral concentrations for Fe, Zn, Cu, or Se (Table 2). The average concentration of Cu, 0.72 and 0.67 ppm, and Se,

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0.13 and 0.11 ppm, for heifers and cows, respectively, were at the low end of the MSU adequate range. The NRC (1996) indicates that Fe, Zn, Cu, and Se requirements are similar for both growing and mature cattle. Similarities in requirements may indicate why no differences were observed in these minerals for cows and heifers.

The percentage of heifer samples and cow samples that were below adequate, adequate, or above adequate are presented in Tables 3 and 4, respectively. Sixty-nine percent of the heifers and 76% of the cows sampled were above the MSU recommended Fe range. Eighty-one percent of the heifers and 84% of the cows were within the range defined as adequate for Zn. Thirty-three percent of heifers and 53% of the cows were below the adequate range for Cu, and 50% and 63% of the heifers and cows, respectively, were below the Se adequate range.

Since variability occurs within farm as well as across farm for blood mineral concentrations, a pooled average blood concentration within a farm was used to determine whether or not a farm was deficient for a particular trace mineral. Percentages of farms below adequate, adequate, or above adequate for Fe, Cu, Zn, and Se are presented in Table 5. All farms with cows were above average for Fe; however, heifer farms tended to differ (P = 0.07) from cow farms with 60% of the farms being above adequate and 20% below adequate. Iron deficiency hasn't been identified as a major problem in Arkansas, and cattle are generally exposed to enough Fe through forages and contact with soil.

One hundred percent of the farms with either heifers or cows were adequate for Zn. There are concerns with the possibility of elevated Zn concentrations of samples due to Zn in the rubber stopper of red top vacutainer tubes. The potential amount of contamination is unknown.

Twenty percent of the heifer farms had below adequate Cu concentrations and 45% of the cow farms were below adequate. The percentage of farms that were adequate or below adequate for Cu did not differ (P = .30) by farm type (heifer vs. cow farm). Liver Cu is a better indicator of Cu status; however, if blood levels are below adequate, copper deficiency is a concern. Some cattle with adequate serum Cu might have been mobilizing liver Cu and therefore could be moving toward a deficiency. Copper deficiency on these farms may be occurring due to low levels of Cu in the forage, low levels of Cu in the mineral supplement or poor mineral supplement intake, and (or) high levels of antagonistic minerals in the diet such as sulfur (S), Fe, and (or) molybdenum (Mo). Breed of cattle has also been shown to affect Cu status (Mullis et al., 2003; Ward et. al., 1995). Davis et al. (2002) indicated that 24%, 10% and 1% of AR hays contained antagonistic levels of S, Fe, and Mo, respectively that can interfere with copper metabolism.

Eighty percent and 63.6% of the heifer and cow farms, respectively, were below adequate for Se, and the percentage adequate or below adequate did not differ (P = 0.48) by farm type.

## Implications

Copper and selenium deficiencies are typically seen in Arkansas forages and cattle herds, despite mineral supplementation. Cattle producers need to evaluate the mineral concentration of their mineral supplements and monitor and adjust supplemental mineral intake to ensure adequate consumption.

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**Table 1. Michigan State University suggested mineral concentrations.**

| | Adequate Range |
|---|---|
| Serum iron (Fe), ppm | 1.30 to 1.40 |
| Serum zinc (Zn), ppm | 0.80 to 1.40 |
| Serum copper (Cu), ppm | 0.65 to 1.50 |
| Serum selenium (Se), ppm | 0.120 to 0.250 |

**Table 2. Serum concentrations[a] of iron, zinc, and copper, and whole blood selenium of heifers and cows.**

| | Heifers | Cows | P-value |
|---|---|---|---|
| Iron (Fe), ppm | 1.60 ± 0.09 | 1.69 ± 0.07 | 0.44 |
| Zinc (Zn), ppm | 1.14 ± 0.05 | 1.08 ± 0.04 | 0.39 |
| Copper (Cu), ppm | 0.72 ± 0.065 | 0.67 ± 0.03 | 0.50 |
| Selenium (Se), ppm | 0.13 ± 0.02 | 0.11 ± 0.01 | 0.46 |

[a] Least-squares means ± standard error

**Table 3. Percentage of heifers with below adequate, adequate, or above adequate serum concentrations of Fe, Zn, and Cu, and whole blood Se concentrations.**

| | Number of Samples | Below adequate (%) | Adequate (%) | Above adequate (%) |
|---|---|---|---|---|
| Iron (Fe) | 59 | 17.3 | 13.5 | 69.2 |
| Zinc (Zn) | 59 | 5.8 | 80.8 | 13.4 |
| Copper (Cu) | 59 | 32.7 | 67.3 | 0 |
| Selenium (Se) | 59 | 50 | 50 | 0 |

**Table 4. Percentage of cows with below adequate, adequate, or above adequate serum concentrations of Fe, Zn, and Cu, and whole blood Se concentrations.**

| | Number of Samples | adequate (%) | Below Adequate (%) | Above adequate (%) |
|---|---|---|---|---|
| Iron (Fe) | 106 | 17.9 | 6.6 | 75.5 |
| Zinc (Zn) | 106 | 6.6 | 84.0 | 9.4 |
| Copper (Cu) | 266 | 53.4 | 46.6 | 0 |
| Selenium (Se) | 286 | 63.0 | 36.0 | 1.0 |

**Table 5. Percentage of farms with below adequate, adequate, or above adequate serum concentrations of Fe, Zn, and Cu, and whole blood Se concentrations.**

| | Heifer farms | | | | Cow farms | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of Samples | Below Adequate (%) | Adequate (%) | Above Adequate (%) | Number of Samples | Below Adequate (%) | Adequate (%) | Above Adequate (%) | $X^2$ P-value |
| Iron (Fe) | 5 | 20 | 20 | 60 | 12 | 0 | 0 | 100 | 0.07 |
| Zinc (Zn) | 5 | 0 | 100 | 0 | 12 | 0 | 100 | 0 | --- |
| Copper (Cu) | 5 | 20 | 80 | 0 | 22 | 45.4 | 54.6 | 0 | 0.30 |
| Selenium (Se) | 5 | 80 | 20 | 0 | 22 | 63.6 | 36.4 | 0 | 0.48 |

# Comparison of Synchrony Rates of *Bos taurus* and *Bos indicus*-Type Females Using CIDR Devices in Combination with Prostaglandin and ECP or GnRH

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


## Story in Brief

Differences in estrous synchrony rates between *Bos indicus* (Beefmaster crossbred; Trial 1) and *Bos taurus* (Gelbvieh X Angus; Trial 2) heifers were evaluated when females were synchronized using controlled internal drug release (CIDR) progesterone inserts plus injections of either estradiol cypionate (ECP) or gonadotropin releasing hormone (GnRH) at the time of CIDR insertion. All animals in both trials were given prostaglandin F2α (PGF) at CIDR removal and an injection of ECP one day later. In trial 1, ECP-treated heifers showed estrus earlier than GnRH treated heifers ($P < 0.05$), but there were no differences in overall synchrony rates. In trial 2, there were no differences in either synchrony rate or time to onset of estrus. When comparing the two breed types, the *Bos taurus* heifers had a greater synchrony rate and exhibited estrus earlier than *Bos indicus* heifers. These results could be explained by season (winter) as *Bos indicus* cattle tend to be long day breeders. Also, the heifers in trial 2 were heavier at breeding than those in trial 1 (852.9 lb vs. 757.2 lb; $P < 0.05$).


## Introduction

In order for large scale artificial insemination to be a viable alternative to natural service, synchronization of females is imperative to reduce time and labor costs. The results of a synchronization protocol must be predictable, repeatable, and provide for a tightly synchronized estrous period to be beneficial to the beef cattle producer. Many different synchronization protocols have been successfully used in beef females. Commonly, a source of progesterone is administered in an effort to suppress the induction of the ovulatory surge of luteinizing hormone (Bo et al., 1994). A protocol that provides sustained progesterone levels, such as placement of a CIDR insert into the female's reproductive tract, is needed to properly suppress ovulation.

Recent research has indicated addition of products that synchronize follicular wave emergence would benefit current protocols by causing synchronous ovulation when the suppressive effect of progesterone is removed (Martinez et al., 2000). Treatments successfully used to synchronize wave emergence have included GnRH, estradiol-17β, and estradiol cypionate (ECP) (Pancarci et al., 2002). The objectives of the current study were to determine the effectiveness of GnRH and ECP in hastening the onset of estrus in heifers and to compare treatment responses between *Bos taurus* and *Bos indicus* females.

## Experimental Procedures

Two trials were conducted at the Southeast Research and Extension Center in Monticello. Both trials incorporated similar treatment comparisons; although, different animal models were used. Trial one consisted of fall born nulliparous Beefmaster sired females (n = 23; 13 to 18 mo old), synchronized and inseminated in December. Trial two consisted of Gelbvieh X Angus crossbred heifers (n = 39; 12 to 15 mo old) which were synchronized and inseminated in May for spring calves. Heifers within trials were randomly assigned to one of two synchronization treatments. The treatment comparison evaluated the effectiveness of a synchronization protocol incorporating the use of GnRH into a CIDR protocol which used prostaglandin and estradiol cypionate. Females in treatment 1 (GnRH) received a CIDR insert and an injection of GnRH (100 Fg) on d 0. Prostaglandin F2α (25 mg) was administered and CIDRs removed on d 7. An injection of estradiol cypionate (0.25 mg) was given 24 to 30 h after CIDR removal. Females in Treatment 2 (ECP) were treated identically except they received a 2 mg injection of estradiol cypionate on d 0 rather GnRH. Females were inseminated approximately 12 h after estrus and efficacy of each protocol was based on synchrony rate. Data were analyzed using the analysis of variance procedures of SAS (SAS Institute, Inc., Cary, NC) with animal as the experimental unit.

## Results and Discussion

There were no differences among treatment groups in synchrony rate during trial 1 (GnRH = 72.7%; ECP = 75%; Table 1). However, time to observed estrus from the second ECP shot was affected by treatment ($P < 0.05$). Beefmaster heifers which receiving 2 mg ECP at the time of CIDR insertion had 12-h shorter ($P < 0.05$) time to estrus onset. This is in contrast to trial two where there were no treatment differences to time of estrus onset ($P = 0.1$). In trial 2, all of the Gelbvieh X Angus crossbred heifers responded to synchronization and showed standing estrus within 40 h of the second ECP injection. When comparing onset of estrus from time of second ECP injection across trials, heifers which received ECP at CIDR insertion came into heat earlier ($P < 0.05$) with no difference overall in synchrony rate.

In comparing the two trials, there were differences ($P < 0.05$) in the time to estrus onset between the two breed types (Table 1). Additionally, the *Bos taurus* heifers in trial 2 showed more positive response to synchronization than their *Bos indicus* counterparts in

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trial 1 (100% synchrony vs. 73.9% synchrony, $P < 0.05$). This may be due to the age of the heifers, seasonality and that the *Bos indicus* heifers may not have attained body size or hypothalamic secretions necessary to cycle regularly. In ideal situations, heifers should weigh 65% of their mature weight at the time of their first breeding. The Beefmaster heifers came from a herd where the average mature female weight is approximately 1350 lb. Ideally, the average weight of the heifers at the time of insemination should have been 877 lb. Instead, these heifers averaged 757.2 lb, indicating that these heifers may simply not have been heavy enough to breed.

Brahman and Brahman-based cattle do not attain puberty as early as *Bos taurus* cattle (Randel, 1994). Often, this breed type does not attain puberty in sufficient time to calve at 2 yr of age. Additionally, it has been documented that *Bos indicus* cattle tend to be long day breeders and thus exhibit reduced conception rates during the winter months. Anestrus is common during winter months in *Bos indicus* cattle, as is increased incidence of quiet ovulation.

## Implications

Addition of ECP or GnRH to currently used CIDR protocols functions to tighten estrous synchrony in bovine females. The use of estradiol cypionate seems to be more effective in this regard. The *Bos taurus* heifers responded better to the protocols used in this trial than *Bos indicus* heifers, possibly due to seasonality or weight at time of breeding.

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**Table 1: Summary of Synchronization Protocols.**

| | Trial one | Trial two | Trial 1 vs. Trial 2 |
|---|---|---|---|
| Weights (lb) | 757.2 | 852.9 | $P < 0.05$ |
| Synchrony rate | 17/23 (73.9%) | 39/39 (100%) | $P < 0.05$ |
| GnRH treated | 8/11 (72.7%) | 20/20 (100%) | |
| ECP treated | 9/12 (75%) | 19/19 (100%) | |
| Average time to estrus (h) | 25.47 | 12.33 | $P < 0.05$ |
| GnRH treated | 32.00[b] | 14.55 | |
| ECP treated | 19.67[a] | 10.00 | |

[a,b] Numbers with different superscripts differ ($P < 0.05$)

# Effect of Respiratory Disease Vaccination Program on Immune Response in Beef Calves

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## Story in Brief

Sixty autumn-born Angus steer and heifer calves at the Beef Cattle Research Facility in Savoy, AR, were stratified in late May 2002 by weight and sex into two treatment groups: 1) Elite-4™, Pulmo-guard™ PHM-1 and Caliber™ 7 followed 3 weeks later at weaning by Express-5™ and Caliber™ 7 and 2) CattleMaster® 4, One Shot , and Caliber™ 7 followed at weaning by Bovi-Shield™ 4 and Caliber™ 7 to compare calf immune responses. Blood samples were collected from calves on d 0 when preweaning vaccinations were administered, d 21 when weaning vaccinations were administered and d 51 (30 d post-weaning). Analyses were performed to determine serum antibody titers to infectious bovine rhinotracheitis, bovine viral diarrhea type I, bovine viral diarrhea type II and bovine respiratory syncytial virus. Results from this study indicate that both vaccination programs were effective in boosting ($P < 0.01$) calf antibody titers to infectious bovine rhinotracheitis, bovine viral diarrhea type II and bovine respiratory syncytial virus.

## Introduction

Bovine respiratory disease complex (BRD), also known as shipping fever or bronchopneumonia, is associated with significant economic losses resulting from morbidity and mortality in newly weaned or received cattle. Factors contributing to the incidence of BRD include stress, nutrition, immunity, and exposure to infectious pathogens. Viral agents commonly involved in pathogenesis of BRD include infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD), bovine respiratory syncytial virus (BRSV), and parainfluenza[3] (PI[3]). Implementation of preweaning respiratory disease vaccination programs may result in heavier weaning calves (Coffey et al., 1999), enhance the immune status of newly weaned calves (Galyean et al., 1999), and decrease post-weaning BRD. Cattle administered a modified-live viral vaccine prior to feedlot entry may also exhibit a lower occurrence of respiratory tract lesions (Grathwohl et al., 2001). Results from the Arkansas Feedout Program indicate that sickness in the feedlot can reduce a calf's ability to grade Choice (Troxel et al., 2001). The objectives of this study were to compare immune responses of beef calves administered either 1) Elite-4™, Pulmo-guard™ PHM-1 and Caliber™ 7 preweaning with Express-5™ and Caliber™ 7 boosters at weaning or 2) CattleMaster® 4, One Shot®, and Caliber™ 7 preweaning with Bovi-Shield™ 4 and Caliber™ 7 boosters at weaning.

## Experimental Procedures

Sixty Angus calves born in autumn 2001 at the Beef Cattle Research Facility in Savoy, AR, grazed mixed forage pastures with their dams. On May 28, 2002, calves on these pastures were stratified by weight and sex into two treatment groups to compare respiratory disease vaccination protocols (Table 1). Group I received vaccinations of Elite-4™ (Boehringer Ingelheim Vetmedica, Inc.), Pulmo-guard™ PHM-1 (Boehringer Ingelheim Vetmedica, Inc.) and Caliber™ 7 (Boehringer Ingelheim Vetmedica, Inc.) followed at weaning by Express-5™ (Boehringer Ingelheim Vetmedica, Inc.) and Caliber™ 7. Group II received CattleMaster® 4 (Pfizer Animal Health), One Shot® (Pfizer Animal Health) and Caliber™ 7 followed at weaning by Bovi-Shield™ 4 (Pfizer Animal Health) and Caliber™ 7. Elite-4™ contained killed IBR, PI[3], BRSV, and BVD viruses, while CattleMaster® 4 was comprised of chemically altered strains of IBR and PI[3] viruses, modified live BRSV, and killed cytopathic and noncytopathic BVD virus strains using an aluminum hydroxide adjuvant. Express-5™ and Bovi-Shield™ 4 each contained modified live strains of IBR, PI[3], BRSV, and BVD viruses. Pulmo-guard™ PHM-1 was a bacterin-toxoid vaccine used to prevent *Pasteurella haemolytica* and *P. multocida* infection, while One Shot® was a bacterin-toxoid vaccine used to prevent *P. haemolytica* type A1 infection. Caliber™ 7 was labeled for vaccination against disease caused by *Clostridium chauvoei*, *C. septicum*, *C. novyi*, *C. sordellii*, and *C. perfringens* types C and D.

Suckling steer and heifer calves with no previous exposure to respiratory disease vaccination received initial vaccinations on May 28, 2002 (d 0) and 3 weeks prior to weaning. Thirty calves were on each vaccination protocol. Booster vaccinations of Bovi-Shield™ 4, Express-5™, and Caliber™ 7 were administered at weaning on June 18, 2002 (21 d following the initial vaccinations). Elite-4™, CattleMaster® 4, Bovi-Shield™ 4, and Express-5™ were administered intramuscularly in the neck region, while Pulmo-guard™ PHM-1, One Shot®, and Caliber™ 7 were administered subcutaneously in the neck region in compliance with Beef Quality Assurance guidelines. In accordance with product label recommendations, the dosage for Elite-4™ was 5 ml per injection, while the dosages for CattleMaster® 4, Pulmo-guard™ PHM-1, One Shot®, Caliber™ 7, Express-5™, and Bovi-Shield™ 4 were 2 ml per injection. Blood samples and calf weights were collected from each animal on d 0 prior to initial vaccination, d 21 prior to weaning vaccination, and d 51. An interim weight was also taken on July 2, 2002 (d 34). Approximately 7 ml of blood was collected from each calf via jugular venipuncture. Blood samples were centrifuged at 2000 rpm for 20 min to separate and harvest serum that was stored at -4°F until assayed. Analysis was performed to determine serum antibody titers to the four respiratory viruses.

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*Statistical analysis.* This experiment utilized a completely randomized design. The GLM procedure of SAS (SAS Inst., Inc., Cary, NC) was used to determine the effects of treatment, calf sex, and interactions. Titer data were tested for normality with the Shapiro-Wilk test. The null hypothesis was rejected ($P < 0.01$) for all titer variables. Because the titer data were not normally distributed, the variations around the means are not reported. Titer data were transformed to a natural logarithm before analysis. Non-transformed least-squares means are reported.

## Results and Discussion

Calf ADG results are presented in Table 2. For the weigh period of June 18 to July 2, steers in the Group II vaccination program had greater ADG than steers in the Group I and heifers in the Group II vaccination programs, while there were no differences in ADG ($P > 0.10$) for heifers between the two vaccination programs (Interaction, $P < 0.02$). There were no other differences observed in ADG ($P > 0.10$) between steers and heifers or between treatment groups.

Serum antibody titer levels appear in Table 3. Antibody titers to IBR were higher ($P < 0.10$) in heifers than steers on day 0, however, no other titer differences were found between steers and heifers. Between day 21 and d 51 IBR antibody titers increased ($P < 0.01$) and BVD Type II antibody titers increased ($P < 0.01$) for both treatments. On day 51 IBR antibody titers were higher ($P < 0.01$) in both steer and heifer calves in Group II. Bovine viral diarrhea Type I ($P < 0.05$) and BVD Type II ($P < 0.01$) antibody titers were higher on day 51 in calves in Group I. In addition, BRSV antibody titers increased ($P < 0.01$) in both treatment groups from day 0 to day 21. On days 21 and 51, BRSV antibody titers were higher ($P < 0.01$) in both steer and heifer calves in Group II.

These results indicate that both respiratory disease vaccination protocols were successful in elevating antibody titers to viral agents commonly involved in BRD development including IBR, BVD Type I, BVD Type II, and BRSV. In addition, booster vaccinations at weaning were effective in increasing antibody titers to IBR and BVD Type II beyond initial titer response to preweaning vaccinations in both treatment groups. This illustrates the importance of booster vaccinations in these vaccination protocols. At 30 d post-weaning, the calves in Group I had an advantage in antibody titer levels for BVD Types I and II, while the calves in Group II had an advantage in antibody titer levels for IBR. There was, however, no demonstrated overall benefit of one vaccination protocol over the other in terms of calf weight gains.

## Implications

Cow-calf producers have several preweaning vaccination program options that are effective in boosting antibody titers and calf immune response against major bovine respiratory disease viruses. Utilizing such a program may have benefits for not only cow-calf producers, but also producers involved in post-weaning phases of beef production.

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**Table 1. Treatment, bleeding and weighing schedule.**

| Sampling date | Group I | Group II |
|---|---|---|
| Preweaning | Elite-4™ | CattleMaster® 4 |
| May 28, 2002 | Pulmo-guard™ PHM-1 | One Shot ® |
| (d 0) | Caliber™ 7 | Caliber™ 7 |
| | Blood sample | Blood sample |
| | Weight | Weight |
| Weaning | Express-5™ | Bovi-Shield™ 4 |
| June 18, 2002 | Caliber™ 7 | Caliber™ 7 |
| (d 21) | Blood sample | Blood sample |
| | Weight | Weight |
| July 2, 2002 | Weight | Weight |
| (d 34) | | |
| Post-Weaning | Blood sample | Blood sample |
| July 18, 2002 | Weight | Weight |
| (d 51) | | |

**Table 2. Average daily gains of steer and heifer calves on different respiratory disease vaccination protocols.**

| | Average daily gain, lb | | | | | |
|---|---|---|---|---|---|---|
| | Steers | | Heifers | | All calves | |
| Weigh period[a] | Group I[b] | Group II[b] | Group I | Group II | Group I | Group II |
| May 28 to | 0.86 ± | 1.07 ± | 0.95 ± | 0.85 ± | 0.90 ± | 0.96 ± |
| June 18 | 0.12 | 0.12 | 0.12 | 0.11 | 0.08 | 0.08 |
| June 18 to | 0.75± | 1.16 ± | 0.95 ± | 0.87 ± | 0.86 ± | 1.01 ± |
| July 2[c] | 0.10[e] | 0.10[d] | 0.09[de] | 0.09[e] | 0.07 | 0.07 |
| July 2 to | 1.44 ± | 1.41 ± | 1.32 ± | 1.25 ± | 1.38 ± | 1.32 ± |
| July 18 | 0.23 | 0.23 | 0.22 | 0.21 | 0.16 | 0.15 |
| May 28 to | 0.95 ± | 1.21 ± | 1.05 ± | 0.97 ± | 1.00 ± | 1.09 ± |
| July 18 | 0.11 | 0.11 | 0.10 | 0.10 | 0.07 | 0.07 |

[a] May 28, 2002: initial vaccinations administered, blood samples and weights collected; June 18, 2002: booster vaccinations administered, blood samples and weights collected, calves weaned; July 2, 2002: weights collected; July 18, 2002: blood samples and weights collected.

[b] Group I received Elite-4TM, Pulmo-guardTM PHM-1, CaliberTM 7 21 d prior to weaning and Express-5TM and CaliberTM 7 at weaning. Group II received CattleMaster ® 4, One Shot ® and CaliberTM 7 21 d prior to weaning and Bovi-ShieldTM 4 and CaliberTM 7 at weaning.

[c] Calf sex x treatment, $P < 0.02$.

d,e Within a row, within steers and heifers or within all calves, means with different superscripts differ, $P < 0.05$. In the absence of superscripts, means within a row are not different.

**Table 3. Bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD) Type I, BVD Type II, and bovine respiratory syncytial virus (BRSV) titers of steer and heifer calves on different respiratory disease vaccination protocols.**

| Sampling | Titer levels | | | | | |
|---|---|---|---|---|---|---|
| date, d | Steers | | Heifers | | All calves | |
| | Group I[a] | Group II[a] | Group I | Group II | Group I | Group II |
| IBR | | | | | | |
| 0[b] | 2.8 | 2.1 | 11.2 | 3.9 | 7.0 | 3.0 |
| 21[c] | 38.1 | 38.3 | 38.0 | 43.3 | 38.1 | 40.8 |
| 51 | 71.1[g] | 144.0[f] | 64.5[g] | 120.0[f] | 67.8[g] | 132.0[f] |
| BVD Type I | | | | | | |
| 0 | 2117.3 | 3630.9 | 2410.7 | 3076.0 | 2264.0 | 3353.4 |
| 21 | 4219.7 | 4315.4 | 4966.4 | 4896.0 | 4593.1 | 4605.7 |
| 51 | 7606.9[h] | 6729.1[i] | 8192.0[h] | 6528.0[i] | 7899.4[h] | 6628.6[i] |
| BVD Type II | | | | | | |
| 0 | 18.9 | 2.0 | 10.8 | 2.0 | 14.9 | 2.0 |
| 21[d] | 18.9 | 2.4 | 6.1 | 2.4 | 12.5 | 2.4 |
| 51 | 274.9[f] | 94.3[g] | 246.4[f] | 98.6[g] | 260.6[f] | 96.5[g] |
| BRSV | | | | | | |
| 0[e] | 4.1 | 3.4 | 3.6 | 4.1 | 3.9 | 3.8 |
| 21 | 9.1[g] | 67.1[f] | 8.1[g] | 53.0[f] | 8.6[g] | 60.1[f] |
| 51 | 8.4[g] | 45.2[f] | 11.7[g] | 48.5[f] | 10.1[g] | 46.9[f] |

[a] Group I received Elite-4TM, Pulmo-guardTM PHM-1, CaliberTM 7 21 d prior to weaning and Express-5TM and CaliberTM 7 at weaning. Group II received CattleMaster ® 4, One Shot ® and CaliberTM 7 21 d prior to weaning and Bovi-ShieldTM 4 and CaliberTM 7 at weaning.

[b] Main effects for calf sex differ: IBR, $P < 0.10$.

[c,d,e] Means change across sampling periods due to treatment effects: c: d 21 to d 51, $P < 0.01$; d: d 21 to d 51, $P < 0.01$; e:d 0 to d 21, $P < 0.01$.

[f,g] Within a row, within steers and heifers or within all calves, means with different superscripts differ, $P < 0.01$. In the absence of superscripts, means within a row are not different.

[h,i] Within a row, within steers and heifers or within all calves, means with different superscripts differ, $P < 0.05$. In the absence of superscripts, means within a row are not different.

# *Escherichia coli* and *Salmonella* Shedding in Beef Cattle Grazing Tall Fescue

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## Story in Brief

Fecal samples were obtained from Angus x Hereford cows (n = 49) and spring-born calves (n = 45) grazing endophyte-infected (E+) tall fescue or non-infected (E-) tall fescue during the summer to examine the effects on shedding of *Escherichia coli* O157:H7 (EHEC) and *Salmonella* (SM). Fecal samples were collected at 7:00 a.m. on each collection date (August 5th and 26th, 2002). One-half of the male calves were treated with a steroid implant at 60 days prior to fecal collection. Body temperature was measured from cattle at time of fecal collection. Mean ambient temperature and humidity at time of fecal collection(s) were 81°F and 77%, respectively. Overall, incidence of EHEC shedding averaged 8.4 and 7.6% for calves and cows, respectively. *Salmonella* shedding was 4.8 and 0% for calves and cows, respectively. Cows grazing E+ fescue were shedding fewer ($P < 0.05$) EHEC than cows grazing E- (1.8% vs 17% for E+ and E- cows, respectively). Likewise, EHEC shedding tended ($P = 0.11$) to be reduced in E+ calves (4.3%) compared with E- calves (13.9%). In calves, type of fescue grazed did not influence ($P > 0.10$) the incidence of SM shedding. Cow shedding of either EHEC or SM did not influence ($P > 0.10$) calf shedding of bacteria. Shedding of EHEC and SM in calves was not influenced ($P > 0.10$) by sex of calf or implant status. Shedding of *E. coli* O157:H7 tended to be reduced in calves and was decreased in cows grazing endophyte-infected tall fescue.


## Introduction

*Escherichia coli* O157:H7 (EHEC) and *Salmonella* (SM) are two of the most common agents of foodborne illness in humans, and both bacteria have been isolated from beef cattle at all stages of production (Elder et al., 2000; Fedorka-Cray et al., 1998). Annually, pathogenic bacteria-related illnesses cost an estimated $2.9 to 6.7 billion (Buzby et al., 1996).

Recently, Fitzgerald et al. (2003) reported that the incidence of shedding of EHEC and SM tended to be increased by production stressors (i.e., milking status and lactation phase) in dairy cows. It is well documented that cattle grazing infected tall fescue during summer months are stressed and have reduced milk production, reproductive performance, and weight gain (Stuedemann and Hoveland, 1988).

A majority of the research investigating EHEC and SM shedding has been conducted on grain-fed cattle. A survey of 100 feedyards throughout the U.S. reported a 1.8% incidence of EHEC shedding (APHIS, 1995). Objectives of this study were to determine the: 1) influence of grazing endophyte-infected (E+) or non-infected (E-) tall fescue on shedding of EHEC and SM, 2) relationship of shedding EHEC and SM between cow and calf, and 3) influence of calf sex and steroid implant of male calves on bacteria shedding.

## 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. Mature Angus x Hereford cows (n = 49) and their spring-born calves (n = 45) were utilized in duplicate (August 5th and 26th, 2002) for fecal collection at 7:00 a.m. Vaccination of cattle and blood sampling for additional studies also occurred on both collection dates. Cows and their calves grazed either endophyte-infected (E+) tall fescue (*Festuca arundinacea*) or non-infected (E-) tall fescue. Approximately 15 grams of fecal material was obtained via rectal palpation using separate veterinary palpation sleeves. Fecal samples were placed in Whirlpacks™ (Modesto, CA), packed on ice, and shipped to the USDA-ARS Food and Feed Safety Research Laboratory, College Station, TX, to determine the prevalence of *Escherichia coli* O157:H7 (EHEC) and *Salmonella* (SM).

*Salmonella isolation.* Fecal material (3 to 5 grams) was enriched in 20 mL of tetrathionate broth for 24 h at 37°C. Post-enrichment of samples in Rapport-Vassilidis R10 broth was followed by streaking each sample on brilliant green agar with novobiocin for identification. Samples were characterized biochemically using lysine iron agar and triple sugar iron agar if they displayed typical morphology of *Salmonella*.

*Escherichia coli O157:H7 isolation.* A homogenous sample containing 10 grams of feces, vancomycin (8 mg/L; Sigma Co.), cefixime (0.5 mg/L; Lederle Laboratories), and cefsulodin (10 mg/L; Sigma Co.) was prepared. The suspension was incubated at 37°C for 6 h followed by immunomagnetic bead enrichment consisting of a 30 min incubation of 1 mL of GN (gram negative; Fisher Scientific) enrichment broth with 20 L of anti-O157 immunomagnetic beads at 25°C containing 0.05% Tween 20 (Dynal, Lake Success, NY). Fifty microliters of bead suspension was spread plated on sorbitol MacConkey plates containing cefixime (0.05 mg/L) and potassium tellurite (2.5 mg/L; Difco Laboratories; SMACct). Three sorbitol-negative colonies displaying typical EHEC morphology were selected from each plate and confirmed by enzyme-linked immunoassay.

*Heat stress parameters.* Maximum ambient temperature and relative humidity were collected for each replicate from the Dale

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Bumpers Small Farms Research Center in Booneville, Arkansas. A temperature-humidity index (THI) was calculated for day of fecal collections. Briefly, THI was calculated as follows: THI = 0.45 T + 0.55 TH - 31.9 H + 31.9 where T = dry bulb temperature expressed in °F and H = relative humidity/100.

One-half of the male calves were implanted (Synovex-C®, Fort Dodge Animal Health, Fort Dodge, IA) approximately 60 days prior to fecal collection. Body temperature of cows and calves was monitored via the rectum at time of fecal collection. Blood serum samples were collected at the second replicate by venipuncture of the tail into 15 mL tubes, placed on ice, and centrifuged (2,500 x g for 15 min) after 6 h of clotting. Samples were stored at -4°F until concentrations of prolactin were quantified. Intra-assay coefficient of variation was 9%. Sensitivity of the assay was 0.3 ng/mL. Fescue plant samples were harvested and sent to the College of Veterinary Medicine, Oregon State University, for quantification of concentrations of ergovaline.

*Statistical Analyses*. Chi-square analysis, using the FREQ procedure of SAS (SAS Inst., Inc., Cary, NC), was used to determine influence of forage, sex of calf, and implant status of male calves on shedding of EHEC and SM. Influence of maternal bacterial shedding on incidence of calf bacteria shedding also was analyzed by chi-square analysis.

## Results and Discussion

Average ambient temperature and humidity at time of fecal collection were 81°F and 77%, respectively. A calculated THI of 84.5 was indicative of moderate heat stress at the time of fecal collection. Body temperature of cattle ranged from 104 to 106°F. There was a fescue treatment (E+ or E-) by age interaction ($P < 0.001$) for body temperature. Calves maintained on E- had the highest ($P < 0.05$) body temperature (106°F) of all cattle in the experiment. To decrease heat stress of E+ cattle during fecal collection, cows and calves consuming E- fescue were transported to the handling facility (approximately 1/4 mile) nearest to the E+ cattle, and E+ cattle were processed before E- cattle, presumably during cooler temperatures. Thus, handling and transporting of E- cattle during increased ambient temperatures may have attributed to increased body temperatures in this group compared with E+ cattle. Concentrations of ergovaline were 1,642 parts per billion (ppb) for the E+ fescue and 57 ppb for the E- fescue. Current research data indicate fescue toxicosis is induced in livestock at concentrations of ergovaline from 400 to 750 ppb. Concentrations of prolactin were reduced ($P < 0.05$) in E+ calves (14.6 ng/mL) compared with E- calves (62.3 ng/mL) indicating toxicosis in cattle grazing E+ fescue.

Overall, incidence of EHEC shedding averaged 8.4 and 7.6% for calves and cows, respectively. *Salmonella* shedding was 4.8 and 0% for calves and cows, respectively. Body temperature of cattle or ambient temperature did not influence ($P > 0.10$) shedding of EHEC or SM in cows and calves. Previous researchers report that 1.8% (APHIS, 1995) to 28% (Elder et al., 2000) of fed cattle evaluated were positive for *E. coli* O157:H7. Furthermore, *Salmonella* was found in 4% of fecal samples and 38% of hide samples from feedlot cattle (Beach et al., 2002). Fitzgerald et al. (2003) reported the incidence of *E. coli* O157:H7 and *Salmonella* shedding was 56 and 53%, respectively, in dry-lot, confined dairy cows in the Southwest. Peak shedding of EHEC occurs in late summer and early fall, and seasonality of SM shedding also has been observed. The differences in prevalence of bacteria shedding between studies may be related to management of cattle, fecal sampling method, time of year samples were collected, and/or the culture technique used.

This is an initial report of data reporting the effects of grazing E+ and E- fescue on the incidence of EHEC and SM shedding in cows and their calves. Cows grazing E+ fescue shed less ($P < 0.05$) EHEC than cows grazing E- fescue (1.8% vs 17% for E+ and E- cows, respectively; Figure 1). Likewise, calves maintained on E+ fescue (4.3%) tended ($P = 0.11$) to shed less EHEC than calves on E- fescue (13.9%; Figure 1). In the current study, no cows shed SM, and SM shedding was not influenced ($P > 0.10$) by type of fescue (E+ or E-) in calves (Figure 2). These data suggest consumption of E+ fescue by cattle could reduce the incidence of fecal shedding of EHEC. However, the possibility of transportation stress affecting EHEC shedding in E+ cattle should be investigated. Further research, including in vitro studies, is necessary to fully understand the relationship of E+ fescue and the presence of ergot alkaloids with *E. coli* O157:H7 shedding.

Transmission and/or infection of the calf from the cow were not conclusive in the current study. Shedding of bacteria from cows was not associated ($P > 0.10$) with their calves shedding bacteria. Furthermore, EHEC or SM was not affected ($P < 0.10$) by sex of calf or implant status of male calves.

## Implications

Knowledge of factors that may influence shedding of pathogenic bacteria, such as grazing endophyte-infected fescue, in cattle is necessary to decrease the incidence of bacteria-related illnesses in both cattle and the possible transmission of these bacteria to humans.

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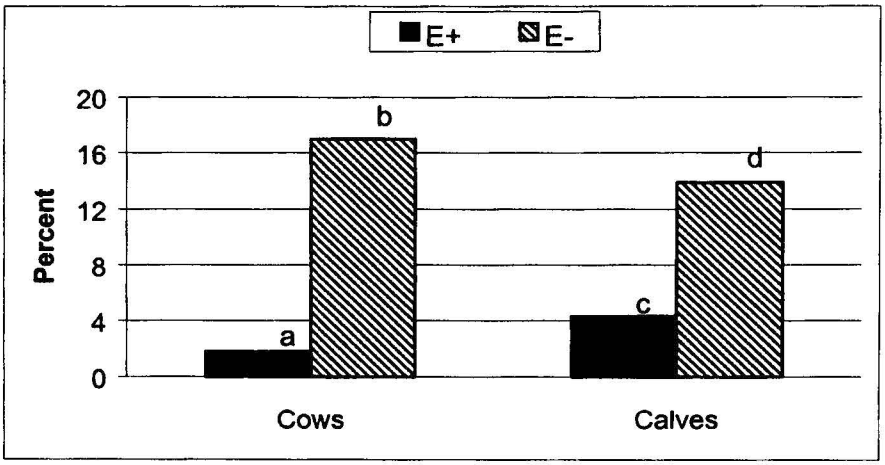


**Fig. 1. Incidence of *E. coli* O157:H7 shedding in cows and calves grazing endophyte-infected (E+) or non-infected (E-) tall fescue. $^{a,b}P < 0.05$; $^{c,d}P = 0.11$.**

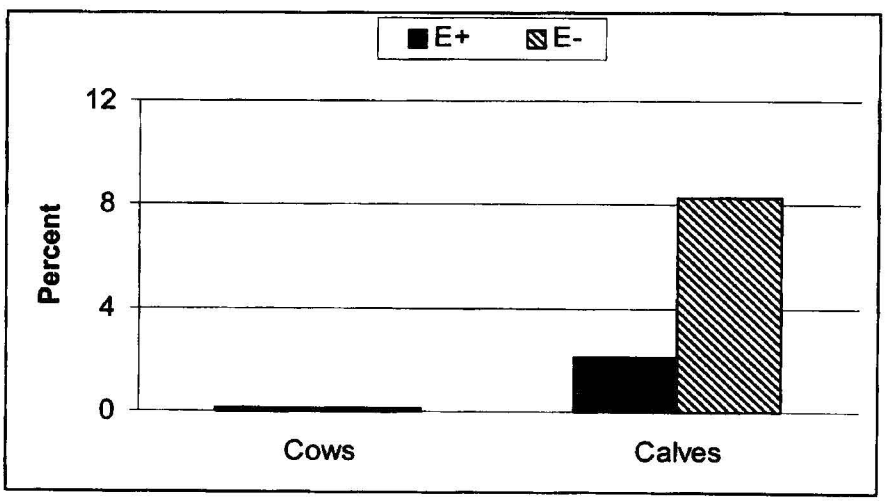


**Fig. 2. Incidence of Samonella shedding in cows and calves grazing endophyte-infected (E+) or non-infected (E-) tall fescue ($P > 0.10$).**

# Supplemental Lacto Edge for Shipping-Stressed Cattle

*E.B. Kegley*[1] *and J. Kafka*[2]


## Story in Brief

The impact of a probiotic, Lacto Edge, on the growth performance and health of newly received stocker calves was determined. Ninety-six heifers (493 ± 2.7 lb) were purchased from regional sale barns and shipped to the research farm. Calves were allocated randomly, within eight weight blocks, to treatment. There were six calves in each of 16 pens (1.1 acre grass paddocks), for a total of 48 animals/treatment. Treatments consisted of a grain supplement with or without addition of Lacto Edge (up to 1 oz/d for d 1 to 28 and 0.5 oz/d for d 29 to 41). Calves had ad libitum access to bermudagrass hay and water. There was no effect of supplemental Lacto Edge on average daily gain or final weights. Supplemental Lacto Edge did not affect the percentage of calves that received the first or second round of antibiotic therapy for bovine respiratory disease. However, calves supplemented with Lacto Edge tended to have a lower (P = 0.08) average number of antibiotic treatments. There was also a tendency for calves supplemented with Lacto Edge to have lower (P = 0.06) medication costs. Lacto Edge supplementation resulted in a tendency for a decreased neutrophil:lymphocyte ratio (P = 0.10), which indicates that these calves were less stressed by d 40. Supplementation with Lacto Edge (a combination of yeast, bacteria, and mannan oligosaccharides) tended to reduce the need for antibiotic treatment for bovine respiratory disease complex. However, no impact of supplemental Lacto Edge was detected on growth.


## Introduction

Morbidity in receiving cattle is a costly economic problem that may, in part, be addressed by nutritional intervention. Research indicates that not only are there medication costs associated with morbid cattle, but that these calves also usually grow slower throughout the feedlot phase, are less efficient in converting feed to gain, and their carcasses grade lower after slaughter.

Lacto Edge is a probiotic feed additive that contains two strains of live yeast (Strain 1026 and 8417 of *Sacchraromyces cerevisiae*), two strains of micro-encapsulated bacteria (*Lactobacillus acidophilus* and *Streptococcus faecium*), and mannan oligosaccharides. The addition of mannan oligosaccharides to diets has enhanced immune function in weanling pigs. This project began to assess effects of Lacto Edge on morbidity and growth performance of stressed cattle.

## Experimental Procedures

Ninety-six heifers (493 ± 2.7 lb) were purchased from regional sale barns and shipped to the University of Arkansas Beef Cattle Facility at Savoy. Upon arrival (October 16, 2003), calves were weighed and kept in a common pen with access to hay and water overnight. The following morning, calves were weighed, branded, and ear-tagged with an individual identification number. Calves were routinely processed with viral (Bovi-Shield 4, Pfizer Animal Health, Exton, PA) and clostridial (Electroid 7, Schering-Plough Animal Health Limited, Upper Hutt, New Zealand) vaccinations, and were dewormed (Ivermectin, Durvet, Blue Springs, MO). Horned animals had their horns tipped. Vaccination boosters were given on d 14.

Animals were allocated randomly within eight weight blocks (using the arrival weight) to treatment. There were six calves in each of 16 pens, for a total of 48 animals per treatment. Calves were housed on 1.1-acre grass paddocks. All calves were fed a grain supplement (Table 1) that served as the carrier for the treatments. Treatments consisted of the supplement with or without addition of Lacto Edge (Alltech, Lexington, KY). Calves were fed 1.5 lb supplement/d on the first day; this was gradually increased to 5 lb supplement/d by d 16. From d 1 to 28 supplements were formulated so that when calves were fed 5 lb of supplement they received 1 oz of Lacto Edge. From d 29 to 41, the Lacto Edge in the treated supplement was reduced to a level of 0.5 oz/d. Any supplement refusals were noted. Calves had ad libitum access to bermudagrass hay (12.2% CP, 36.5% acid detergent fiber, 65.8% neutral detergent fiber) and water throughout the study. Weights were taken initially and prior to supplement feeding on d 7, 14, 28, 40, and 41. Average daily gain was calculated.

Calves were observed daily for signs of morbidity beginning on the day of arrival. Calves were scored by one of the pen checkers and given a clinical illness score of 1 to 5 (Table 2). Calves with a score > 1 were brought to the chute and a rectal temperature was taken. If the rectal temperature was ≥ 104°F the calf was treated according to a preplanned antibiotic regimen (Table 3). Records were kept of all antibiotics given. Sick animals were returned to their home pen for convalescence.

Calves were bled on d 40 via jugular venipuncture into vacuum tubes containing sodium heparin. In the laboratory, the whole blood sample was split, and an aliquot was analyzed on the Cell-Dyn 3500 (Abbott Diagnostics, Abbott Park, IL) for total and differential cell counts, hemoglobin concentration and hematocrit. Another aliquot was incubated with 5 □g phytohemagglutinin (PHA)/ml of whole blood for 24 h at 99°F, then centrifuged and plasma was stored frozen until analyzed for interferon-gamma by ELISA (Bovigam, Biocor Animal Health, Inc., Omaha, NE).

Data were analyzed as a randomized complete block design. Pen was the experimental unit for ADG. Calf was the experimental unit for the morbidity and blood data.

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## Results and Discussion

There was no effect of supplemental Lacto Edge on ADG or final weights (Table 4). Calves gained 1.83 lb/d for the 41-d study. Supplemental mannan oligosaccharides, derived from yeast cell wall material, have improved gain in poultry (Stanley et al., 1996), nursery pigs (Davis et al., 2002a; 2002b), and young milk-fed calves (Newman et al., 1993); however, no research has evaluated the effects of this combination of additives (Lacto Edge) in calves with functioning rumens. A recent study (Busby et al., 2002), investigating the supplementation of a product containing brewer's yeast to newly arrived steers, reported no improvement in ADG or feed efficiency for the initial 34 d of the feedlot phase. However, they did detect a tendency for increased dry matter intake in the yeast supplemented calves. The current study was not designed to measure hay intakes. There were no observed palatability problems between the grain supplements fed. All pens were increased at the same rate to the pre-determined daily allotment of supplement (5 lb/d).

Supplemental Lacto Edge did not affect the percentage of calves that received the first or second round of antibiotic therapy for bovine respiratory disease (Table 5). Numerically, fewer calves supplemented with Lacto Edge were treated with antibiotics. This resulted in a statistical tendency for calves supplemented with Lacto Edge to have a lower ($P = 0.08$) average number of antibiotic treatments. There was also a tendency for calves supplemented with Lacto Edge to have lower ($P = 0.06$) medication costs. Research in poultry indicates that one effect of supplemental mannan oligosaccharides is to inhibit colonization of some strains of bacteria in the intestinal tract (Oyofo et al., 1989). In addition, supplemental mannan oligosaccharides have altered the immune response of nursery pigs (Davis et al., 2002b; Kim et al., 2000).

On d 40, there were no differences in total white blood cell counts, or the percentage of neutrophils, monocytes, and basophils due to supplemental Lacto Edge (Table 6). There was a decreased percentage of eosinophils ($P = 0.03$) and a tendency for an increased percentage of lymphocytes ($P = 0.07$) in the calves supplemented with Lacto Edge. A tendency for a decreased neutrophil:lymphocyte ratio ($P = 0.10$) indicated that calves supplemented with Lacto Edge were less stressed by d 40. An increased neutrophil:lymphocyte ratio has been used as an indicator of stress in veal calves (Friend et al., 1985).

On d 40, hemoglobin concentration and percentage hematocrit were increased ($P = 0.02$) by supplemental Lacto Edge (Table 6). However, the biological significance of this is unclear; all means were within the expected range for cattle. There were no differences due to dietary treatment in the production of interferon-gamma by PHA stimulation of whole blood samples taken on d 40. Only 61% of the samples had detectable concentrations of interferon-gamma, and these were all < 0.15 ng/mL (data not shown).

Data from this pilot study showed generally positive results to supplementing Lacto Edge in the diets of receiving cattle. To the investigator's knowledge this was the first experiment investigating this feeding situation. This combination of yeast, bacteria, and mannan oligosaccharides tended to reduce the need for antibiotic treatment for bovine respiratory disease complex. After 40 d of supplementation the white blood cell profile of calves supplemented with Lacto Edge indicated that they were less stressed. No impact of supplemental Lacto Edge was detected on growth during this 41 d study; however, since supplemented calves tended to be healthier an improvement in growth rate might be expected over subsequent growing and finishing periods.

## Implications

This combination of yeast, bacteria, and mannan oligosaccharides tended to reduce the need for antibiotic treatment for bovine respiratory disease complex in these newly received stocker calves. However, there was no impact of supplemental Lacto Edge on growth during this 41-day study.

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**Table 1. Grain supplement offered 1.5 lb on d 1 increasing to 5 lb/d on d 16 to 41.**

| Ingredient | % |
|---|---|
| Corn-cracked | 75 |
| Soybean meal | 18 |
| Molasses | 2 |
| Mineral and vitamin premix[a] | 5 |
| Rumensin premix[b] | + |
| Lacto Edge[c] | - / + |

[a] Vigortone 35S premix contained at least 20% Ca, 3.5% P, 20.5% NaCl, 0.6% Mg, 0.4% K, 830 ppm Cu, 26.4 ppm Se, 2,000 ppm Zn, 300,000 IU vitamin A/lb, 30,000 IU vitamin D3/lb, and 100 IU vitamin E/lb.
[b] Provided 200 mg monensin/day when supplement was fed at 5 lb/day.
[c] In treatment with Lacto Edge added so that from day 1 to 28, 5 lb of supplement contained 1 oz of Lacto Edge. From day 29 to 41, Lacto Edge was added so that 5 lb of supplement contained 0.5 oz of Lacto Edge.

**Table 2. Clinical illness scores for calves.**[a]

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

[a] Modified from clinical assessment score criteria provided by Dr. Dianne Hellwig.

**Table 3. Treatment Schedule for calves treated for Bovine Respiratory Disease (BRD).**

Therapy 1: Nuflor (6 mL/100 lb) SQ

- Check in 48 hours. If Clinical Illness Score was > time 0 score or > 2 and rectal temperature was >104°F, then treatment failed and go to Therapy 2, otherwise considered a treatment success.

Therapy 2: Baytril (5 mL/100 lb) SQ

- Check in 48 hours. If Clinical Illness Score was > time 0 score or > 2 and rectal temperature was > 104°F, then go to Therapy 3 (treatment failed) otherwise considered a treatment success.
- Also for animals that recovered from Therapy 1 and relapsed at a later date (< 21 days since Therapy 1).

Therapy 3: Excenel (1.5 ml/100 lb) SQ

- Repeat treatment at 24-hour intervals for three consecutive days.
- Check on fourth day, if Clinical Illness Score was > time 0 score or > 2 and rectal temperature was > 104°F, then this was a treatment failure and the calf identified as a "Chronic", otherwise considered a treatment sucess.
- Also for animals that recovered from Therapy 2 and relapsed at a later date (< 21 days since Therapy 2).

***** If bovine respiratory disease symptoms occurred > 21 days after administering the previous therapy, then it was considered a new episode and antibiotic treatment began again with Therapy 1.

**Table 4. Impact of supplemental Lacto Edge on calf weights and average daily gain.**

| | Control | Lacto Edge | SE | P-value |
|---|---|---|---|---|
| Initial wt, lb | 494 | 491 | 0.88 | 0.06 |
| Final wt, lb | 569 | 567 | 3.03 | 0.65 |
| ADG, lb | | | | |
| Day 1 to 14 | 1.85 | 2.1 | 0.262 | 0.52 |
| Day 1 to 28 | 1.89 | 1.92 | 0.127 | 0.87 |
| Day 1 to 41 | 1.82 | 1.84 | 0.090 | 0.89 |

**Table 5. Impact of supplemental Lacto Edge on calf morbidity.**

| | Control | Lacto Edge | SE | P-value |
|---|---|---|---|---|
| Morbidity | | | | |
| % treated at least once | 69 | 56 | 6.8 | 0.20 |
| Number treated at least once | 33 | 27 | | |
| % treated at least twice (retreats) | 27 | 15 | 5.6 | 0.12 |
| Number treated at least twice (retreats) | 13 | 7 | | |
| % treated three times | 12.5 | 6.25 | 4.2 | 0.30 |
| Number treated three times | 6 | 3 | | |
| Number of chronics | 1 | 0 | | |
| Average number of treatments | 1.08 | 0.77 | 0.126 | 0.08 |
| Medication costs, $/calf | 15.88 | 10.80 | 1.88 | 0.06 |

**Table 6. Impact of Lacto Edge on total and differential white cell counts and other blood variables measured on day 40.**

| | Control | Lacto Edge | SE | P-value |
|---|---|---|---|---|
| Total white blood cells, no. x $10^3$ | 10.6 | 11.7 | 0.49 | 0.14 |
| Neutrophils, % | 24 | 22 | 1.3 | 0.13 |
| Lymphocytes, % | 66 | 70 | 1.5 | 0.07 |
| Neutrophil:lymphocyte | 0.412 | 0.333 | 0.0334 | 0.10 |
| Monocytes, % | 7.0 | 6.4 | 0.38 | 0.30 |
| Eosinophils, % | 1.4 | 0.8 | 0.18 | 0.03 |
| Basophils, % | 0.8 | 0.7 | 0.06 | 0.70 |
| Hemoglobin, g/dL | 13.57 | 14.19 | 0.183 | 0.02 |
| Hematocrit, % | 35.9 | 37.4 | 0.47 | 0.02 |

# Effect of Electrolyte Supplementation on Growth Performance and(or) Weight Loss of Fasted Calves

*K.P. Coffey*[1], *W.K. Coblentz*[1], *G. Montgomery*[2], *T.F. Smith*[3], *and D.S. Hubbell, III*[3]


## Story in Brief

Fasting and transportation invokes stress on cattle and causes them to accelerate their excretion of vital nutrients. Three experiments were conducted to evaluate the impact of feeding an electrolyte mixture (RATE) prior to a period of fasting (Exp. 1) or transport (Exp. 2 and 3) on calf weight loss. In Experiment 1, calves grazing bermudagrass pastures were fed a control grain sorghum-based supplement (Control) or Control with 1.0 to 1.5 g/head/d of RATE for 79 d beginning June 13. On the last day of the study, calves were fed, then gathered and held without feed or water for 10 h. Animal gain did not differ ($P > 0.10$) between supplement groups. Calves fed Control had lower ($P < 0.05$) shrink during the first 2 h of feed and water deprivation, while those fed RATE had lower shrink during the second 2-h period and tended ($P = 0.05$) to shrink less than Control calves during the first 4 h of feed and water deprivation. Total weight loss did not differ after 10 h of feed and water deprivation. In Exp. 2 and 3, calves were fed Control or 4 g/head/d of RATE for 2 to 4 d prior to transport. Transport shrink did not differ ($P > 0.10$) between Control and RATE in either study. Therefore longer feeding periods of a low level of supplemental electrolytes may reduce shrink during the early periods following feed and water deprivation, but short-term feeding of this electrolyte product does not appear to impact transportation shrink.


## Introduction

Electrolytes are necessary for normal body function, but are generally excreted from the body during periods of transportation, stress, and fasting. Proper electrolyte supplementation may result in reduced animal shrink, but improper electrolyte supplementation can suppress the absorption of other electrolytes. Electrolyte sources vary substantially in their bioavailability. 'RATE' is a mixture of potassium, magnesium, calcium, chromium, and manganese bound to organic molecules to enhance absorption along with glycine and aspartic acid to help with transport of nutrients not provided by RATE. The objective of this study was to feed RATE electrolyte product to cattle prior to periods of fasting or transportation to determine its impact on cattle gain and shrink.

## Experimental Procedures

*Experiment 1*: Forty-eight weaned Beefmaster cross calves from the University of Arkansas Southeast Research and Extension Center cowherd were weighed on June 13 and 14, 2002 without prior removal from pasture and water. The calves were stratified by weight and sex, and allocated randomly to one of six groups. The pasture groups were then allocated randomly to one of six bermudagrass pastures. All pasture groups were offered 4 lb/calf daily of ground grain sorghum and had free-choice access to a commercial trace mineral salt. Groups of cattle were allocated randomly such that three groups received no additional supplemental electrolyte and three groups received 'RATE' electrolyte mix. Calves on RATE were offered 1 g/head daily of RATE for the first 42 d, then 1.5 g/head daily thereafter.

On August 31, 2002, calves were offered their grain supplement, and those groups offered RATE received the desired 1.5 g/head of RATE. Calves were removed from pastures immediately following consumption of the grain supplement and weighed to determine an end of study weight as well as a starting point for subsequent shrink measurements. Following weighing, calves were placed into small pens without water or forage and weighed at 2-h intervals throughout an ensuing 10-h period to determine the rate and extent of body weight loss throughout the day.

*Experiment 2*: A total of 53 calves were used in two replications. Replicate 1 was comprised of 24 yearling heifers that were allocated randomly into two groups. One group received 4 g/head/d of RATE and the other did not. Both groups were fed 2 lb/head of ground corn daily. Heifers were fed their respective supplements for 4 d beginning September 28. On October 1, heifers were fed their respective supplements beginning at 6:30 am. After consuming their respective supplements, heifers were gathered, weighed, and transported from Fayetteville to Batesville, AR. Replicate 2 was comprised of 29 yearling steers that were allocated randomly into two groups at the Livestock and Forestry Branch Station (LFBS) near Batesville, AR. The feeding regimen was identical to that described for replicate 1. After consuming their respective supplements on October 1, steers were gathered and weighed at 10:00 am, then transported from Batesville to Fayetteville. Both replicates were penned and weighed directly off of the truck following transportation.

*Experiment 3*. A total of 36 heifer calves located at LFBS were weaned from their dams on October 9 and allocated into one of 14 groups of calves. The groups were allocated randomly such that seven groups were housed on pasture and seven were housed in a drylot and fed bermudagrass hay. Both groups were fed 2 lb/head daily of corn. Within pasture and drylot-housed calves, four groups were not offered RATE and three groups were offered 4 g/head daily of RATE on November 4 and 5. On November 5, heifers were gathered after consumption of their supplements and transported to Monticello, AR. Heifers were penned and weighed directly off of the truck following transportation.

For purposes of statistical analyses each group, within experiment, was considered a block. The block of calves was used as the experimental unit in each of the experiments to evaluate treatment effects.

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## Results and Discussion

*Experiment 1*: For these six groups, calf weights after 42 (July 25) and 79 d (August 31) did not differ ($P > 0.10$) between calves fed Control and those fed RATE (Table 1). Therefore supplemental electrolytes were not limiting to animal growth in this study. Weight loss during the first 2 h of feed and water deprivation was 8 lb higher ($P < 0.05$) from RATE than from Control. However, during the subsequent 2-h period, calves fed RATE shrank 13 lb less ($P < 0.05$) than Control calves. When combined over the first 4 h of feed and water deprivation, calves fed RATE tended ($P = 0.10$) to lose 5 lb less total weight and have lower ($P < 0.10$) cumulative shrink (%). However, by 10 h of feed and water deprivation, cumulative weight loss and shrink did not differ ($P > 0.10$) between treatments but was numerically 7 lb less from calves fed RATE.

*Experiment 2*: With only four groups, we were unable to detect a difference ($P > 0.10$) in transportation weight loss and % shrink between calves fed RATE and those fed Control (Table 2). Numerically, steers shrank more when fed RATE vs. Control (5.4% vs. 4.7%) whereas heifers shrank less when fed RATE vs. Control (8.0% vs. 8.8%). The discrepancy in shrink between steers and heifers can probably be attributed to the fact that steers were fed and gathered later in the morning prior to shipping whereas the heifers were fed and gathered at daybreak. Previous research (Coffey et al., 1997) has shown that calves allowed to graze for 3 h prior to gathering them had substantially reduced shrink.

*Experiment 3*: Heifers housed on pasture were numerically heavier ($P > 0.10$) at shipping and at receiving than heifers housed in drylots (Table 3). Heifers housed on pasture lost 9 lb or 1.4% more ($P < 0.05$) weight during transport than heifers housed in drylots and fed bermudagrass hay. This is probably because bermudagrass hay should have a much slower passage rate than the fall cool-season forage, leading to greater shrink over a short time period from heifers grazing lush pasture vs. those fed hay. Electrolyte supplementation did not affect ($P < 0.05$) receiving weight, weight loss, or percentage shrink. There were no interactions ($P < 0.05$) between housing and electrolyte supplementation.

## Implications

Feeding an electrolyte formulation (RATE) for an extended period prior to feed and water deprivation reduced shrink during the first four hours following removal from pasture and water. Since this period is when cattle generally have the greatest rate of shrink, feeding this electrolyte mixture for an extended period prior to a short period of fasting or transport could impact sale weight under these conditions. However, short-term feeding of the electrolyte mixture may not have an impact on subsequent transportation shrink.

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**Table 1. Growth performance and shrink by calves grazing bermudagrass pastures and fed RATE (Experiment 1).**

| Item | Treatment | | SE | P-value[b] |
|---|---|---|---|---|
| | Control | RATE[a] | | |
| Calf weight, lb | | | | |
| June 13 | 556 | 554 | 0.9 | 0.17 |
| July 25 | 634 | 622 | 6.7 | 0.28 |
| August 31 | 700 | 688 | 10.9 | 0.46 |
| Gain, lb | | | | |
| June 13 to July 25 | 77 | 71 | 5.6 | 0.49 |
| July 25 to August 31 | 67 | 63 | 13.3 | 0.85 |
| June 13 to August 31 | 144 | 133 | 10.9 | 0.53 |
| Cumulative weight loss, lb[c] | | | | |
| 0 to 2 h | 14 | 22 | 1.7 | 0.03 |
| 0 to 4 h | 29 | 24 | 1.5 | 0.10 |
| 0 to 6 h | 37 | 33 | 2.7 | 0.27 |
| 0 to 10 h | 49 | 42 | 3.0 | 0.20 |
| Cumulative shrink, % | | | | |
| 0 to 2 h | 2.0 | 3.2 | 0.25 | 0.02 |
| 0 to 4 h | 4.1 | 3.5 | 0.16 | 0.05 |
| 0 to 6 h | 5.4 | 4.8 | 0.32 | 0.26 |
| 0 to 10 h | 7.5 | 6.6 | 0.41 | 0.20 |

[a] RATE is an electrolyte mixture fed prior to a period of fasting.
[b] Probability that Control did not differ from RATE.
[c] Weight loss on August 31 after calves were placed in pens without feed or water and weighed at progressive time periods.

**Table 2. Transportation shrink by steers and heifers fed RATE electrolyte formulation prior to transport (Experiment 2).**

| | Treatment | | | |
|---|---|---|---|---|
| Item | Control | RATE[a] | SE | P-value[b] |
| Shipping weight, lb | 659 | 609 | 5.7 | 0.10 |
| Receiving weight, lb | 616 | 569 | 1.4 | 0.03 |
| Weight loss, lb | 44 | 40 | 4.3 | 0.67 |
| Weight loss, % | 6.7 | 6.7 | 0.55 | 0.96 |

[a] RATE is an electrolyte mixture fed prior to transport.
[b] Probability that Control did not differ from RATE.

**Table 3. Transportation shrink by heifers fed RATE electrolyte formulation prior to transport and housed on cool-season pasture or in a drylot (Experiment 3).**

| | Electrolyte | | Housing | | | |
|---|---|---|---|---|---|---|
| Item | Control | RATE[a] | Drylot | Pasture | SE | Effect[b] |
| Shipping weight, lb | 547 | 556 | 538 | 564 | 15.0 | NS |
| Receiving weight, lb | 536 | 546 | 533 | 550 | 13.3 | NS |
| Weight loss, lb | 11 | 10 | 6 | 15 | 2.2 | H |
| Weight loss, % | 1.8 | 1.8 | 1.1 | 2.5 | 0.35 | H |

[a] RATE is an electrolyte mixture fed prior to transport.
[b] NS = non-significant, H = effect of housing ($P < 0.05$).

# Effect of Extrusion Processed De-Oiled Rice Bran Plus Whole Cottonseed on Growth Performance of Calves

*M.S. Gadberry[1], P.A. Beck[2], S.A. Gunter[2], and D.W. Kellogg[3]*


## Story in Brief

Seventy-two crossbred beef steers were used to evaluate the growth response to supplementing low quality hay with a conventional feed supplement (corn plus cottonseed meal) or de-oiled rice bran plus whole cottonseed, with and without extrusion processing. Supplements were formulated to contain 20% crude protein. Steers fed the corn plus cottonseed meal supplement consumed more hay than calves fed the de-oiled rice bran and whole cottonseed supplements; however, there was no significant difference in body weight or weight gain between treatments throughout the study. Supplementing low quality hay with de-oiled rice bran and whole cottonseed can be an potential alternative to conventional feedstuffs for Arkansas cattle producers. Extrusion processing of the de-oiled rice bran plus whole cottonseed did not affect animal performance, however, extrusion processing, resulting in a pellet, can improve feeding and handling characteristics.


## Introduction

Calves wintered on grass hay generally require supplemental feeds to achieve higher rates of gain. Cotton and rice are two commodities that are produced in Arkansas. Whole cottonseed can be both a good source of supplemental energy and protein. However, its fat concentration (17.5%; NRC, 1996) generally limits the level of inclusion in the diet. De-oiled rice bran is a co-product of the rice milling industry. Extracting the fat from rice bran increases the protein content of the co-product and may also result in improved digestibility of the fiber of the bran. In addition, feed processing such as pelleting, can result in improvements in intake, digestibility, and handling characteristics of feed grains.

The objective of this study was to evaluate the performance of growing beef steers fed hay and a conventional (corn plus cottonseed meal) supplement or supplemented with de-oiled rice bran plus cottonseed with and without extrusion processing.

## Experimental Procedures

Seventy-two crossbred beef steers were blocked by weight (heavy and light) and randomly assigned to one of twelve pens (six head/pen and four pens/treatment) at the feedlot facility of the Southwest Research and Extension Center in Hope, AR. Pens were assigned to one of three dietary treatments consisting of: mixed grass hay (10.9% crude protein, 42.3% ADF, and 71.8% NDF, dry weight basis) and 1) corn plus cottonseed meal (CCSM, positive control), 2) de-oiled rice bran plus whole cottonseed (DRBCS), or 3) extrusion processed de-oiled rice bran plus whole cottonseed (EXT, Compass Feeds, Inc). Supplements were formulated to contain 20% crude protein (DM basis), and were fed at 1% expected mean shrunk body weight for the 63-day study. A complete mineral mix was added to each supplement to provide 1.5 lb per pen, daily.

Shrunk body weights were taken at the beginning of the study and at 21-day intervals until day 63. Hay and supplements were weighed prior to feeding and left-over feed was weighed and dry matter composition determined weekly.

Steer weight and gain data were analyzed as a randomized complete block design using the GLM procedure in SAS (SAS Inst., Inc., Cary, NC). Pen was the experimental unit and block by treatment interaction was used as the error term to test for block and treatment effects. Pen average daily hay dry matter intake was tested for the main effects, block and treatment. When the model was significant ($P \leq 0.10$), treatment contrasts were tested for CCSM versus DRBSC + EXT and DRBSC versus EXT.

## Results and Discussion

Hay dry matter intake was affected by supplemental feed. Pens fed the CCSM supplement consumed 3 lb more hay, daily, than pens fed the DRBCS or EXT diets ($P = 0.07$; 70, 67, and 67 lb hay dry matter, respectively). Hay intake was similar for the DRBCS and EXT supplemented pens.

There were no treatment differences for body weight at the beginning of the study (Table 1). Average daily gain did not differ significantly during any period of the study, and subsequent weights throughout the study were similar for all treatments.

## Implications

Feeding de-oiled rice bran and whole cottonseed instead of conventional supplements with corn and cottonseed meal is an option for Arkansas cattle growers. Extrusion processing did not improve animal performance, but may improve handling characteristics as compared to receiving, blending, and feeding the raw ingredients on the farm.

## Literature Cited

NRC. 1996. Nutrient Requirements of Beef Cattle.

[1] Cooperative Extension Service, Little Rock

[2] Southwest Research and Extension Center, Hope, AR

[3] Department of Animal Science, Fayetteville

**Table 1. Hay intake and weight gain of calves supplemented with corn plus cottonseed meal (CCSM), de-oiled rice bran plus whole cottonseed (DRBCS), or extrusion processed de-oiled rice bran plus whole cottonseed (EXT).**

| | Treatment | | | | |
|---|---|---|---|---|---|
| | CCSM | DRBCS | EXT | SE | P-value |
| Hay intake | | | | | |
| (lb DM/pen/day)[a] | 70 | 67 | 67 | 1.2 | 0.18 |
| Steer wt, lb | | | | | |
| Initial, Apr 10 | 465 | 474 | 467 | 1.7 | 0.12 |
| May 1 | 556 | 562 | 554 | 4.8 | 0.55 |
| May 22 | 610 | 606 | 604 | 4.8 | 0.66 |
| Final, June 12 | 641 | 640 | 640 | 1.9 | 0.90 |
| Average Daily Gain, lb | | | | | |
| Period I | 4.3 | 4.1 | 4.1 | 0.28 | 0.88 |
| Period II | 2.6 | 2.2 | 2.4 | 0.18 | 0.40 |
| Period III | 1.4 | 1.6 | 1.7 | 0.14 | 0.50 |
| Overall | 2.8 | 2.6 | 2.7 | 0.05 | 0.33 |

[a] CCSM versus DRBCS and EXT (P = 0.07)

# Performance of Crossbred Beef Cows Supplemented with De-Oiled Rice Bran

*M.S. Gadberry[1], P.A. Beck[2], and S.A. Gunter[2]*


## Story in Brief

One hundred twenty Brahman influenced beef cows were used to evaluate the effects of supplementing low quality hay with one of three levels of de-oiled rice bran (DORB). Cows had free choice access to hay and were supplemented with DORB at 0.5, 0.7 or 0.9% BW. Increasing DORB in the diet did not significantly improve cow body weight or body condition during gestation, lactation, or the overall feeding period. In addition, calf birth weights, calf weights at the end of the study, and pregnancy rates as determined by rectal palpation were not affected by level of supplementation. Hay offerings tended to be affected (P = 0.10) by level of supplementation during the gestation period, resulting in a linear (P = 0.04) reduction in hay offerings as level of supplementation increased. However, hay offerings were unaffected by level of supplementation during the lactation period and across the overall feeding period. Feeding higher levels, 0.9 vs 0.5% BW, of DORB may not improve animal performance, and influences of higher levels of supplementation on hay intake will likely go unrecognized under traditional hay feeding systems.


## Introduction

Arkansas produces 47.5% of the rice produced in the U.S. (NASS, 2001). Milling white rice requires removing the hull and brown (bran) layer from rough rice. While the hull is poor in nutritive value, the bran layer contains moderate levels of protein (12%, as-fed), fat (12%,as-fed), and fiber (12%, as-fed). This is commonly referred to as 12-12-12 rice bran. However, the fat of unprocessed rice bran can cause the bran to become rancid. Some rice processors extract and market rice oil from the bran. The remaining de-oiled rice bran contains less fat, more protein, and more fiber than the full fat bran and can be stored for longer periods of time. Both of these co-products are often cost effective alternatives to more traditional feedstuffs. However, there is limited research on the performance of beef cattle supplemented with de-oiled rice bran. Therefore, the objective of the following study was to evaluate the effects of supplementing beef cows, fed low quality hay, with different levels of DORB on animal performance.

## Experimental Procedures

On December 13, 120 crossbred beef cows (1043 ± 11.7 lb; 5.4 ± 0.08 body condition score, BCS) were sorted into one of twelve pastures based on age and previous weight. All cows selected for the study were previously determined pregnant by rectal palpation and were bred to calve within a 60-day calving season. Pastures were randomly assigned to one of three supplemental DORB levels. De-oiled rice bran was fed As-Is at 0.5, 0.7, or 0.9 % initial body weight per head, daily. A free choice mineral mix and water were available at all times. The lowest level of de-oiled rice bran was chosen to balance the expected maintenance energy requirements with the available hay supply. Hay and supplement feeding continued until April 18, when sufficient spring pasture was available for grazing.

Cows were fed large round hay bales from two lots of hay during the study and quantity of hay fed during the trial was determined. The lower quality hay, lot one (Table 1), was fed during gestation and lot two was fed during lactation.

Cows were weighed and body condition scored (1 to 9 scale with 1 being the thinnest and 9 being fattest) at the beginning of the study, start of the calving season, and the end of the study. Calves were weighed at birth and at the end of the hay and supplement feeding period. At the conclusion of the study, cows were co-mingled and exposed to bulls throughout a 60-day breeding season. In October, cows were palpated for pregnancy status. Calving data from the subsequent calf crop were used to determine calving interval.

*Statistical Analyses.* Amount of hay fed during gestation, lactation, and overall was analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Body weight and body condition were analyzed using the GLM procedure. Cows that were not nursing at the end of the study were excluded from the body weight and body condition data analysis for the lactation and overall feeding period. Initial body weight and body condition score were analyzed using calf date of birth as a covariate. The effect of treatment was tested using pasture within treatment as the error term. The effect of level of supplement on calf birth weight and end of study weight was tested using pasture within treatment as the error term, and calf sex, calf date of birth, and age of cow were included in the model as covariates. Differences in pregnancy rates were determined by chi-square analysis.

## Results and Discussion

Initial body weight was different (P = 0.03) across treatments. Cows were initially sorted into treatment groups based on age and previous weight. This unexpectedly resulted in unequal weights across treatment groups. The inequality in initial weights across treatments resulted in a higher than anticipated supplemental feeding rate, as a percentage of body weight across treatment groups, because the cattle with the lowest initial body weight inadvertently were assigned to the highest level of supplementation.

Increased level of supplemental feeding tended to affect (P = 0.10) the amount of hay offered (number of bales fed) during the gestation period. As the amount of supplemental feed increased, there was a linear reduction in hay offered (P = 0.04, Table 2).

[1] Cooperative Extension Service, Little Rock

[2] Southwest Research and Extension Center, Hope, AR

Despite a tendency toward feeding less hay during the gestation period, level of supplementation did not affect hay offered during the lactation period or the overall amount of hay offered during the study. Potentially lower hay intake at the 0.9% supplemental feeding level was not recognizable under the current feeding conditions, and the overall amount of hay offered was not affected by level of supplementation. If beef cattle producers intend to utilize inexpensive feed supplements to partially substitute for hay, then hay feeding must be managed to minimize excessive offerings and reduce potential waste. Further research should be conducted measuring hay intake and waste under higher levels of supplemental feeding with DORB.

Despite differences in initial body weight, body weight and body weight change did not differ throughout the remainder of the study (Table 3). In addition, body condition score and change in body condition score were similar for cattle supplemented with the three different levels of DORB.

Calf birth weight averaged 74 lb ± 3.1 lb, and calf weight at the end of the study averaged 164 ± 9.9 lb. Neither differed with level of supplementation (P = 0.46 and P = 0.63, respectively). Percentage of cows determined pregnant by rectal palpation did not differ (P = 0.19) across levels of supplementation and averaged 85, 77, and 93% for the 0.5, 0.7 and 0.9% BW treatments, respectively. In addition, calving interval averaged 360 ± 20 days and did not differ (P = 0.39) by treatment.

## Implications

De-oiled rice bran can be utilized to supplement low quality hay fed to gestating and lactating beef cows. However, feeding higher levels of de-oiled rice bran may not improve performance, and under traditional feeding systems, a reduction in hay intake with higher levels of supplementation will likely go undetected.

## Literature Cited

NASS. 2001. Agricultural statistics data base. Available: http://www.nass.usda.gov:81/ . Accessed Dec. 17, 2001.

**Table 1. Composition of hay and de-oiled rice bran (DM basis).**

| | Hay Lot 1 | Hay Lot 2 | De-oiled Rice Bran |
|---|---|---|---|
| CP | 5.0 | 8.5 | 17.6 |
| ADF | 53.5 | 45.6 | 11.5 |
| NDF | 78.9 | 70.0 | 24.1 |
| Calculated TDN | 42.7 | 51.6 | 79 |

**Table 2. Hay offerings to beef cows supplemented with three different levels of DORB.**

| | DORB (% BW) | | | | |
|---|---|---|---|---|---|
| | 0.5 | 0.7 | 0.9 | Model P-value | Linear |
| Gestation period | | | | | |
| 12-13 to 2-11 | 17 | 16.5 | 16 | 0.10 | 0.04 |
| Lactation period | | | | | |
| 2-11 to 4-18 | 18.8 | 20.2 | 20 | 0.33 | NS[a] |
| Overall | 35.8 | 36.7 | 36 | 0.58 | NS |

[a] NS = not significant

**Table 3. Effects of de-oiled rice bran supplementation on cow body weight and body condition score.**

| | DORB (% BW) | | | | |
|---|---|---|---|---|---|
| | 0.5 | 0.7 | 0.9 | Pooled SE | P-value |
| Gestation period | | | | | |
| Body weight | | | | | |
| 12-13 wt | 1067[a] | 1023[a,b] | 1002[b] | 13.9 | 0.03 |
| 2-11 wt | 1153 | 1133 | 1101 | 18.3 | 0.18 |
| Difference | 86 | 110 | 99 | 15.4 | 0.57 |
| Body condition score | | | | | |
| 12-13 BCS | 5.2 | 5.0 | 5.1 | 0.19 | 0.73 |
| 2-11 BCS | 5.2 | 5.3 | 5.4 | 0.15 | 0.59 |
| Difference | 0.0 | 0.3 | 0.3 | 0.17 | 0.36 |
| Lactation period[c] | | | | | |
| Body weight | | | | | |
| 2-11 wt | 1148 | 1130 | 1092 | 20.2 | 0.19 |
| 4-18 wt | 1059 | 1038 | 1033 | 16.3 | 0.50 |
| Difference | 89 | 92 | 59 | 22.4 | 0.56 |
| Body condition score | | | | | |
| 2-11 BCS | 5.2 | 5.3 | 5.4 | 0.16 | 0.65 |
| 4-18 BCS | 5.4 | 5.2 | 5.4 | 0.22 | 0.70 |
| Difference | 0.2 | -0.1 | 0.0 | 0.16 | 0.41 |
| Overall change[c] | | | | | |
| Body wt | 2 | 21 | 41 | 15.4 | 0.24 |
| BCS | 0.3 | 0.2 | 0.5 | 0.09 | 0.24 |

[ab] Least-squares means within a row with no superscripts in common, differ ($P < 0.05$)
[c] Lactation Period and Overall only include cows with calves on April 18.

# Poultry Fat Addition to Finishing Rations Influences Cattle Performance[1]

*S. Hutchison[2], E.B. Kegley[2], J.K. Apple[2], and T.J. Wistuba[3]*


## Story in Brief

Poultry fat has become a more economical energy source than by-products that are currently used. However, little research has quantified the effects of poultry fat on cattle performance and carcass quality. Therefore, a 112-d finishing study was initiated to determine the effects of type of fat (poultry or tallow) on growth performance and carcass quality. Sixty Angus crossbred steers (903.8 lb initial BW) were stratified by source and blocked by weight, and assigned to 15 pens (four steers/pen). Then, pens were assigned randomly within blocks to one of three dietary treatments consisting of: 1) a corn-soybean meal control diet devoid of added fat; 2) the control diet formulated with 4% tallow; or 3) the control diet formulated with 4% poultry fat. Average daily gain for the entire study was not ($P > 0.05$) different among dietary treatments, however steers fed diets formulated with poultry fat had approximately a 10% numeric improvement ($P = 0.17$) in ADG over control and tallow fed steers. Over the entire 112-d feeding period, steers fed 4% beef tallow consumed less ($P < 0.05$) feed daily than the steers fed the control diet. Steers fed the diets containing poultry fat had improved ($P < 0.05$) feed efficiencies when compared to the steers fed the control diet with steers fed tallow being intermediate. Feeding poultry fat tended to improve performance and feed efficiency. Therefore, poultry fat may serve as an alternative energy source in finishing cattle rations without compromising performance or carcass quality.


## Introduction

Ruminants have the ability to utilize by-products from numerous industries as nutrients. Poultry industry by-products are potential sources of valuable nutrients, including energy and protein. Therefore, methods of converting poultry industry by-products into reliable sources of animal feeds would benefit both the beef and poultry industries by providing a market for the poultry fat and an economical energy source for cattle diets. Currently poultry fat is not widely utilized by the cattle industry. However, recently poultry fat has become a more economical energy source than by-products that are currently used.

Typically fat is limited to <5% of the diet in order to minimize negative effects on ruminal fiber digestion. In the rumen, most triglycerides are broken down and the fatty acids are hydrogenated. Recent research however, has indicated that increasing the proportion of omega-3 fatty acids in ruminant diets modifies the fatty acid composition of their muscle tissue; indicating that all dietary fatty acids are not completely hydrogenated in the rumen. In the future, there will be considerably more emphasis placed on the modification of the fatty acid composition of beef in efforts to produce healthier beef products. The objective of this study was to determine the effects of adding poultry fat to finishing diets on growth performance, and carcass and meat characteristics of cattle.

## Experimental Methods

Sixty Angus cross steers were obtained from the Livestock and Forestry Branch Station in Batesville and the University of Arkansas Cow/Calf unit in Savoy. Steers were adapted to a high concentrate diet by feeding a 20% cottonseed hull growing diet for 55 d. The finishing study was initiated on December 5, 2002 and the initial body weight was 903.8 lb. Steers were stratified by source and blocked by weight, and assigned to 15 pens (four steers/pen). Then, pens were assigned randomly within blocks to one of three dietary treatments (Table 1) consisting of: 1) a corn-soybean meal control diet devoid of added fat; 2) the control diet formulated with 4% tallow; or 3) the control diet formulated with 4% poultry fat. Diets were mixed at approximately 2-wk intervals. Steers were allowed ad libitum access to feed and water for the 112-d study. Steers were weighed on consecutive days at d 0 and 112 to start and finish the trial, and interim weights were collected on d 28, 55, and 83.

Steers were transported approximately 360 miles to a commercial beef packing plant, and harvested after a 12-h rest period. Carcasses were individually identified and hot carcass weights were recorded. After a 24-h conventional spray-chill, carcass yield and quality grade data were collected. Wholesale ribs from the left sides were captured after being graded and boxed, and were then transported under refrigeration back to the University of Arkansas Red Meat Abattoir for further processing.

Beginning at the posterior end of each wholesale rib (12th rib), the first of six 1-in thick steaks cut from each rib was assigned for Warner-Bratzler shear force determination. Briefly, steaks were weighed and cooked to an internal temperature of 170°F in a forced-air convection oven. After cooking, steaks were blotted dry on paper towels and re-weighed to calculate cooking loss percentage. Then, at least six 0.5-in diameter cores were removed from each steak parallel to the fiber orientation, and each core was sheared once through the center with a Warner-Bratzler shear device attached to an Instron Universal testing machine (110-lb load-cell and a crosshead speed of 200 mm/sec).

Analyses of variance were conducted on performance and carcass data using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) with pen as the experimental unit. The model for the data included block and dietary treatment. If treatment was significant ($P < 0.05$), then a F-protected student's t-test (PDIFF option) was used to separate means.

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## Results and Discussion

The addition of dietary fat, regardless of source, did not ($P > 0.05$) affect ADG during the first 55 d on feed (Table 2). However, steers fed the poultry fat diet had greater ($P < 0.05$) ADG than steers fed either the control or the tallow diet from d 0 to d 83. Even though ADG was not ($P > 0.05$) different among dietary treatments over the entire 112-d period, steers fed diets formulated with poultry fat had approximately a 10% numeric improvement ($P = 0.17$) in ADG over control and steers fed tallow. Scollan et al. (2001) reported similar results that feeding oil had no negative impact on growth performance.

As expected, including fat in the diet reduced ($P < 0.05$) ADFI of steers after 28, 55, and 83 d on feed compared to the steers fed the control diet (Table 2). Moreover, over the entire 112-d feeding period, steers fed 4% beef tallow consumed less ($P < 0.05$) feed daily than the steers fed the control diet; however, ADFI of steers fed 4% poultry fat were intermediate to those of the steers fed the control and tallow diets. Previous research has indicated that feed intake could be depressed when diets contain over 8% fat because of adverse effects of fat, particularly polyunsaturated fat, on rumen microbial populations (Rule et al., 1989). Recent research, however, has indicated that the feeding value of fat may be influenced by the unsaturate:saturate fatty acid ratio and that this ratio may determine the fat's impact on intake and digestion (Plascencia and Zinn, 2001).

As documented in previous experiments, including fat in a finishing ration improved feed efficiency. Addition of fat to the finishing diet had little effect during the first 28 d of the trial (Table 2). However, when feed efficiencies were compared at 55 d the steers fed fat had improved ($P < 0.05$) feed efficiency when compared to the control, and the steers fed poultry fat had more desirable ($P < 0.05$) feed efficiency than the tallow fed steers. Conversely, when feed efficiencies were compared at d 83, steers consuming the poultry fat ration were the most efficient ($P < 0.05$), while control and tallow fed calves did not differ in their performance ($P > 0.05$). Moreover, when diets were compared at d 112, steers fed the diets containing poultry fat had a 14.8% improvement ($P < 0.05$) in feed efficiency when compared to the steers fed the control diet, and tallow fed steers performed intermediately.

Inclusion of fat, regardless of source, in the diet of finishing steers did not ($P > 0.05$) impact carcass weight, ribeye area, fat thickness, internal fat percentage, yield grade, marbling score, or quality grade (Table 3). Bartle et al. (1994) reported similar results when feeding 4.6% tallow. Plascencia and Zinn (2001) reported similar results when they compared the feeding value of tallow and yellow grease. However, tallow in their trial resulted in steers having a higher percentage of internal fat. Additionally, in the current trial cooking loss percentages were similar ($P > 0.05$) among the dietary treatments. However, steaks from steers fed the fat diets were less ($P < 0.05$) tender (higher Warner-Bratzler shear force values) than steaks from steers fed the control diet.

## Implications

Feeding poultry fat in the current study had no effect on feed intake or average daily gain compared to the tallow and control diets. However, poultry fat addition to the ration improved feed efficiency compared to the control ration and slightly improved efficiency compared to the tallow ration.

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Plascencia, A. and R. A. Zinn. 2001. Proc. West. Amer. Soc. Anim. Sci. 52:566-568.

**Table 1. Ingredient composition (as-fed basis) of experimental diets.**

| Ingredient | Control | Tallow | Poultry fat |
|---|---|---|---|
| | | % | |
| Corn, cracked | 78.2 | 73.3 | 73.3 |
| Cottonseed hulls | 10 | 10 | 10 |
| Soybean meal | 8.2 | 9.1 | 9.1 |
| Molasses | 2 | 2 | 2 |
| Dicalcium phosphate | 0.1 | 0.1 | 0.1 |
| Limestone | 1.35 | 1.35 | 1.35 |
| Salt, white | 0.15 | 0.15 | 0.15 |
| Vitamin premix[a] | 0.075 | 0.075 | 0.075 |
| Trace mineral premix[b] | + | + | + |
| Rumensin premix[c] | + | + | + |
| Tallow | 0.0 | 4.0 | 0.0 |
| Poultry fat | 0.0 | 0.0 | 4.0 |

[a] Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin D3, and 0.15 IU vitamin E.
[b] Premix supplied: 20 ppm of Zinc as ZnO, 10 ppm of Manganese as MnO, 0.10 ppm of Selenium as $Na_2SeO_3$, and 0.10 ppm of Cobalt as $CoCO_3$.
[c] Premix supplied 20 ppm monensin.

**Table 2. Influence of poultry fat supplement on ADG, ADFI, and feed:gain (F:G).**

| Item | Control | Tallow | Poultry fat | SE |
|---|---|---|---|---|
| D 0 to 28 | | | | |
| ADG | 3.82 | 3.13 | 3.28 | 0.350 |
| ADFI | 23.34$^{x}$ | 19.49$^{y}$ | 19.41$^{y}$ | 0.758 |
| F:G | 6.17 | 6.44 | 6.05 | 0.462 |
| D 0 to 55 | | | | |
| ADG | 4.19 | 4.17 | 4.53 | 0.135 |
| ADFI | 25.58$^{x}$ | 23.58$^{y}$ | 23.49$^{y}$ | 0.447 |
| F:G | 6.13$^{x}$ | 5.66$^{y}$ | 5.18$^{z}$ | 0.122 |
| D 0 to 83 | | | | |
| ADG | 3.70$^{y}$ | 3.48$^{y}$ | 4.06$^{x}$ | 0.092 |
| ADFI | 25.03$^{x}$ | 22.71$^{y}$ | 23.57$^{y}$ | 0.347 |
| F:G | 6.80$^{x}$ | 6.55$^{x}$ | 5.81$^{y}$ | 0.124 |
| D 0 to 112 | | | | |
| ADG | 3.31 | 3.35 | 3.67 | 0.152 |
| ADFI | 24.78$^{x}$ | 22.88$^{y}$ | 23.46$^{xy}$ | 0.424 |
| F:G | 7.51$^{x}$ | 6.88$^{xy}$ | 6.40$^{y}$ | 0.257 |

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

**Table 3. Influence of fat level and source on carcass and meat characteristics.**

| Item | Control | Tallow | Poultry fat | SE |
|---|---|---|---|---|
| Carcass weight, lb | 787 | 786 | 813 | 9.79 |
| Ribeye area, in$^2$ | 13.65 | 12.71 | 13.47 | 0.395 |
| Actual fat thickness, in | 0.47 | 0.41 | 0.49 | 0.05 |
| Adjusted fat thickness, in | 0.58 | 0.51 | 0.54 | 0.04 |
| Marbling score | Small$^{38}$ | Small$^{11}$ | Small$^{14}$ | 18.6 |
| Quality grade | Choice$^{06}$ | Select$^{89}$ | Select$^{87}$ | 11.0 |
| Kidney, pelvic and heart fat, % | 2.30 | 2.15 | 2.23 | 0.15 |
| Yield grade | 2.76 | 2.87 | 2.94 | 0.200 |
| Cooking loss, % | 34.47 | 34.24 | 34.96 | 1.24 |
| Warner-Bratzler shear force, lb | 9.37$^{x}$ | 10.6$^{y}$ | 10.91$^{y}$ | 0.371 |

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

# Seasonal Weight Changes and Prepartum Weight:Height Ratio in Angus and Brahman Cows Grazing Common Bermudagrass or Endophyte-Infected Tall Fescue

*M.A. Brown[1], A.H. Brown, Jr.[2], and B.A Sandelin[2]*


## Story in Brief

Cow weights, hip heights, and reproductive data taken from 1986 to 1992 on 80 Angus (AN) and 80 Brahman (BR) cows grazing common bermudagrass (BG)or tall fescue (E+) were used to evaluate the effects of breed, forage environment, and production status on seasonal weight changes and prepartum body condition. Cows were managed as commercial females and supplemental feed was provided in both forage environments from late November to late April. Heifers were managed to calve as 3-yr olds to preclude parity differences between the breeds and were exposed to bulls during 75-d breeding seasons starting in late May/early June. Cow gains were computed for winter (October/November to February), spring (February to May/June), and summer (June to October) seasons prior to the subsequent calving season the next year. Weight:height ratios (lb/in) were computed from hip height data taken in February of each year of the study to estimate body condition prior to calving and breeding. Cows in each breed-forage subclass were classified into four groups based on all possible combinations of prior year and subsequent year calving data. There was a breed x forage interaction for spring ADG in both primiparous and multiparous cows ($P < 0.10$); BR and AN had similar ADG on E+ but BR had higher ADG on BG than AN ($P < 0.01$). There was a breed x forage interaction for summer ADG in both primiparous and multiparous cows ($P < 0.01$); BR and AN had similar ADG on BG but BR had higher ADG on E+ than AN ($P < 0.01$). These data indicate the best predictor of subsequent reproduction in spring-calving cows is summer weight change from late May/early June to late October/early November.


## Introduction

Nutrition derived from forages by beef cows plays a major role in the efficiency of cow-calf production. In heifers, winter and spring gains prior to the first breeding season are associated with reproductive performance. Postpartum weight changes can have an additive effect on subsequent rebreeding performance in conjunction with body condition at calving. However, there is little information on the impact of breed and forage type on seasonal weight gains and prepartum body condition in reproductive beef females. Consequently, the objectives of this research were to evaluate the effects of breed, forage environment, and production status on seasonal weight changes and prepartum body condition in Angus (AN) and Brahman (BR) heifers and cows grazing common bermudagrass(BG) or endophyte-infected tall fescue(E+) pastures.

## Experimental Procedures

Five years of data from approximately 80 Angus and 80 Brahman females born in the spring of 1985 were used in this study. In the winter of 1985 and early spring of 1986, heifers were stratified by source and breed and assigned at random to one of four 40-acre BG or one of four 40-acre E+ pastures. Stocking rate for each pasture within forage environment ranged from 19 to 24 females with approximately equal numbers of BR and AN. Normal fertilization procedures were followed throughout the study.

Prior to the first breeding season in 1987, heifers were managed to gain approximately 0.77 lb/d by supplementing with approximately 1.87 lb/d grain (cottonseed meal, chopped corn), and E+ or BG hay. Supplemental feed was provided from late November to late April to cows in both forages; supplemental grain (1.87 lb/d) was continued in the E+ pastures in the late fall and early spring in an attempt to moderate potential toxicity. Minerals were fed free choice throughout the year. Females were managed to calve first as 3-yr olds in both breeds and were bred during a 75-d breeding season starting in early June in 1987 and late May in 1988, 1989, 1990, and 1991. Four BR and four AN sires were rotated among breeding pastures in both forage treatments each year. Breed of sire was alternated in a breeding pasture to facilitate sire of calf identification. Cows were culled only on the basis of structural unsoundness and, infrequently, temperament until the fall of 1990. After pregnancy check in the fall of 1990, 18 AN and 11 BR cows were culled on the basis of reproductive performance or structural unsoundness.

Calves were born from late February to late May each year and were weighed and tagged at birth. A cow was credited with having a calf if she had a full-term calf, alive or dead. The exception to this was three AN cows from tall fescue and one BR cow from BG that were palpated as pregnant in the fall of 1990, culled subsequently, and credited with a full-term calf for the 1991 calf crop. The 25 cows palpated as open and culled in the fall of 1990 were counted as open for the 1991 calf crop. Cows remaining for the 1992 calf crop had at least one calf born from 1988 to 1991 and were exposed to four Beefmaster and four BR sires during the 1991 breeding season.

Cows in the study were weighed annually in late October or early November; February; and in late May or early June. Cow gains were computed for winter (October/November to February), spring (February to May/June), and summer (June to October) grazing seasons prior to the subsequent calving season. Weight:height ratios (lb/in) were computed from hip height data taken in February of each year of the study to estimate body condition (Klosterman et al., 1968) prior to calving and breeding. Thus, the gain and condition data corresponded to seasons prior to the subsequent calf crop. Dates for each season and calf crop are given in Table 1.

Cows in each breed-forage subclass were classified into groups based on prior year and subsequent year calving data. Class 1 cows were open during the winter, spring, and summer prior to the subject

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calf crop year and open for the subject calf crop year (1988 to 1992). Class 2 cows were open during the same seasons and calved during the subject calf crop year. Class 3 cows were pregnant during the winter and calved in the spring prior to the subject calf crop year and were open the subject calf crop year. Class 4 cows were pregnant during the winter and calved in the spring prior to the subject calf crop year and calved during the subject calf crop year. Because the first-calf heifers calving in 1988 did not contain Class 3 or 4 data, the 1988 calf crop (primiparous heifers) was analyzed separately from the 1989 through 1992 calf crops (multiparous cows).

Data were analyzed by methods of mixed model least squares. Linear models for winter, spring, and summer ADG and precalving condition for the 1988 calf crop included the fixed effects of breed, forage, class (Class 1 or 2) and appropriate interactions among these effects. Calf crop was added to the model (fixed effect) for the 1989 through 1992 data and was analyzed as a repeated measure with individual cow as the subject. Tests of hypothesis concerning breed, forage, class or interaction effects were done using t-tests and associated observed significance levels.

## Results and Discussion

*Winter ADG.* Least-squares means and standard errors for winter ADG for each parity, class, breed, and forage are given in Table 2. In multiparous cows, there was of a breed x forage x class interaction ($P = 0.12$). Winter ADG was similar in cows that calved the next calf crop compared to cows that were open the next calf crop. Forage differences in winter ADG were higher in AN than BR cows ($P < 0.01$), with AN cows on E+ exceeding AN cows on BG by 0.72 lb/d ( $P < 0.01$) and BR cows on E+ exceeding BR cows on BG by 0.51 lb/d ($P < 0.01$). In this study, winter gains were not significantly associated with whether a heifer or cow became pregnant in the subsequent breeding season, suggesting that management for moderate weight gains was acceptable with respect to reproduction. Additionally, winter ADG means in multiparous cows reflected the nutritional advantage of supplemented growing tall fescue over supplemented dormant BG in both AN and BR cows, but the advantage of E+ over BG was less in BR than AN cows.

*Spring ADG.* Least-squares means and standard errors for spring ADG for each parity, class, breed, and forage are given in Table 3. Angus heifers on E+ exceeded AN heifers on BG by 0.79 lb/d ($P < 0.01$) while BR heifers on E+ exceeded BR heifers on BG by 0.46 lb/d ($P < 0.01$). However, spring ADG was similar in heifers that calved in 1988 compared to those that were open in 1988 ($P = 0.99$). In multiparous cows, class differences depended on breed ($P < 0.05$). There was no difference in spring ADG between Classes 1 and 2 in either AN or BR cows averaged over forage ($P = 0.51$ and $P = 0.32$, respectively). Cows that were open during the winter and spring gained similarly, whether they calved the subsequent year, or not. However, spring ADG in Class 3 cows differed ($P < 0.01$) from that of Class 4 AN cows. Essentially, AN cows in Class 4 lost less weight in the spring compared to AN cows in Class 3. Spring gains in open heifers or cows did not appear to influence reproduction, but AN cows that calved in the spring and calved the next year either lost less weight during calving and/or managed to recover a higher proportion of weight after calving compared to contemporaries that calved in the spring but did not rebreed. A similar response was not found in BR multiparous cows, but it is possible that the lower birth weights in BR cows (Brown et al., 2000) may have an influence on subsequent recovery and reproduction. In this study, spring ADG means in primiparous and multiparous cows reflected both the more moderate spring weather and the tolerance of the BR to E+ toxicity (Brown et al., 2000) with gains of AN and BR similar on tall fescue.

*Summer ADG.* Least-squares means and standard errors for summer ADG for each parity, class, breed, and forage are given in Table 4. A breed x forage interaction in summer ADG was evident ($P < 0.05$) for primiparous heifers. Primiparous AN and BR heifers gained similarly on BG during the summer, but BR heifers on E+ had higher ADG than AN heifers on E+ (0.66 vs 0.42 lb/d, $P < 0.01$). There was also a class difference in summer ADG; heifers calving in 1988 had higher ADG during the breeding season than heifers open in 1988 (0.83 vs 0.60 lb/d, $P < 0.01$). There was a breed x forage interaction in multiparous cows ($P < 0.01$). Summer ADG was similar in AN and BR cows on BG while summer ADG was higher in Brahman cows on E+ compared to AN cows on E+ (0.35 vs 0.07 lb/d, $P < 0.01$). There was no difference in summer ADG between Class 1 and Class 2 cows suggesting summer ADG had little impact on subsequent pregnancy when the cows did not calve the previous spring. However, there was a difference in summer ADG between Class 3 and Class 4 cows (0.17 vs 0.37 lb/d, $P < 0.01$). Thus, summer ADG during the breeding season was a useful indicator of subsequent reproduction in primiparous heifers and in cows that had calved the previous spring, but not in cows that had not calved. These data indicate that the best predictor of subsequent reproduction in spring-calving cows is summer weight change from late May/early June to late October/early November.

*Prepartum Weight:height Ratio.* Least-squares means and standard errors for prepartum weight:height ratio for each parity, class, breed, and forage are given in Table 5. There was a breed x forage x class interaction in primiparous heifers with a class difference in BR heifers on BG ($P < 0.05$) but no class differences in other breed x forage means. Weight:height ratios in AN heifers were similar on BG and E+ ($P = 0.54$) while weight:height ratios of BR heifers on BG were larger than those of BR heifers on E+ (2.59 vs 2.15, $P < 0.01$). Class differences in condition were evident with open cows (Classes 1 and 2) having lower weight:height ratios than pregnant cows (Classes 3 and 4) (3.1 vs 3.35, $P < 0.01$, data not shown). Weight height:ratios in AN cows were similar on BG and E+ ($P = 0.27$) while weight:height ratios of BR cows on BG were larger than BR cows on E+ (3.02 vs 2.86, $P < 0.05$).

## Implications

Cow-calf management systems should be designed to take advantage of prior knowledge of breed characteristics, reproductive status, body condition and body weight changes resultant from forage growth and quality during each season of the year. Forage growth and quality will partly determine the season to make body condition and body weight changes in spring-calving cows. This is especially true in the upper-mid south where production systems often involve bermudagrass and endophyte-infected fescue pastures.

## Literature Cited

Brown, M.A., et al., 2000. J. Anim. Sci. 78: 546-551.
Klosterman, E.W., et al. 1968. J. Anim. Sci. 27:242-246.

**Table 1. Dates associated with winter, spring, and summer ADG for calf crops 1988 through 1992.**

| | Season | | |
|---|---|---|---|
| Calf Crop Year | Winter | Spring | Summer |
| 1988 | 11/4/1986-2/24/1987 | 2/24/1987-5/19/1987 | 5/19/1987-11/3/1987 |
| 1989 | 11/3/1987-2/22/1988 | 2/22/1988-6/1/1988 | 6/1/1988-10/25/1988 |
| 1990 | 10/25/1988-2/21/1989 | 2/21/1989-6/14/1989 | 6/14/1989-10/24/1989 |
| 1991 | 10/24/1989-2/13/1990 | 2/13/1990-6/6/1990 | 6/6/1990-10/28/1990 |
| 1992 | 10/28/1990-2/7/1991 | 2/7/1991-5/16/1991 | 5/16/1991-10/30/1991 |

**Table 2. Winter ADG for Angus and Brahman heifers and cows on common bermudagrass and E+ tall fescue (lb/d).**

| | | Angus | | | Brahman | | |
|---|---|---|---|---|---|---|---|
| Parity[a] | Class[b] | Bermuda | Fescue | Avg. | Bermuda | Fescue | Avg. |
| Primiparous | 1 | 0.62 ± 0.11 | 0.84 ± 0.13 | 0.73 ± 0.09 | 0.26 ± 0.22 | 0.37 ± 0.09 | 0.33± 0.13 |
| | 2 | 0.64 ± 0.05 | 0.90 ± 0.05 | 0.77 ± 0.03 | 0.15 ± 0.05 | 0.35 ± 0.05 | 0.26 ± 0.03 |
| | Avg | 0.63 ± 0.05 | 0.88 ± 0.07 | 0.75 ± 0.05[w] | 0.22 ± 0.11 | 0.36 ± 0.05 | 0.28 ± 0.07[x] |
| | B vs F | P < 0.01 | | | P = 0.22 | | |
| Multiparous | 1 | -0.07 ± 0.26 | 0.95 ± 0.15 | 0.44 ± 0.15 | -0.11 ± 0.17 | 0.38 ± 0.24 | 0.13 ± 0.15 |
| | 2 | 0.15 ± 0.09 | 1.08 ± 0.11 | 0.62 ± 0.07 | -0.17 ± 0.11 | 0.37 ± 0.11 | 0.09 ± 0.09 |
| | 3 | 0.66 ± 0.07[o] | 0.99 ± 0.07 | 0.81 ± 0.05 | 0.05 ± 0.09 | 0.53 ± 0.09 | 0.29 ± 0.07 |
| | 4 | 0.48 ± 0.05[p] | 1.12 ± 0.05 | 0.81 ± 0.03 | 0.07 ± 0.05 | 0.53 ± 0.05 | 0.31 ± 0.03 |
| | Avg | 0.31 ± 0.07 | 1.03 ± 0.05 | 0.68 ± 0.05[w] | -0.05 ± 0.07 | 0.46 ± 0.07 | 0.20 ± 0.05[x] |
| | B vs F | P < 0.01 | | | P < 0.01 | | |

[a] Primiparous=2-yr-old first calf heifers bred in 1987 to calve in 1988; Multiparous=3-yr-old and older bred 1988-1991.
[b] 1=open winter, spring, summer; open post-breeding season; 2=open winter, spring, summer; calved next year
3=pregnant winter, calved spring; open post-breeding season; 4=pregnant winter, calved spring; calved next year
[w,x] Means in the same row with different superscripts differ (P < 0.01)
[o,p] Means in the same column with different superscripts differ (P < 0.01)

**Table 3. Spring ADG for Angus and Brahman heifers and cows on common bermudagrass and E+ tall fescue (lb/d).**

| | | Angus | | | Brahman | | |
|---|---|---|---|---|---|---|---|
| Parity[a] | Class[b] | Bermuda | Fescue | Avg. | Bermuda | Fescue | Avg. |
| Primiparous | 1 | 0.28 ± 0.13 | 1.06 ± 0.15 | 0.68 ± 0.11 | 0.48 ± 0.26 | 0.84 ± 0.09 | 0.66 ± 0.15 |
| | 2 | 0.20 ± 0.05 | 1.01 ± 0.05 | 0.59 ± 0.03 | 0.44 ± 0.05 | 1.03 ± 0.05 | 0.73 ± 0.05 |
| | Avg | 0.24 ± 0.07 | 1.03 ± 0.09 | 0.64 ± 0.05 | 0.46 ± 0.13 | 0.92 ± 0.07 | 0.70 ± 0.07 |
| | B vs F | P < 0.01 | | | P < 0.01 | | |
| Multiparous | 1 | 0.59 ± 0.35 | 0.66 ± 0.20 | 0.64 ± 0.20 | 0.33 ± 0.24 | 0.37 ± 0.33 | 0.35 ± 0.20 |
| | 2 | 0.09 ± 0.13 | 0.86 ± 0.15 | 0.48 ± 0.11 | 0.31± 0.15 | 0.86 ± 0.15 | 0.57 ± 0.11 |
| | 3 | -1.78 ± 0.09[o] | -0.75 ± 0.09 | -1.25 ± 0.07[o] | -0.97 ± 0.011 | -0.68 ± 0.011 | -0.81 ± 0.07 |
| | 4 | -1.41 ± 0.05[p] | -0.55 ± 0.07 | -0.99 ± 0.05[p] | -1.06± 0.07 | -0.59 ± 0.07 | -0.81 ± 0.05 |
| | Avg | -0.62 ± 0.11 | 0.07 ± 0.07 | -0.29 ± 0.07 | -0.35 ± 0.07 | -0.00 ± 0.09 | -0.18 ± 0.07 |
| | B vs F | P < 0.01 | | | P < 0.01 | | |

[a] Primiparous=2-yr-old first calf heifers bred in 1987 to calve in 1988; Multiparous=3-yr-old and older bred 1988-1991.
[b] 1=open winter, spring, summer; open post-breeding season; 2=open winter, spring, summer; calved next year
3=pregnant winter, calved spring; open post-breeding season; 4=pregnant winter, calved spring; calved next year
[o,p] Means in the same column with different superscripts differ (P < 0.01)

**Table 4. Summer ADG for Angus and Brahman heifers and cows on common bermudagrass and E+ tall fescue (lb/d).**

| | | Angus | | | Brahman | | |
|---|---|---|---|---|---|---|---|
| Parity[a] | Class[b] | Bermuda | Fescue | Avg. | Bermuda | Fescue | Avg. |
| Primiparous | 1 | 0.86 ± 0.09 | 0.29 ± 0.11[q] | 0.57 ± 0.07[q] | 0.57 ± 0.15 | 0.51 ± 0.07[o] | 0.64 ± 0.09[o] |
| | 2 | 0.95 ± 0.05 | 0.56 ± 0.05[r] | 0.75 ± 0.03[r] | 0.99 ± 0.03 | 0.81± 0.05[p] | 0.90 ± 0.03[p] |
| | Avg | 0.90± 0.05 | 0.42 ± 0.07 | 0.66 ± 0.05[y] | 0.88 ± 0.07 | 0.66 ± 0.05 | 0.77 ± 0.05[z] |
| | B vs F | P < 0.01 | | | P < 0.05 | | |
| Multiparous | 1 | 1.36 ± 0.24 | 0.44 ± 0.15 | 0.90 ± 0.15 | 1.12 ± 0.15 | 0.73 ± 0.20 | 0.90 ± 0.13 |
| | 2 | 1.30 ± 0.09 | 0.40 ± 0.11 | 0.84 ± 0.07 | 1.21 ± 0.011 | 0.81 ± 0.09 | 1.01 ± 0.07 |
| | 3 | 0.59 ± 0.07[q] | -0.37 ± 0.07[q] | 0.11 ± 0.05[o] | 0.57 ± 0.07[q] | -0.09 ± 0.09[s] | 0.24 ± 0.05[o] |
| | 4 | 0.77 ± 0.05[r] | -0.15 ± 0.05[r] | 0.31 ± 0.03[p] | 0.36 ± 0.05[r] | 0.79 ± 0.07[t] | 0.42 ± 0.03[p] |
| | Avg | 1.01 ± 0.07 | 0.07 ± 0.05 | 0.55 ± 0.05[y] | 0.92 ± 0.05 | 0.35 ± 0.07 | 0.64 ± 0.05[z] |
| | B vs F | P < 0.01 | | | P < 0.01 | | |

[a] Primiparous=2-yr-old first calf heifers bred in 1987 to calve in 1988; Multiparous=3-yr-old and older bred 1988-1991.
[b] 1=open winter, spring, summer; open post-breeding season; 2=open winter, spring, summer; calved next year
3=pregnant winter, calved spring; open post-breeding season; 4=pregnant winter, calved spring; calved next year
[y,z] Means in the same row with different superscripts differ (P < 0.10)
[o,p] Means in the same column with different superscripts differ (P < 0.01);
[q,r] Means in the same column with different superscripts differ (P < 0.05)
[s,t] Means in the same column with different superscripts differ (P < 0.10)

**Table 5. Precalving weight:height ratios for Angus and Brahman heifers and cows on common bermudagrass and E+ tall fescue (lb/in).**

| | | Angus | | | Brahman | | |
|---|---|---|---|---|---|---|---|
| Parity[a] | Class[b] | Bermuda | Fescue | Avg. | Bermuda | Fescue | Avg. |
| Primiparous | 1 | 2.58 ± 0.09 | 2.61 ± 0.13 | 2.60 ± 0.08 | 2.84 ± 0.22[q] | 2.13 ± 0.08 | 2.49 ± 0.11[s] |
| | 2 | 2.74 ± 0.03 | 2.61 ± 0.03 | 2.68 ± 0.02 | 2.35± 0.03r | 2.17 ± 0.04 | 2.26 ± 0.02[t] |
| | Avg | 2.66 ± 0.05 | 2.61 ± 0.07 | 2.64± 0.04[u] | 2.59 ± 0.11 | 2.15 ± 0.04 | 2.37 ± 0.06[v] |
| | B vs F | | | | P < 0.01 | | |
| Multiparous | 1 | 3.12 ± 0.19 | 3.49 ± 0.11 | 3.31 ± 0.11 | 3.02 ± 0.13 | 2.61 ± 0.17 | 2.81 ± 0.11 |
| | 2 | 3.36 ± 0.07 | 3.54 ± 0.08 | 3.45 ± 0.05 | 2.93 ± 0.09 | 2.76 ± 0.09 | 2.85 ± 0.06 |
| | 3 | 3.79 ± 0.05[q] | 3.59 ± 0.05 | 3.69 ± 0.03 | 3.01 ± 0.06[s] | 3.04 ± 0.06 | 3.03 ± 0.04 |
| | 4 | 3.65 ± 0.02[r] | 3.59 ± 0.03 | 3.62 ± 0.02 | 3.13 ± 0.02[t] | 3.02 ± 0.03 | 3.07 ± 0.02 |
| | Avg | 3.48 ± 0.05 | 3.55 ± 0.03 | 3.52 ± 0.03[u] | 3.02 ± 0.04 | 2.86 ± 0.05 | 2.95 ± 0.03[v] |
| | B vs F | | | | P < 0.05 | | |

[a] Primiparous=2-yr-old first calf heifers bred in 1987 to calve in 1988; Multiparous=3-yr-old and older bred 1988-1991.
[b] 1=open winter, spring, summer; open post-breeding season; 2=open winter, spring, summer; calved next year
3=pregnant winter, calved spring; open post-breeding season; 4=pregnant winter, calved spring; calved next year
[u,v] Means in the same row with different superscripts differ (P < 0.01)
[q,r] Means in the same column with different superscripts differ (P < 0.05)
[s,t] Means in the same column with different superscripts differ (P < 0.10).

# Story in Brief: Three-Year Evaluation of Cool-Season Annual Grasses for Stocker Cattle

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## Story in Brief

Combinations of cool-season annual grasses were planted in mid-September of 1999, 2000, and 2001 to evaluate the effect of species of cool-season annual grass on the growth of stocker calves at a set stocking rate. The cool-season annuals planted included: oats (O), rye (R), annual ryegrass (RG), rye + ryegrass (RRG), wheat (W), wheat + rye (WR), wheat + ryegrass (WRG), or wheat + rye + ryegrass (WRRG). In the fall before planting, 24 two-acre pastures were clean tilled and fertilized according to soil test. Grazing was initiated when adequate forage was accumulated on January 6, 2000; October 23, 2000; and October 30, 2001. Across the three-year study, gains/acre (G/A) were not different ($P > 0.10$) for RRG, RG, WRG, and W, while RRG had higher ($P < 0.05$) G/A than WRRG. Gain/acre was the lowest ($P < 0.05$) for O compared to the other treatments. Oat pastures performed well in two of the three years, but froze out during the coldest of the three winters. Economic analysis, by partial budgeting, ranked the cost of gain W = RG = RRG = WRG < WR = WRRG = R < O. Of the best forage combinations, coefficients of variation indicate that the most dependable gains/acre and costs of gain are with RRG followed by W, WRG, and RG. If a grain crop is not to be harvested and forages are to be grazed-out, producers have the opportunity to plant RG, RRG, W, or WRG for efficient and economical cattle performance.


## Introduction

In the fall and early spring, wheat pasture has been extensively used to improve net farm income in the high plains region of the United States. This improvement comes from the availability of high-quality forage at a time of year when it is usually scarce and when the availability of weaned calves is at a seasonally low price. This system allows the wheat grain to be harvested if the calves are removed before the jointing stage. The calves can also graze-out wheat during late spring instead of harvesting the grain. Daniels et al. (2002) reported that grazing wheat pasture is a viable system in northeastern Arkansas and reported gains/acre (G/A) averaged 287 to 341 lb/acre over three years. When grazing was terminated before jointing, grain yields increased on grazed wheat compared to ungrazed wheat. High stocker cattle gains are a product of high forage quality and forage availability that is adequate to maximize forage intake. If graze-out is the preferred option the question arises; which species of small-grain or cool-season annual grass allows for the production of the best animal performance? Thus, this research was designed to compare gains of stocker cattle grazing cool-season annual grasses, or combinations of these on clean-till fields in northeast Arkansas.

## Experimental Procedures

Combinations of small grains or small grains and annual ryegrass were planted on 24 two-acre pastures in mid-September of 1999, 2000, and 2001 The cool-season annuals planted included: Bob oats (O), Elbon rye (R), Marshall ryegrass (RG), rye + ryegrass (RRG), wheat (W; Jaypee in 1999 and Delta King 9027 in 2000 and 2001), wheat + rye (WR), wheat + ryegrass (WRG), or wheat + rye + ryegrass (WRRG). Three pastures were planted to each cool-season species or combination. In the fall before planting, seedbeds were clean-tilled and fertilized according to soil test (Chapman, 1998) to meet N, phosphorus, and potassium requirements using urea, ammonia nitrate, 19-19-19, or 20-15-20. Tiiling operations included: offset disking (1-2 times), and chisel plowing (1-2 times), followed by use of a finishing disk and cultipacker. Pastures were planted on September 27 to 29 of 1999 and on September 12 to 14 of 2000 and 2001. The pastures were topdressed with 130 lb urea/acre on February 16, 2000, and 110 lb urea/acre on March 7, 2001 and February 14, 2002. When planted alone, oats, wheat, and rye were seeded at 120 lb/acre. Annual ryegrass was seeded at 40 lb/acre when planted alone and 20 lb/acre when planted in combination with small grains. Seeding rate was reduced to 90 lb/acre for wheat and rye when planted in combination with ryegrass. Rye and wheat, when planted in combination (in the WR and WRRG treatments), were seeded at a rate of 75 lb/acre of each.

Pastures were stocked with three calves (average BW = 426 ± 2.6 lb) for fall/winter grazing each year (1.5 calves/acre, 639 lb BW/acre). Grazing was initiated when forage accumulation was visually appraised to be adequate to carry the desired number of calves (January 6, 2000, October 23, 2000, and October 30, 2001). Cold weather, ice and snow cover would not allow grazing from December 20, 2000 to January 24, 2001, so calves were removed from pastures and fed hay and supplement. The initial set of calves was removed from pasture on April 18, 2000, March 20, 2001, and February 22, 2002. During the spring, new calves were placed on the pastures after preconditioning (average BW = 478 ± 2.6 lb). Each spring the set stocking rate was determined based on visual estimation of forage accumulation. In the spring of 2000, three calves were added to each pasture on March 30 and removed on May 19. Because of the late start to grazing and high forage availability both sets of calves grazed concurrently during the first year until removal of the initial set of calves. During the spring of 2001, the calves were removed on February 21 from the O pastures, and the pastures were not grazed during the graze-out period. Three new calves were placed on the 21 remaining pastures on April 3 and removed on May 9. In the spring of 2002, four calves were placed on each pasture on March 6 and removed on April 25 for W and WR or May 30 for W, RG, RRG, WRG, and WRRG. Calves were weighed following a 16-h fast at the beginning and end of each trial and at approximately 28-d intervals.


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Partial budgeting analysis was conducted on the data from the experiment, using Arkansas Cooperative Extension enterprise budgets compiled by Windham (2002). Actual seed costs from the fall of 2001 were used, which included wheat at $11.80/cwt, rye at $17.50/cwt, oats at $12.34/cwt, and ryegrass at $38.00/cwt. In 1999, fall applied 19-19-19 was assumed on all pastures (240 lb /acre) with a cost of $9.00/cwt. Other fertilizer costs included: urea at $9.50/cwt, ammonium nitrate at $8.90/cwt, and 20-15-20 at $9.30/cwt. The custom rate for fertilizer application was assumed to be $2.50/acre. Implement labor and maintenance ($3.02/acre), tractor labor and maintenance ($6.27/acre), diesel fuel ($3.60/acre), and tractor and implement fixed costs ($11.26/acre) were also included in the analysis, tractor and implement costs were based on the assumption of one pass with each implement type. Gain/acre was calculated using the pasture average ADG, grazing days, and stocking rate. Total G/A was divided into the total cost of crop per acre to determine the pasture only cost of gain (COG).

Data were analyzed using the general linear model procedure of SAS (SAS Inst., Inc., Cary, NC) as a completely randomized experimental design with treatment as the main effect. Pasture was considered the random experimental unit. The treatment effects on average daily gain (ADG) were tested by pasture within treatment as the error term. Because G/A and COG were calculated based on pasture averages the effect of treatments on G/A and COG were tested by residual error. The effect of year and the year by treatment interaction were tested using pasture within treatment by year as the error term.

## Results and Discussion

The interaction between year and treatment was significant ($P < 0.01$) for ADG and G/A, so cattle performance is shown by year in Table 1. In the first year, ADG during the winter and spring as well as G/A were not affected ($P > 0.10$) by treatment. Warm dry conditions during the fall of 1999 slowed seedling emergence and forage growth that caused a late start of grazing during the first year of the trial. Temperatures in the spring of 2000 were above normal from January to May, and precipitation was near normal so performance was excellent for cattle in all treatments.

In the second year during the fall, ADG of cattle in the R, WRRG, RRG, and WR treatments were greater than ($P < 0.05$) ADG of cattle in the O, RG, W, and WRG treatments. In the fall of 2000, low temperatures and ice and snow cover made the de-stocking of pastures necessary from December 20 to January 24, and caused severe winter kill of O, and delayed re-growth of wheat and ryegrass. Reduced performance in the O, RG, W, and WRG treatments indicates that observed forage growth was reduced by cooler temperatures more in these treatments than in treatments that included a rye component. Animal performance did not differ ($P = 0.18$) among treatments during the spring. In the spring of 2001, temperatures were slightly above normal and precipitation was 4.5 inches below normal, yet performance of the cattle was excellent for all treatments except O. Gains/acre were highest ($P < 0.05$) for the treatments that included R or rye blends, although the R and WR treatments were not different ($P > 0.05$) from W. The O treatment had the lowest ($P < 0.05$) G/A of all treatments in year 2.

In the fall and winter of the third year, ADG of WRG and W did not differ ($P = 0.15$), while W did not differ ($P > 0.10$) from RG, WRRG, WR, RRG, and O. In the spring of the third year, the highest ($P < 0.05$) ADG was with O, RG, and RRG, which did not differ ($P > 0.10$). Year three gains/acre did not differ ($P > 0.52$) among RG, RRG, WRG, and W; while WRRG had lower ($P < 0.05$) G/A than RG and RRG. Gains/acre were lowest ($P < 0.05$) for R, O, and WR. Temperatures and precipitation were above normal during the fall and spring of the final year of the trial. Warm wet conditions may have caused the reduced performance with R in the fall, and O, R, and WR in the spring by possibly by increasing maturity of the forage.

Across the three-year study, ADG in the fall and winter were not affected ($P = 0.20$) by species of cool-season annual grass. Three-year average spring ADG and G/A did not differ ($P > 0.10$) among RG, RRG, W, and WRG. Spring ADG and G/A of RRG were higher ($P < 0.05$) than O, R, WR and WRRG. Gain/acre was the lowest ($P < 0.05$) for O compared to the other treatments. Coefficients of variation (CV) were used to indicate the relative variability of the treatments. The lowest CV in G/A was found with R, yet this treatment did not produce as much animal gain as RG, RRG, W, WRG, or WRRG. The CV of WRRG was 5% lower than the CV for RRG, yet this forage was not as productive. The highest variability was found in the O treatment (45%) indicating it is not a dependable choice for forage production.

Significant interactions ($P < 0.01$) between year and treatment were also found in the economic analysis (Table 2). Cost of pasture establishment per acre ranged from a low of $77.05/acre for O to $91.82/acre for WRRG. The differences in pasture cost are the result of the cost of seed. During year 1, costs of gain were not different ($P > 0.07$) for O, RG, RRG, W, and WRG; while costs of gain for O, RG and W were lower ($P < 0.05$) than R, WR, and WRRG. During year 2, costs of gain were not different ($P > 0.10$) for RRG, R, WR, W, WRG, WRRG, or RG, but were less than ($P < 0.05$) O, because of the absence of spring grazing for O. During year 3, costs of gain for RG, W, WRG, and RRG did not differ ($P > 0.25$) and were less than ($P < 0.05$) WRRG, O, WR, and R. Over the three-year study, costs of gain for W, RG, RRG, and WRG did not differ ($P > 0.28$), and were less than ($P < 0.05$) WR, WRRG, and R, which were less than ($P < 0.05$) O. Of the low cost treatments, the least variability in COG was observed in RRG followed by W, WRG, and RG.

## Implications

Arkansas producers have the opportunity to utilize W, RG, RRG, or WRG with little difference in cattle performance and economic efficiency. Analysis of the variability across the three-year study indicates the most dependable animal performance and least variable cost of production can be found with a mixture of rye and ryegrass.

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**Table 1. Effect of Cool-Season Annual Species on Performance of Steers.**

| | Treatment[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | O | R | RG | RRG | W | WR | WRG | WRRG | SEb |
| Winter ADG | | | | | | | | | |
| Year 1 | 3.21 | 3.01 | 2.92 | 3.34 | 3.05 | 3.19 | 3.44 | 3.31 | 0.17 |
| Year 2 | 2.02$^{e}$ | 2.44$^{f}$ | 1.77$^{e}$ | 2.38$^{f}$ | 1.96$^{e}$ | 2.37$^{f}$ | 1.87$^{e}$ | 2.40$^{f}$ | 0.12 |
| Year 3 | 2.24$^{ef}$ | 1.90$^{e}$ | 2.45$^{fg}$ | 2.24$^{ef}$ | 2.58$^{fg}$ | 2.26$^{ef}$ | 2.93$^{g}$ | 2.27$^{ef}$ | 0.17 |
| Average[c] | 2.49 | 2.45 | 2.37 | 2.65 | 2.53 | 2.61 | 2.74 | 2.66 | 0.10 |
| Spring ADG | | | | | | | | | |
| Year 1 | 3.51 | 2.97 | 3.24 | 3.12 | 3.24 | 2.96 | 3.50 | 2.96 | 0.21 |
| Year 2 | --- | 2.11 | 2.39 | 2.77 | 2.69 | 2.47 | 2.77 | 2.47 | 0.18 |
| Year 3 | 3.23$^{g}$ | 2.28$^{e}$ | 2.81$^{fg}$ | 2.84$^{fg}$ | 2.46$^{ef}$ | 2.28$^{e}$ | 2.72$^{ef}$ | 2.67$^{ef}$ | 0.17 |
| Average | 2.25$^{e}$ | 2.45$^{ef}$ | 2.81$^{gh}$ | 2.91$^{h}$ | 2.80$^{gh}$ | 2.57$^{fg}$ | 2.74$^{gh}$ | 2.48$^{ef}$ | 0.12 |
| Gain per acre | | | | | | | | | |
| Year 1 | 738 | 644 | 707 | 714 | 700 | 663 | 711 | 695 | 32.1 |
| Year 2 | 261$^{e}$ | 532$^{gh}$ | 431$^{f}$ | 557$^{h}$ | 480$^{fg}$ | 539$^{gh}$ | 469$^{f}$ | 544$^{h}$ | 21.7 |
| Year 3 | 573$^{e}$ | 553$^{e}$ | 900$^{g}$ | 870$^{g}$ | 832$^{fg}$ | 616$^{e}$ | 837$^{fg}$ | 732$^{f}$ | 40.6 |
| Average | 524$^{e}$ | 576$^{f}$ | 679$^{gh}$ | 714$^{h}$ | 671$^{gh}$ | 606f | 672$^{gh}$ | 657$^{g}$ | 18.7 |
| CV%[c] | 41.2 | 9.3 | 30.7 | 20.0 | 24.1 | 13.5 | 25.8 | 15.0 | - |

[a] O = Oats, R = Rye, RG = Ryegrass, RRG = Rye + Ryegrass, W = Wheat, WR = Wheat + Rye, WRG = Wheat + Ryegrass, WRRG = Wheat + Rye + Ryegrass.
[b] Standard error of the mean.
[c] Three year average.
[d] Coefficient of variation .
[efgh] Least-squares means within rows with no superscript in common differ ($P < 0.05$).

**Table 2. Effect of Cool-Season Annual Species on Economic Performance of Grazing Enterprise.**

| | Treatment[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | O | R | RG | RRG | W | WR | WRG | WRRG | SE[b] |
| Cost, $/ac[c] | 77.05 | 83.25 | 77.45 | 85.60 | 76.41 | 84.22 | 80.47 | 91.82 | - |
| Cost of gain, $/cwt.[d] | | | | | | | | | |
| Year 1 | 10.73$^{g}$ | 13.23$^{h}$ | 11.26$^{g}$ | 12.28$^{gh}$ | 11.21$^{g}$ | 13.04$^{h}$ | 11.71$^{g}$ | 13.51$^{h}$ | 0.56 |
| Year 2 | 27.23$^{h}$ | 14.33$^{g}$ | 16.35$^{g}$ | 14.14$^{g}$ | 14.46$^{g}$ | 14.36$^{g}$ | 15.69$^{g}$ | 15.84$^{g}$ | 1.06 |
| Year 3 | 14.54$^{hi}$ | 16.01$^{i}$ | 9.22$^{g}$ | 10.49$^{g}$ | 9.88$^{g}$ | 14.79$^{hi}$ | 10.30$^{g}$ | 13.27$^{h}$ | 0.74 |
| Average[e] | 17.50$^{i}$ | 14.52$^{h}$ | 12.27$^{g}$ | 12.30$^{g}$ | 11.85$^{g}$ | 14.06$^{h}$ | 12.57$^{g}$ | 14.21$^{h}$ | 0.47 |
| CV%[f] | 44.88 | 8.63 | 26.32 | 14.23 | 18.06 | 11.36 | 20.90 | 12.78 | - |

[a] O= oats, R= Rye, RG= Ryegrass, RRG= Rye + Ryegrass, W= Wheat, WR= Wheat + Rye, WRG= Wheat + Ryegrass, WRRG= Wheat + Rye + Ryegrass.
[b] Standard error of the mean.
[c] Cost of pasture establishment per acre using actual costs and enterprise budgets.
[d] Pasture only cost per pound of gain, does not include animal costs and supplementation.
[e] Three year average.
[f] Coefficient of variation.
[ghi] Least-squares means within rows with differing superscripts differ ($P < 0.05$).

# Growth Performance and Health of Dairy Calves Bedded with Different Types of Materials

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## Story in Brief

Granite fines, sand, rice hulls, long wheat straw and wood shavings were compared as bedding for 60 heifer calves at the Ark-Tenn Dairy Research and Development Facility, a commercial 1,100-cow dairy in central Arkansas. Growth, health, and stress indices of calves; as well as physical characteristics and bacterial counts of bedding were evaluated for 42 d from August to October, 2002. During wk 2, dry matter intake (DMI) was greatest for calves bedded with rice hulls and was lowest for calves bedded with wood shavings ($P < 0.05$). Average daily gain and DMI for the entire 42-d trial did not differ ($P > 0.05$) among bedding types. There was a bedding material by week interaction ($P < 0.01$) for the amount of antibiotics given to treat scours. During the first 2 wk, calves housed on long wheat straw received the fewest antibiotics. Serum cortisol, alpha1-acid glycoprotein, and immunoglobulin G concentrations; and blood neutrophil:lymphocyte ratio were not affected ($P > 0.05$) by bedding type. Initially, granite fines were hardest, and long wheat straw was softest ($P < 0.05$). Moreover, there was a bedding material by week interaction ($P < 0.05$) for coliform counts. On d 0, coliform counts were lowest in granite fines and greatest in rice hulls. However, on d 14, 28 and 42, counts were greatest in long wheat straw. Growth performance of calves bedded for 42 d with five bedding materials was similar. However, the amount of antibiotics given for scours and bacterial counts in the bedding varied by bedding type.


## Introduction

The early preweaning stage of a calf's life is critical. The use of bedding material for calves can provide comfort and can decrease the risk of contracting disease. In the United States, the most common bedding materials for dairy calves are sand and/or soil because they improve drainage and remove moisture from the calves' environment (Wells and Heinrichs, 1994). Long wheat straw has also been used traditionally, but it is expensive and/or not available in many areas. Other more reasonably priced materials available in central Arkansas are granite fines, rice hulls, and wood shavings. The objectives of this study were to determine the effects of five types of bedding material on calf growth, physiological stress, and bacterial counts in the bedding.

## Experimental Procedures

Dairy calves were housed in an open barn at the Ark-Tenn Dairy Research and Development Facility near Center Ridge, AR. Pens were located in the middle of the calf barn. The floors were covered with 1 in of ground limestone (grade 4) averaging 218 lb per pen. Then the ground limestone was covered with 2 in of the different types of bedding material composing the five treatments as follows: river sand (Lentz Company, Morrilton, AR); granite fines, a by-product of crushing syenite granite rock (Donna Fill Granite Fines, Little Rock, AR); rice hulls; long wheat straw; or wood shavings.

Within 6 h of birth, 60 calves were vaccinated, identified with an ear tag, and their navels were dipped with 10% tincture of iodine. Calves were fed a colostrum replacement one time. Calves were weighed at 0 and 1 d of age to establish an average initial BW. Calves were randomly assigned to individual pens on one of the five treatments of bedding materials (12 calves per treatment). Calves were started over a 4-wk period (three calves per treatment per week).

Calves were fed 2.1 quarts of medicated milk replacer twice daily at 0700 and 1530 h. Commercial calf starter beginning on d 3 was offered once daily in the morning. Calves were offered 0.25 lb/d in wk 1, 0.50 lb/d in wk 2, and were increased to ad libitum in wk 3 until weaning date after wk 6. Starter intake and milk replacer intake were recorded daily. Fresh drinking water was available at all times. Calves were weighed initially, then at 1, 2, 4, and 6 wk of age (an average of weights on 2 consecutive d was used for the final BW).

Bedding samples were collected to measure moisture content, and absorbency on d 0. On d 0, hardness was measured at 5 points in each pen by a DICKEY-john Soil Compaction tester at 200 lb pressure with a 2.5 in diameter disk. Bedding samples were collected on d 0 and at 14-d intervals for coliform counts. Coliform populations were evaluated by weighing 10 g of bedding sample into 90 ml of sterile phosphate buffer saline (PBS) at pH 7.2 in sterile stomacher bags then mixing for 1 min. A serial dilution of 1:10 was made with 1 ml of solution into 9 ml of sterile PBS per tube. Each dilution starting at $1 \times 10^3$ to $1 \times 10^7$ was plated on the surface of MacConkey agar (Remel, Lenexa, KS). Bacteria were counted after being incubated for 18 to 24 h at 98.6°F and recorded as colony-forming units (cfu) per gram wet weight. Plates with 30 to 300 colonies were used to calculate cfu/g. Every 2 wk, after sample collection for coliform counts, bedding materials that had been forced outside the pen were placed back into the pen before adding any new bedding material. Additional bedding was added at approximately 0.5 in depth over the previous bedding, if required, based on a bedding score > 3 (1 = dry and clean to 5 = > 80% of surface dirty or wet).

Calf health was observed daily after the morning feeding. Fecal fluidity was scored as 1 = normal fluidity to 4 = watery (Larson et al., 1977). Rectal temperatures were taken on calves with fecal fluidity score > 2. When the fecal fluidity score was > 2, antibiotic treatments were given until the fecal fluidity score was < 2.

Blood was collected (approximately 4 h after the milk replacer feeding) into plain glass vacuum tubes at 1 d and at 3 and 6 wk of age. Blood was centrifuged and serum frozen (-4°F) until analyzed for immunoglobulin G (IgG), cortisol, and alpha1-acid glycoprotein.

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Blood smear slides were prepared to measure the neutrophil to lymphocyte ratio.

Growth, dry matter intake (DMI), and feed efficiency data were analyzed as a randomized complete block design by analysis of covariance using initial weight as a covariant. Calves were blocked (four blocks) by the week in which they began the study. Dry matter, absorbency, and hardness were analyzed as a randomized completed block design by general linear models. Least-squares means were compared with an F-protected t-test. Scour days, fecal fluidity score, blood cell parameters, bedding score, coliform counts, and bedding material additions were analyzed with PROC MIXED (SAS, Inst., Inc., Cary, NC). Analyses of these data used a repeated measures model that included: effects of subject (calf), bedding material type, time, and the first-order interaction (bedding material type x time). Significance was declared at $P < 0.05$.

## Results and Discussion

*Growth Performance, Feed Intake, and Health Status.* Body weight gain (Table 1) for d 0 through 42 did not differ due to bedding materials but was lower than normal (1.45 lb/d; Davis and Drackley, 1998). Intake of DM varied among bedding types during wk 2. Calves housed on wood shavings and sand had lower starter intake than calves housed on rice hulls; with intake of calves bedded on long wheat straw and granite fines being intermediate. Dry matter intake from d 0 to 42 did not differ due to bedding materials.

There was an interaction between bedding materials and week (Table 2) for calves observed scouring (fecal fluidity score > 2). Calves housed on granite fines had more scour days than those housed on other materials during the first 2 wk. From d 7 to 14 calves bedded with granite fines had the greatest number of scour days observed. The lowest number of scour days during the first 2 wk was for calves bedded with long wheat straw. Calves bedded on rice hulls, granite fines, and sand produced fecal fluidity scores higher than those bedded on long wheat straw and wood shavings. It is possible that long wheat straw and wood shavings with their larger particle sizes made it harder to see scouring. Granite fines were packed after use, and it was easier to see any scouring.

Serum IgG concentration was affected by week ($P < 0.05$; Table 3). Failure of passive immune transfer occurred in these calves on d 1 as indicated by an average IgG concentration of 958 mg/dl. That was less than the recommended 1000 mg/dl (Higginbotham and Stull, 1997). Serum cortisol, and alpha1-acid glycoprotein concentrations and neutrophil:lymphocyte (N:L) ratio (Table 3) were also different by week ($P < 0.05$). The cortisol and alpha1-acid glycoprotein levels and the N:L ratio peaked on d 1 and declined at wk 3 and 6 of age. Higher cortisol concentrations and N:L ratios indicated calves were more stressed. Alpha1-acid glycoprotein is a marker of disease and inflammation. Higginbotham and Stull (1997) and Hiroshi et al. (1993) reported that neonatal calves had serum alpha1-acid glycoprotein concentrations of $1368 \pm 206$ μg/ml, levels similar to our results on d 1. Bedding type did not affect any of these physiological responses.

*Characteristics of Bedding Materials.* Prior to use, long wheat straw had the greatest absorbency ($P < 0.05$; Table 4) and was the softest ($P < 0.05$). Sand and granites fines were the least absorbent. Pens bedded with sand had the highest bedding score ($P < 0.05$) indicating they were wetter than other pens. The sand mixed with the base material (ground limestone) after use and appeared to not drain adequately. Granite fines were packed after use and appeared to dry faster than sand when wet. Rice hulls, long wheat straw, and wood shavings formed a layer on top of the ground limestone rock and also appeared to drain adequately.

Coliform counts showed a bedding material by week interaction ($P < 0.05$; Table 4). The peak of coliform counts for all bedding types was d 14. Long wheat straw had the highest counts after d 0, probably because it had nutrients such as amino acids, a low C:N ratio (Ward et al., 2000), and higher absorbency for bacteria growth, and no inhibitory substrates (Bay et al., 2002; Johnston et al., 2001).

Costs (Table 5) of materials (without delivery charges) were \$2.00/ton for granite fines, \$4.00/ton for sand, \$45.00/ton for rice hulls, \$166.70/ton for long wheat straw and \$56.25/ton for wood shavings. The cost/pen for the entire 42 d of the materials was lowest for granite fines and rice hulls, and highest ($P < 0.05$) for long wheat straw.

## Implications

Growth performance of calves, regardless of bedding materials during the preweaning stage, was similar. Calves housed on long wheat straw required fewer antibiotic treatments for scours. The long wheat straw may be more comfortable because it was softer; however, it had the highest coliform counts. Granite fines and rice hulls were the least cost materials.

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**Table 1. Growth performance, weight gain, and feed utilization of calves bedded with five different materials.**

| Item | Granite fines | Sand | Rice hulls | Wheat straw | Wood shavings | SE |
|---|---|---|---|---|---|---|
| Initial BW, lb | 75.7 | 75.2 | 75.2 | 70.4 | 77.7 | 11.0 |
| Final BW, lb | 106.0 | 107.4 | 104.7 | 102.1 | 104.7 | 14.1 |
| BW gain, lb/d | | | | | | |
| D 0 to 42 | 0.73 | 0.74 | 0.68 | 0.75 | 0.65 | 0.06 |
| Starter intake, lb DM/d | | | | | | |
| D 7 to 14 | 0.11$^{ab}$ | 0.05$^{bc}$ | 0.14$^{a}$ | 0.07$^{abc}$ | 0.03$^{c}$ | 0.03 |
| D 0 to 42 | 0.69 | 0.54 | 0.53 | 0.68 | 0.56 | 0.07 |
| Milk replacer intake, lb DM/d | | | | | | |
| D 0 to 42 | 1.13 | 1.13 | 1.13 | 1.14 | 1.13 | 0.002 |
| DMI, lb/d | | | | | | |
| D 7 to 14 | 1.24$^{ab}$ | 1.18$^{bc}$ | 1.27$^{a}$ | 1.21$^{abc}$ | 1.16$^{c}$ | 0.03 |
| D 0 to 42 | 1.82 | 1.67 | 1.66 | 1.81 | 1.69 | 0.07 |
| BW gain/DMI | | | | | | |
| D 0 to 42 | 0.331 | 0.382 | 0.339 | 0.336 | 0.314 | 0.026 |

$^{a,b,c}$ Means within a row without a common superscript letter differ ($P < 0.05$).

**Table 2. Scour days and fecal fluidity scores of calves bedded on five different materials.**

| Item | Granite fines | Sand | Rice hulls | Wheat straw | Wood shavings | Mean | SE |
|---|---|---|---|---|---|---|---|
| Calf treated, no | 12/12 | 11/12 | 12/12 | 5/12 | 10/12 | | |
| Scour days | | | | | | | |
| D 0 to 7 | 1.2$^{c}$ | 0.6$^{d}$ | 0.6$^{d}$ | 0.1$^{e}$ | 0.7$^{d}$ | 0.7 | 0.1 |
| D 7 to 14 | 2.6$^{a}$ | 2.2$^{b}$ | 1.5$^{c}$ | 0.4$^{e}$ | 1.0$^{c}$ | 1.6 | 0.1 |
| D 14 to 28 | 0.2$^{e}$ | 0.1$^{e}$ | 0.0$^{f}$ | 0.0$^{f}$ | 0.0$^{f}$ | 0.1 | 0.1 |
| D 28 to 42 | 0.0$^{f}$ | 0.0$^{f}$ | 0.0$^{f}$ | 0.0$^{f}$ | 0.0$^{f}$ | 0.0 | 0.1 |
| D 0 to 42 | 0.9 | 0.7 | 0.5 | 0.1 | 0.4 | | |
| SE | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | |
| Fecal fluidity score[1] | | | | | | | |
| D 0 to 7 | 2.2 | 2.3 | 2.4 | 1.7 | 1.7 | 2.0$^{y}$ | 0.1 |
| D 7 to 14 | 2.5 | 2.5 | 2.4 | 1.8 | 2.1 | 2.3$^{y}$ | 0.1 |
| D 14 to 28 | 1.4 | 1.2 | 1.1 | 1.3 | 1.1 | 1.2$^{z}$ | 0.1 |
| D 28 to 42 | 1.2 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1$^{z}$ | 0.1 |
| D 0 to 42 | 1.6$^{n}$ | 1.6$^{n}$ | 1.6$^{n}$ | 1.4$^{m}$ | 1.4$^{m}$ | | |
| SE | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | |

[1] Fecal fluidity score using scale 1 = normal to 4 = watery.

$^{a,b,c,d,e,f}$ Means within a category without a common superscript letter differ ($P < 0.05$), bedding by day interaction ($P < 0.05$).

$^{m,n}$ Means within a row without a common superscript letter differ ($P < 0.05$).

$^{y,z}$ Means within a column and a category without a common superscript letter differ ($P < 0.05$).

**Table 3: Blood parameters of calves as affected by five different bedding materials.**

| Item | Granite fines | Sand | Rice hulls | Wheat straw | Wood shavings | Mean | SE |
|---|---|---|---|---|---|---|---|
| Cortisol, µg/dl | | | | | | | |
| D 1 | 3.81 | 5.02 | 5.79 | 4.52 | 5.07 | 4.84$^{x}$ | 0.20 |
| Wk 3 | 0.58 | 0.80 | 0.39 | 0.60 | 0.37 | 0.55$^{y}$ | 0.20 |
| Wk 6 | 0.31 | 0.64 | 0.44 | 0.38 | 0.48 | 0.45$^{y}$ | 0.20 |
| Mean | 1.57 | 2.15 | 2.21 | 1.83 | 1.97 | | |
| SE | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | | |
| Immunoglobulin G, mg/dl | | | | | | | |
| D 1 | 897 | 892 | 1068 | 947 | 989 | 958$^{y}$ | 74 |
| Wk 3 | 796 | 854 | 1245 | 762 | 947 | 921$^{y}$ | 74 |
| Wk 6 | 1193 | 1138 | 1291 | 1249 | 1322 | 124$^{x}$ | 74 |
| Mean | 962 | 962 | 1201 | 986 | 1086 | | |
| SE | 97 | 97 | 97 | 97 | 97 | | |
| Alpha1-acid glycoprotein, µg/ml | | | | | | | |
| D 1 | 1282 | 1486 | 1610 | 1357 | 1280 | 1403$^{x}$ | 53 |
| Wk 3 | 591 | 722 | 702 | 563 | 486 | 612$^{y}$ | 53 |
| Wk 6 | 286 | 389 | 435 | 315 | 289 | 343$^{z}$ | 53 |
| Mean | 720 | 866 | 916 | 745 | 685 | | |
| SE | 89 | 89 | 89 | 89 | 89 | | |
| Neutrophil:lymphocyte ratio | | | | | | | |
| D 1 | 1.51 | 1.86 | 2.12 | 1.76 | 2.02 | 1.85$^{x}$ | 0.12 |
| wk 3 | 0.34 | 0.36 | 0.45 | 0.38 | 0.39 | 0.38$^{y}$ | 0.11 |
| wk 6 | 0.35 | 0.42 | 0.38 | 0.36 | 0.35 | 0.37$^{y}$ | 0.11 |
| Mean | 0.73 | 0.88 | 0.98 | 0.83 | 0.92 | | |
| SE | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | | |

$^{x,y,z}$ Means within a column and a category without a common superscript letter differ ($P < 0.05$).

**Table 4. Physical characteristics of bedding, and bacteria count on bedding as affected by five different materials.**

| Item | Granite fines | Sand | Rice hulls | Wheat straw | Wood shavings | Mean | SE |
|---|---|---|---|---|---|---|---|
| D 0 | | | | | | | |
| Dry matter, % | 97.4$^{m}$ | 100.0$^{m}$ | 89$^{n}$ | 90.5$^{n}$ | 91.0$^{n}$ | | 1.2 |
| Absorbency, % | 32.5$^{o}$ | 26.5$^{o}$ | 185.4$^{n}$ | 340.8$^{m}$ | 186.1$^{n}$ | | 19.8 |
| Hardness, in[1] | 0.6$^{o}$ | 1.0 $^{n}$ | 0.8 $^{no}$ | 3.6$^{m}$ | 0.9 $^{no}$ | | 1.0 |
| Bedding score[2] | | | | | | | |
| D 0 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | 1.1$^{z}$ | 0.14 |
| D 14 | 2.5 | 2.8 | 1.7 | 1.8 | 1.8 | 2.1$^{y}$ | 0.14 |
| D 28 | 2.6 | 3.2 | 2.4 | 2.6 | 2.1 | 2.6$^{x}$ | 0.14 |
| D 42 | 2.2 | 3.0 | 2.7 | 2.3 | 2.4 | 2.5$^{x}$ | 0.14 |
| Mean | 2.1$^{m}$ | 2.5$^{n}$ | 2.0$^{m}$ | 1.9$^{m}$ | 1.8$^{m}$ | | |
| SE | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | | |
| Coliform, $\log_{10}$ cfu/g | | | | | | | |
| D 0 | 1.1$^{e}$ | 2.3$^{d}$ | 5.0$^{b}$ | 1.8$^{e}$ | 2.9$^{d}$ | 2.63 | 0.21 |
| D 14 | 5.2$^{b}$ | 3.9$^{c}$ | 4.9$^{bc}$ | 6.7$^{a}$ | 5.5$^{b}$ | 5.22 | 0.21 |
| D 28 | 4.1$^{c}$ | 2.9$^{d}$ | 4.1$^{c}$ | 5.5$^{b}$ | 4.2$^{c}$ | 4.15 | 0.21 |
| D 42 | 3.9$^{c}$ | 3.4$^{d}$ | 4.1$^{c}$ | 5.6$^{b}$ | 4.7$^{bc}$ | 4.33 | 0.21 |
| Mean | 3.6 | 3.1 | 4.5 | 4.9 | 4.3 | | |
| SE | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | | |

[1] Higher number indicates softer surface.

[2] Bedding score 1 = dry and clean to 5 = more than 80% of surface dirty and wet.

$^{a,b,c,d,e}$ Means within category without a common superscript letter differ ($P < 0.05$), bedding by day interaction ($P < 0.05$).

$^{m,n,o}$ Means within a row without a common superscript letter differ ($P < 0.05$).

$^{x,y,z}$ Means within a column and a category without a common superscript letter differ ($P < 0.05$).

**Table 5. Amount used and cost of bedding materials.**

| Item | Granite fines | Sand | Rice hulls | Wheat straw | Wood shavings | Mean | SE |
|---|---|---|---|---|---|---|---|
| Materials used, lb/pen | | | | | | | |
| D 0 | 418[a] | 352b | 22[d] | 17[d] | 33c[d] | 168 | 3.2 |
| D 21 | 39.4[d] | 49.9[cd] | 2.4[d] | 2.4[d] | 8.4[d] | 21 | 3.2 |
| D 35 | 68.6[c] | 73.5[c] | 4.6[d] | 3.3[d] | 7.5[d] | 32 | 3.2 |
| Mean | 175.3 | 158.6 | 9.7 | 7.5 | 16.3 | | |
| SE | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | | |
| Total used, lb/pen | 526.0[m] | 483.3[n] | 29.5[o] | 22.2[o] | 48.8[o] | | 10.8 |
| Total cost, $/pen[1] | 0.53[p] | 0.97[o] | 0.66[p] | 1.85[m] | 1.37[n] | | 0.05 |

1 Cost did not include ground limestone rock for base (217.8 lb per pen = $1.71). Calculated based on a cost of $2/ton for granite fines, $4/ton for sand, $45/ton for rice hulls, $166.7/ton for long wheat straw and $56.25/ton for wood shavings. Cost did not include transportation to the farm.

[a,b,c,d] Means within category without a common superscript letter differ ($P < 0.05$), bedding by day interaction ($P < 0.05$).

[m,n,o,p] Means within a row without a common superscript letter differ ($P < 0.05$).

# Post-Weaning Performance of Fall-Born Steers and Heifers that Grazed Endophyte-Infected Tall Fescue Pastures at Two Rotational Grazing Intensities and Were Weaned on Two Dates

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## Story in Brief

A 3-year study was initiated to investigate the impact of rotational management (2x monthly vs. 2x weekly) regime and weaning date (early April vs. early June) on production of fall-calving cow-calf pairs grazing *Neotyphodium coenophialum*–infected fescue overseeded with legumes and crabgrass. A secondary objective of the study was to evaluate long-term impacts of the above treatments after the calves were weaned and treated similarly. During the first two post-weaning cycles, heifers weaned in early June were heavier ($P < 0.05$) at breeding than those weaned in mid-April. However, a greater proportion of heifers previously managed in a twice-monthly rotation conceived compared with those previously managed in a twice-weekly rotation (18/25 vs. 11/27). A rotational management by weaning date interaction was detected ($P < 0.05$) for steer initial and final feedlot pay weight, feedlot gain, hot carcass weight, and dressing percentage. Generally, steers weaned in mid-April from a twice weekly rotation regime weighed less ($P < 0.05$) at the beginning and end of the feedlot period, had lower ($P < 0.05$) hot carcass weights and lower ($P < 0.05$) dressing percentages than steers from the other treatment combinations. Therefore, rotational management regimes for cow-calf pairs appears to have little long-term implications, whereas fall-born calves weaned at an average of 188 days of age had reduced weaning weights that were at best marginally compensated for when compared with calves weaned at an average of 243 days of age.


## Introduction

Numerous studies have evaluated the impact of grazing *Neotyphodium coenophialum*-infected fescue under different management systems. Other studies have evaluated potential carryover effects of grazing infected fescue pastures. Few if any studies have evaluated the impact of being born and reared until weaning on infected fescue pastures managed under different rotational management regimes on long-term calf performance. Furthermore, numerous studies have evaluated early weaning as a means of allowing cows more days from weaning until conception to regain body condition. However, few if any studies have evaluated the impact of weaning date on long-term performance of calves previously grazing infected tall fescue pastures. The goal of this project was to wean fall-born calves in mid-April or early June from tall fescue pastures overseeded with legumes and crabgrass that were rotated twice weekly vs. twice monthly, and monitor post-weaning impacts of these weaning and grazing management programs.

## Experimental Procedures

Sixty pregnant cows and heifers of predominantly Angus breeding that were bred to Gelbvieh bulls were stratified by age and weight and allocated randomly to one of 11 pasture groups in early April of 2000. The groups of cows were then allocated to one of 11 pastures with established stands of infected tall fescue to set an initial stocking rate of 2.5 acres/cow. Pastures were allocated randomly to one of four pasture management or weaning date treatments in a 2 x 2 factorial treatment arrangement (Table 1). Treatments consisted of dividing each pasture area into either two or eight sections and rotating cows to a new section either twice weekly or twice monthly. Within each of the rotation regimes, calves were weaned either in mid-April (188 days of age) or early June (243 days of age).

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

The weaning program consisted of vaccination against respiratory infection at 4 wk followed by a booster vaccination 2 wk prior to being weaned. Calves from each treatment were removed from their dams, weighed, then transported to a sale auction, handled according to routine auction procedures, then transported back to the University of Arkansas facilities the following morning. Upon return to the University of Arkansas cattle facilities, calves were housed in a drylot facility for 21 days and fed alfalfa hay ad libitum along with 2 lb of ground corn daily. After the 21-day drylot period, calves were co-mingled and grazed on pastures of common bermudagrass during the summer and fescue during the fall. Heifer calves were retained and mated naturally. In the first year, steers were shipped to Scott City, KS and finished in a commercial feedlot facility. In the second year, steers were shipped to the University of Arkansas facilities at Savoy, AR, and finished on a high concentrate feedlot diet. Pay weights were determined by applying a 4% pencil shrink to weights measured directly from pasture prior to shipping (initial pay wt) or at the feedlot facilities (final pay wt).

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

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## Results and Discussion

As expected, actual weaning weights were greater (131 lb; $P < 0.05$) for heifers weaned in June vs. April, but rotational management did not affect ($P > 0.10$) actual weaning weights (Table 2). On the day June-weaned heifers were weaned, those heifers were 81 lb heavier ($P < 0.05$) than heifers weaned in mid-April although heifers weaned in mid-April had had 55 days to recover from the stresses of weaning. Heifers weaned in June were 96 lb heavier ($P < 0.05$) at the beginning of the breeding season, demonstrating that the stressors causing the weight differences at the time of weaning had long-term implications and were not compensated for during ensuing periods when heifers were commingled. Heifer conception rates did not follow the pattern of weaning and breeding weights. Heifers weaned from a twice-monthly rotation system had numerically higher conception rates than those weaned from a twice-weekly rotation system (18 out of 25 heifers bred vs. 11 out of 27 heifers).

For steers, a rotational management by weaning date interaction was detected ($P < 0.05$) for actual weaning weight, weight at the June weaning, initial and final feedlot pay weight, feedlot gain, hot carcass weight, and dressing percentage (Table 3). Actual weaning weight, weight at the June weaning, and initial feedlot weight were greatest ($P < 0.05$) from steers weaned in June from a twice weekly rotation regime, lowest from steers weaned in April from a twice weekly rotation regime, and intermediate from calves weaned from a twice monthly rotation regime in April or June. Final feedlot weight was lower ($P < 0.05$) from steers weaned in April from a twice-weekly rotation regime than from the other treatment combinations. When the weight of steers weaned in April from a twice weekly rotation is compared with the average of the other three treatment combinations, those steers were 127 lb lighter than the average at the June weaning, 118 lb lighter at the time they were shipped to the feedlot, and 195 lb lighter than the average of the three remaining treatments when they left the feedlot. This implies that the treatment combination of April weaning from pastures managed in a twice-weekly rotation regime had long-term negative impacts on steer growth. Steers weaned in April from a twice-monthly rotation regime did not appear to be affected as dramatically as those weaned in April from a twice-weekly rotation regime, as their final live weight did not differ ($P > 0.10$) from those of calves weaned in June from either rotation regime.

Feedlot gain was greatest ($P < 0.05$) by steers weaned in April from a twice-monthly rotation regime. Gains by those steers were greater ($P < 0.05$) than gains by steers weaned in June from a twice-monthly rotation regime or by those weaned in April from a twice-weekly rotation regime.

Hot carcass weights and dressing percentage were lower ($P < 0.05$) from steers weaned in April from a twice-weekly rotation regime than from the other treatment combinations. Longissimus eye area, fat thickness, and marbling scores did not differ ($P > 0.10$) among treatment combinations.

## Implications

Having cows grazing endophyte-infected fescue calve in the fall may be beneficial for cow reproduction. However, time of weaning of the resulting calves may be critical. Weaning fall-born calves grazing infected fescue pastures in early to mid-April may have long-term negative impacts on those calves causing the heifers to weigh less at breeding time and steers to weigh less at the time they should be ready to enter the feedlot.

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

| Forage management | No. pastures | Weaning date | Grazing duration | Rest duration |
|---|---|---|---|---|
| 2-cell | 3 | mid-April | 14 days | 14 days |
| 2-cell | 3 | early-June | 14 days | 14 days |
| 8-cell | 2 | mid-April | 3 to 4 days | 24 to 25 days |
| 8-cell | 3 | early-June | 3 to 4 days | 24 to 25 days |

**Table 2. Post-weaning performance of heifers grazing tall fescue pastures managed in a twice-weekly or twice-monthly rotation regime and weaned in mid-April or early June.**

| | 2 rotations/month | | 2 rotations/week | | | |
|---|---|---|---|---|---|---|
| Item | April | June | April | June | SE | Effect[a] |
| Actual weaning wt, lb | 474 | 589 | 449 | 595 | 29.1 | W |
| Wt at June weaning, lb | 516 | 589 | 505 | 595 | 29.1 | W |
| Breeding wt, lb | 629 | 728 | 606 | 710 | 33.6 | W |
| No. conceived/total no. | 9/13 | 9/12 | 5/13 | 6/14 | | |

[a] W=weaning date effect ($P < 0.05$).

**Table 3. Post-weaning performance of steers grazing tall fescue pastures managed in a twice-weekly or twice-monthly rotation regime and weaned in mid-April or early June.**

| | 2 rotations/month | | 2 rotations/week | | | |
|---|---|---|---|---|---|---|
| Item | April | June | April | June | SE | Effect[a] |
| Actual weaning wt, lb | 519[cd] | 588[bc] | 411[d] | 646[b] | 28.6 | W, RxW |
| Wt at June weaning, lb | 576[cd] | 588[bc] | 467[d] | 646[b] | 25.1 | W, RxW |
| Initial feedlot wt, lb[e] | 614[cd] | 636[bc] | 526[d] | 683[b] | 19.0 | W, RxW |
| Final live wt, lb[e] | 1302[b] | 1271[b] | 1106[c] | 1329[b] | 25.9 | R, W, RxW |
| Feedlot gain, lb | 688[b] | 637[c] | 580[c] | 646[bc] | 17.7 | R, RxW |
| Feedlot gain, lb/day | 4.06[b] | 3.76[c] | 3.42[c] | 3.80[bc] | 0.106 | R, RxW |
| Hot carcass wt, lb | 843[b] | 817[b] | 685[c] | 855[b] | 19.3 | R, W, RxW |
| Dressing % | 62.2[b] | 61.7[b] | 59.4[c] | 61.7[b] | 0.54 | R, RxW |
| Longissimus area, in2 | 14.6 | 14.3 | 13.3 | 14.4 | 0.82 | NS |
| Fat thickness, in | 0.45 | 0.44 | 0.35 | 0.52 | 0.099 | NS |
| Marbling score[f] | 367 | 371 | 375 | 352 | 22.2 | NS |
| USDA yield grade | 2.3 | 2.4 | 2.2 | 2.6 | 0.10 | w |

[a] W=weaning date effect ($P < 0.05$); R=rotation frequency effect ($P < 0.05$); RxW=rotation frequency by weaning date interaction ($P < 0.05$); w=weaning date effect ($P < 0.10$); NS=not statistically significant.

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

[e] Weight was determined by weighing steers directly off of pasture or out of their feedlot pen and applying a 4% pencil shrink to the weights.

[f] Marbling scores 200-299=Slight 00-99; 300-399=Small 00-99; 400-499=Modest 00-99, etc.

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

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## Story in Brief

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


## Introduction

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

## Experimental Procedures

Sixty pregnant (confirmed by rectal palpation) cows and heifers of predominantly Angus breeding were stratified by age and weight and allocated randomly to one of 11 pasture groups in early April of 2000. The groups of cows were then allocated to one of 11 pastures with established stands of endophyte-infected tall fescue that ranged between 10 and 16 acres in size. The number of cows per group was determined to set an initial stocking rate of 2.5 acres/cow. The pasture area was located on a 190-acre block of Clarksville very cherty silt loam; characterized as being deep, somewhat excessively drained, and having moderate to steep slopes. It is one of the predominant soil types in the Ozark Highlands and is not adapted to tillage.

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

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

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

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

The weaning program consisted of vaccination against respiratory infection at 4 wk followed by a booster vaccination 2 wk prior to being weaned. Calves from each treatment were removed from their dams, weighed, then transported approximately 30 miles to a sale auction and were handled according to routine auction procedures. Calves were weighed at the auction facility between 8:00 and 9:30 pm to determine sale value. Calves were then held overnight at the sale barn and transported back to the University of Arkansas facilities. Upon return to the University of Arkansas cattle facilities, calves were weighed, blood samples were gathered via jugular puncture and calves were housed in a drylot facility for 21 days and fed alfalfa hay ad libitum along with 2 lb of ground corn daily. Calves were observed three times daily for sickness over the 3-week period following weaning. Calves diagnosed as having respiratory illness were treated with Micotil® initially and with Nuflor® if a second treatment was necessary.


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

## Results and Discussion

Cow performance during the first 2 yr is shown in Table 2. Cow BW at calving, breeding and weaning, and cow BW change between the different production periods did not differ ($P > 0.10$) between cows rotated 2x monthly and those rotated 2x weekly. Body condition scores (BCS) at breeding were 0.3 units higher ($P < 0.05$) for cows rotated 2x monthly than for those rotated 2x weekly. Cow BW and BCS did not differ ($P > 0.10$) due to calf weaning date, but cow BW change from calving or breeding to weaning was greater ($P < 0.05$) from cows whose calves were weaned later. The amount of hay offered during the winter and milk production did not differ ($P > 0.10$) among treatments. Calving rates tended to be higher ($P < 0.10$) from cows rotated 2x monthly with calves weaned in April and those rotated 2x weekly with calves weaned in June than from cows rotated 2x monthly with their calves weaned in June. However, calving rates were greater than 90% from all treatment combinations, and differences represent a difference of only one open cow per treatment.

Calf birth weight did not differ ($P > 0.10$) among rotation and weaning treatments (Table 3). Calves weaned early were 142 lb lighter ($P < 0.05$) at the time of weaning than those weaned late, but pasture rotation frequency did not affect ($P > 0.10$) actual weaning weights (Table 3). Actual BW on the early weaning date was greater ($P < 0.05$) from early weaned calves rotated twice monthly than late weaned calves rotated twice monthly or early weaned calves weaned twice weekly. Actual BW on the late weaning date ($P > 0.10$) was 89 lb heavier ($P < 0.05$) from calves weaned late compared with those weaned early. Adjusted 205-d weaning weights did not differ ($P > 0.10$) across rotation schedules or weaning dates.

Actual weight loss during transport to the local auction facility, and total weight loss during the day calves were removed from their dams, transported to the auction facility, then returned to the experiment station was higher ($P < 0.05$) from calves weaned late (Table 4). However, since those calves were also heavier at this time, calf shrink expressed as a percentage did not differ ($P > 0.10$) among treatments during this time. Daily gain during the 21-d receiving period did not differ ($P > 0.10$) among treatment combinations, but calves weaned in early June required almost 10 d more ($P < 0.05$) to recover their weight that was lost during transport to the local auction facility.

## Implications

Fall-born calves grazing endophyte-infected tall fescue prior to weaning should not be weaned in mid April. Such early weaning appears to provide no benefits to the cow, and may have negative effects on calves that are not overcome when calves are placed on non-infected forages following weaning.

## Literature Cited

Coffey, K.P., et al. 2001. Prof. Anim. Sci. 17:166-173.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th ed. National Academy Press, Washington, DC.

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

| Forage management | No. pastures | Weaning date | Grazing duration | Rest duration |
|---|---|---|---|---|
| 2-cell | 3 | mid-April | 14 days | 14 days |
| 2-cell | 3 | early-June | 14 days | 14 days |
| 8-cell | 2 | mid-April | 3 to 4 days | 24 to 25 days |
| 8-cell | 3 | early-June | 3 to 4 days | 24 to 25 days |

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

| | 2 rotations/month | | 2 rotations/week | | | |
|---|---|---|---|---|---|---|
| Item | April | June | April | June | SE | Effect[a] |
| Cow weight, lb | | | | | | |
| Initial | 1090 | 1091 | | | 0.5 | |
| At calving[b] | 1338 | 1303 | 1300 | 1271 | 26.7 | NS |
| At breeding[c] | 1257 | 1228 | 1199 | 1197 | 29.8 | NS |
| At weaning | 1127 | 1170 | 1079 | 1141 | 53.0 | NS |
| Cow weight change, lb | | | | | | |
| Calving to breeding | -81 | -75 | -101 | -74 | 22.2 | NS |
| Breeding to weaning | -33 | -44 | -11 | -50 | 19.9 | W |
| Calving to weaning | -114 | -27 | -112 | -28 | 34.7 | W |
| Body condition score | | | | | | |
| At calving | 7.2 | 7.0 | 7.0 | 7.1 | 0.12 | NS |
| At breeding | 6.6 | 6.6 | 6.1 | 6.4 | 0.39 | R |
| At weaning | 6.1 | 6.3 | 5.6 | 6.1 | 0.49 | NS |
| Body condition score change | | | | | | |
| Calving to breeding | -0.8 | -0.6 | -1.1 | -0.9 | 0.16 | R |
| Breeding to weaning | 0.0 | 0.2 | 0.0 | 0.2 | 0.30 | NS |
| Calving to weaning | -0.8 | -0.4 | -1.1 | -0.8 | 0.35 | NS |
| Hay offered, lb/cow | 3021 | 2847 | 2882 | 2851 | 273.2 | NS |
| Milk prod, lb/d[d] | 12.2 | 11.5 | 11.9 | 13.9 | 1.20 | NS |
| Calving rate, % | 97[x] | 91[y] | 92[xy] | 97[x] | 2.12 | R x W |

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

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

[c] Beginning of breeding season.

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

[xy] Means within the same row without a common superscript letter differ ($P < 0.10$).

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

| | 2 rotations/month | | 2 rotations/week | | | |
|---|---|---|---|---|---|---|
| Item | April | June | April | June | SE | Effect[a] |
| Birth wt, lb | 75 | 74 | 74 | 79 | 7.8 | ns |
| Actual weaning wt, lb | 496 | 589 | 430 | 621 | 25.0 | W |
| Wt at April weaning, lb | 496[x] | 458[yz] | 430[z] | 487[xy] | 12.7 | R x W |
| Wt at June weaning, lb | 546 | 589 | 486 | 621 | 25.1 | W |
| Adjusted 205-d wt, lb | 561 | 509 | 506 | 535 | 24.1 | NS |
| Age at weaning, d | 190 | 242 | 185 | 244 | 3.5 | W |

[a] W = weaning date effect ($P < 0.05$); R = rotation frequency effect ($P < 0.05$); R x W = rotation frequency by weaning date interaction ($P < 0.05$).

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

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

| | 2 rotations/month | | 2 rotations/week | | | |
|---|---|---|---|---|---|---|
| Item | April | June | April | June | SE | Effect[a] |
| Wt loss, lb | | | | | | |
| To sale barn | 23 | 28 | 20 | 29 | 1.7 | W[b] |
| Sale to farm | 10 | 14 | 8 | 18 | 2.8 | W |
| Total | 34 | 42 | 28 | 47 | 4.0 | W |
| % Shrink | | | | | | |
| To sale barn | 4.8 | 4.8 | 4.7 | 4.6 | 0.17 | NS |
| Sale to farm | 2.1 | 2.5 | 1.8 | 3.0 | 0.46 | NS |
| Total | 6.7 | 7.2 | 6.4 | 7.5 | 0.45 | NS |
| ADG, receiving period, lb | 2.1 | 1.7 | 2.1 | 2.1 | 0.29 | NS |
| Recovery time, d | 7.9 | 18.1 | 5.7 | 15.2 | 3.88 | W |
| Hay offered, lb | 183 | 211 | 187 | 216 | 8.5 | W |

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

[b] W = weaning date effect ($P < 0.05$); w = weaning date effect ($P < 0.10$).

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

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## Story in Brief

A 3-year study was initiated in April 2000 to investigate the impact of rotational management (2x monthly vs. 2x weekly) program and weaning date (mid April vs. early June) on production of fall-calving cow-calf pairs grazing *Neotyphodium coenophialum*–infected fescue overseeded with legumes and crabgrass. A secondary objective of the experiment was to evaluate changes in forage species composition. Pastures were predominated by tall fescue throughout the first three grazing seasons and the proportion of bare ground was greater ($P < 0.05$) in pastures rotated twice weekly vs. those rotated twice monthly. The proportion of legumes was very low in all treatment combinations, but the proportion of crabgrass continued to increase during the summer and fall samplings throughout the study regardless of rotation program. Therefore, after the third grazing season of the experiment, rotation frequency and/or weaning date has had little impact of forage species composition. The third and final grazing cycle was recently completed when calves were weaned in the spring of 2003.


## Introduction

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

## Experimental Procedures

Sixty pregnant fall-calving cows and heifers (Avg. calving date = Oct. 1) were stratified by age and weight and allocated randomly to one of 11 pasture groups in early April, 2000. The groups of cows were then allocated to one of 11 pastures with established stands of infected tall fescue that ranged between 10 and 16 acres in size. The number of cows per group was determined to set an initial stocking rate of 2.5 acres/cow. The pasture area is located on a 190-acre block of Clarksville very cherty silt loam; characterized as being deep, somewhat excessively drained, and having moderate to steep slopes. It is one of the predominant soil types in the Ozark Highlands and is not adapted to tillage.

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

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

The forage fertility program consisted of applications of 40 lb N/acre in early June, and late August. Phosphorus and potassium were applied per soil test recommendation in late August, and 1 to 2 lb boron/acre was applied each year in the spring to enhance legume growth. Lime was applied as needed according to soil test recommendations.

Forage species frequency and basal cover were determined in February, July, and October, 2000, and April, July, and October of 2001 and 2002 by the modified step-point procedure of Owensby (1973). Each pasture was walked in a random zigzag manner carrying a step-pointer, which is a tripod constructed of PVC pipe. Extending beyond the tripod is a screw rod of approximately 15 inches. When the desired distance was walked, the step-pointer was placed on the ground. The observer recorded the forage species the screw rod contacted. Direct contact was reported if the screw rod contacted the crown of a plant, otherwise bare ground was recorded if the screw rod did not contact the plant crown. If bare ground was recorded, the forage species closest to the screw rod within a 180° radius in front of the step-pointer was also recorded. Fifteen observations were measured per acre.

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


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## Results and Discussion

Basal cover differed ($P < 0.05$) across sampling season and year (Table 2). Part of this could be directly attributed to seasonal differences, but part of these differences was also attributed to an infestation of armyworms that consumed the spring fescue growth in June, 2001. The proportion of basal cover was greater ($P < 0.05$) on pastures rotated twice monthly vs. twice weekly when averaged across sampling dates and years.

The pastures were dominated by tall fescue throughout the study, averaging 60.7% fescue across all sampling dates and years (Table 3). Tall fescue proportion varied ($P < 0.05$) across years and was higher ($P < 0.05$) during the spring than during the summer and fall but was not affected ($P > 0.10$) by grazing management or weaning date.

Pastures contained very low proportions of red (Table 4) and ladino (Table 5) clovers. The summers of 2000 and 2001 were extremely dry, possibly contributing to the low percentage of clover in the pastures. Furthermore, the study site is a harsh environment that is more drought-prone than many other soil types in Arkansas. In all cases, weaning date or rotation frequency had little impact ($P > 0.10$) on forage species composition.

Year and sampling season effects were detected ($P < 0.05$) for the proportion of lespedeza (Table 6). July, 2002 had the greatest proportion of lespedeza, averaging approximately 11% of the forage species. However, it is questionable whether this proportion of the pasture as lespedeza would contribute substantially to improved animal gains.

Crabgrass showed the most promise in a mixture with tall fescue at the research site (Table 7). The proportion of crabgrass increased in 2001 and 2002, averaging 25 and 24% of the total species present in July and October, 2002, respectively. At this proportion, crabgrass should significantly dilute out some of the toxic effects of tall fescue. The major observed disadvantage of the crabgrass is that its production occurs primarily after mid-July. At this time, moisture restrictions can severely hamper its production.

Most of the experimental pastures contained plant species other than those mentioned above (Table 8). These included orchardgrass, annual cool-season grasses such as cheat and little barley, bermudagrass, and broadleaf weeds. These other species were predominated by broadleaf weeds and were combined into the 'other' category for simplicity. Both year effects and season effects were detected ($P < 0.05$) for other species, but the proportion of other species was not affected ($P > 0.10$) by rotational management or weaning date.

## Implications

After three years of grazing tall fescue pastures overseeded with legumes and crabgrass, differences observed in species composition were due to season and year. Therefore, it is likely that intensive grazing management will require greater than three years to demonstrate improvements in beneficial plant species on sites with steep slopes and poor soil.

## Literature Cited

Owensby, C.E. 1973. J. Range Manage. 26:302-303.

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

| Forage management | No. pastures | Weaning date | Grazing duration | Rest duration |
|---|---|---|---|---|
| 2-cell | 3 | mid-April | 14 days | 14 days |
| 2-cell | 3 | early-June | 14 days | 14 days |
| 8-cell | 2[a] | mid-April | 3 to 4 days | 24 to 25 days |
| 8-cell | 3 | early-June | 3 to 4 days | 24 to 25 days |

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

**Table 2. Percentage of basal cover of tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 73.1 | 71.0 | 72.8 | 65.7 | 4.43 |
| July | 33.4 | 28.2 | 30.3 | 26.8 | 3.59 |
| October | 24.8 | 27.2 | 22.0 | 18.2 | 3.03 |
| Year mean | 43.7 | 42.1 | 43.0 | 36.9 | 4.26 |
| 2001 | | | | | |
| April | 35.1 | 39.9 | 38.2 | 35.9 | 1.97 |
| July | 28.7 | 28.4 | 26.2 | 23.8 | 1.62 |
| October | 43.3 | 32.2 | 23.9 | 29.9 | 2.27 |
| Year mean | 35.7 | 33.5 | 30.7 | 29.9 | 4.26 |
| 2002 | | | | | |
| April | 32.8 | 40.8 | 36.2 | 36.0 | 2.99 |
| July | 43.9 | 37.5 | 35.4 | 33.5 | 2.82 |
| October | 30.8 | 36.0 | 32.4 | 30.6 | 2.37 |
| Year mean | 35.9 | 38.1 | 34.7 | 33.3 | 3.97 |

[a] Effect of sampling seasons, main effect of rotation frequency, and year effects were significant ($P < 0.05$).

**Table 3. Percentage of tall fescue in pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 69.6 | 81.4 | 71.7 | 81.2 | 6.58 |
| July | 58.2 | 63.1 | 57.6 | 59.9 | 7.28 |
| October | 76.8 | 91.1 | 80.8 | 83.3 | 3.84 |
| Year mean | 68.2 | 78.5 | 70.3 | 74.8 | 4.37 |
| 2001 | | | | | |
| April | 59.8 | 66.5 | 64.1 | 56.2 | 6.08 |
| July | 59.3 | 72.1 | 63.0 | 67.1 | 8.63 |
| October | 37.6 | 45.9 | 41.8 | 47.1 | 8.86 |
| Year mean | 52.3 | 61.5 | 56.6 | 56.8 | 4.37 |
| 2002 | | | | | |
| April | 63.3 | 72.6 | 58.8 | 63.0 | 5.97 |
| July | 41.6 | 53.0 | 44.1 | 47.6 | 8.78 |
| October | 40.0 | 54.3 | 41.4 | 51.4 | 9.44 |
| Year mean | 48.3 | 60.0 | 48.1 | 54.0 | 4.07 |

[a] Year effects and sampling season effects were significant ($P < 0.05$)

**Table 4. Percentage of red clover in tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 1.3 | 3.0 | 0.3 | 2.4 | 1.64 |
| July | 6.3 | 3.6 | 4.5 | 3.7 | 1.80 |
| October | 0.0 | 0.0 | 0.0 | 0.3 | 0.15 |
| Year mean | 2.5 | 2.2 | 1.7 | 2.1 | 0.57 |
| 2001 | | | | | |
| April | 0.0 | 0.3 | 0.0 | 0.0 | 0.15 |
| July | 0.0 | 0.0 | 0.0 | 0.6 | 0.30 |
| October | 0.0 | 0.0 | 0.0 | 0.1 | 0.07 |
| Year mean | 0.0 | 0.1 | 0.1 | 0.2 | 0.57 |
| 2002 | | | | | |
| April | 0.0 | 0.1 | 0.2 | 0.6 | 0.21 |
| July | 0.1 | 0.4 | 0.0 | 0.8 | 0.28 |
| October | 0.0 | 0.3 | 0.0 | 0.1 | 0.10 |
| Year mean | 0.0 | 0.3 | 0.1 | 0.5 | 0.53 |

[a] Year effects and sampling season effects were significant ($P < 0.05$).

**Table 5. Percentage of ladino clover in tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 0.0 | 0.4 | 3.3 | 0.0 | 1.05 |
| July | 5.0 | 7.6 | 5.7 | 6.5 | 1.99 |
| October | 0.0 | 0.0 | 0.0 | 0.3 | 0.15 |
| Year mean | 1.7 | 2.7 | 3.0 | 2.3 | 0.72 |
| 2001 | | | | | |
| April | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| July | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| October | 0.0 | 0.0 | 0.0 | 0.3 | 0.14 |
| Year mean | 0.0 | 0.0 | 0.0 | 0.1 | 0.72 |
| 2002 | | | | | |
| April | 0.3 | 1.5 | 0.6 | 1.3 | 0.61 |
| July | 0.0 | 0.0 | 0.0 | 0.6 | 0.30 |
| October | 0.1 | 0.0 | 0.0 | 0.4 | 0.14 |
| Year mean | 0.2 | 0.5 | 0.2 | 0.8 | 0.67 |

[a] Year effects and sampling season effects were significant ($P < 0.05$).

**Table 6. Percentage of lespedeza in tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| July | 5.8 | 5.7 | 4.2 | 5.0 | 1.76 |
| October | 0.4 | 0.1 | 1.0 | 0.2 | 0.31 |
| Year mean | 2.1 | 2.0 | 1.8 | 1.8 | 1.17 |
| 2001 | | | | | |
| April | 0.0 | 0.1 | 0.0 | 0.8 | 0.26 |
| July | 5.8 | 2.4 | 1.3 | 5.4 | 3.47 |
| October | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| Year mean | 1.9 | 0.9 | 0.5 | 2.1 | 1.17 |
| 2002 | | | | | |
| April | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| July | 12.4 | 10.3 | 7.4 | 15.4 | 3.46 |
| October | 2.2 | 2.1 | 0.1 | 7.8 | 2.44 |
| Year mean | 4.9 | 4.1 | 2.5 | 7.7 | 1.09 |

[a] Year effects and sampling season effects were significant ($P < 0.05$).

**Table 7. Percentage of crabgrass in tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 1.6 | 0.8 | 0.3 | 0.2 | 0.64 |
| July | 7.9 | 8.2 | 11.3 | 6.2 | 2.81 |
| October | 2.5 | 0.3 | 3.5 | 1.0 | 0.76 |
| Year mean | 4.0 | 3.1 | 1.1 | 2.5 | 3.61 |
| 2001 | | | | | |
| April | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| July | 10.6 | 6.5 | 10.5 | 2.6 | 3.04 |
| October | 34.0 | 33.9 | 34.0 | 15.9 | 7.21 |
| Year mean | 14.9 | 13.5 | 10.9 | 6.2 | 3.61 |
| 2002 | | | | | |
| April | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| July | 27.4 | 25.0 | 29.7 | 18.0 | 7.76 |
| October | 33.2 | 26.0 | 25.7 | 11.3 | 10.08 |
| Year mean | 20.2 | 17.0 | 18.4 | 9.7 | 3.36 |

[a] Year effects and sampling season effects were significant ($P < 0.05$).

**Table 8. Percentage other forage and weed species in tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid- April or early June.[a]**

| | 2 rotations/month | | 2 rotations/week | | |
|---|---|---|---|---|---|
| Item | April | June | April | June | SE |
| 2000 | | | | | |
| February | 27.6 | 14.3 | 24.3 | 16.2 | 5.82 |
| July | 16.8 | 11.9 | 16.8 | 18.6 | 3.54 |
| October | 20.2 | 8.5 | 14.7 | 14.9 | 3.12 |
| Year mean | 21.5 | 11.6 | 22.1 | 16.6 | 2.71 |
| 2001 | | | | | |
| April | 40.2 | 33.1 | 35.9 | 43.0 | 6.20 |
| July | 24.4 | 19.0 | 25.2 | 24.3 | 7.07 |
| October | 28.3 | 20.1 | 24.3 | 36.4 | 5.78 |
| Year mean | 30.9 | 24.1 | 32.0 | 34.6 | 2.71 |
| 2002 | | | | | |
| April | 36.3 | 25.8 | 40.4 | 35.2 | 5.96 |
| July | 18.4 | 11.3 | 18.8 | 17.6 | 5.09 |
| October | 24.4 | 17.4 | 32.8 | 29.0 | 5.47 |
| Year mean | 26.4 | 18.2 | 30.7 | 27.3 | 2.52 |

[a] Year effects and sampling season effects were significant ($P < 0.05$).

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

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


## Story in Brief

A total of 80 Gelbvieh x Angus crossbred heifers (556 ± 3.9 lb initial BW) grazed one of eight 5-acre pastures of common bermudagrass overseeded with wheat and ryegrass during the winters of 2002 and 2003 to compare the effect of seeding dates and tillage intensities on heifer growth performance. One half of the pastures were seeded during the first week of September (EARLY) and half were seeded in mid-October (LATE). Within each seeding date, half of the pastures were disked once (1x) and the other half were disked twice (2x) before seeding. Grazing began December 20, 2001 on each pasture for year 1, and began November 20, 2002 on all EARLY pastures and December 5, 2002 for all LATE pastures in year 2. Grazing continued through May 11, 2002 in year 1 and through April 25, 2003 in year 2. Initial forage mass was greater ($P < 0.05$) and average forage mass tended ($P < 0.10$) to be greater from EARLY than from LATE seeded pasture. Body weights and gain did not differ ($P > 0.10$) between seeding dates or tillage intensity. Based on 2 years of grazing animal performance data, producers may have considerable flexibility in their decisions as to when to seed annual forages and to what level they till their sod.


## Introduction

Sod-seeded winter annual forages provide a high-quality feed source for wintering weaned calves. In a previous 3-year study at the University of Arkansas Southeast Research and Extension Center, weaned calves gained approximately 2 lb/day between mid-December and mid-April while grazing sod-seeded winter annuals (Coffey et al., 2002). The major disadvantages of the sod-seeded winter annual program were the year-to-year variability and the inability to begin grazing prior to mid-December. This means producers must find other forage alternatives to winter annuals between the time of weaning and initiation of grazing in mid- to late December. Our objective in this study was to evaluate earlier seeding dates of winter annuals and more intensive tillage of the bermudagrass sod to determine if those practices would promote more fall forage growth, allowing for earlier grazing or greater animal gains.

## Experimental Procedures

A total of 80 Gelbvieh x Angus crossbred heifers (556 ± 3.9 lb initial BW) grazed one of eight 5-acre pastures of common bermudagrass during the winters of 2002 and 2003 that were previously overseeded with winter annual forages. All pastures were seeded with 30 lb/acre of 'Marshall' annual ryegrass plus 120 lb/acre of 'Madison' soft wheat. One half of the pastures were broadcast seeded during the first week of September (EARLY) and half were broadcast seeded in mid-October (LATE). Within each seeding date, half of the pastures were disked once (1x) and the other half were disked twice (2x) prior to seeding. The eight pastures were divided into two blocks of four pastures and the pastures were allocated randomly within block to one of the four treatment combinations. Pastures were fertilized with a complete fertilizer mixture to provide 50 lb/acre each of N, $P_2O_5$, and $K_2O$ (as potassium chloride) during the fall and with an additional 50 lb/acre of N in the spring.

Within each year, heifers were stratified by weight and allocated in a random stratified manner to each pasture. Grazing began December 20, 2001 on all pastures and continued until May 11, 2002 in year 1. During year 2, grazing began November 20, 2002 on EARLY pastures and on December 5, 2002 on LATE pastures and continued until April 25, 2003. At that time, heifers were co-mingled to facilitate breeding. Weights were measured monthly without prior removal from pasture and water. Heifers were offered 2 lb/day of a grain sorghum-based supplement that contained trace mineralized salt and 150 mg Rumensin®.

Available forage mass was determined monthly during the study using a calibrated disk meter. Data were analyzed as a 2 x 2 factorial arrangement of a repeated measures experiment using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC).

## Results and Discussion

No seeding date by tillage intensity interactions or year by treatment interactions were detected ($P > 0.05$) for any of the measurements in this study. Therefore, data were combined across years. Available forage mass at the time grazing was initiated was almost 1,000 lb/acre higher ($P < 0.05$) from EARLY than from LATE (Table 1). Average forage mass tended ($P < 0.10$) to be greater from EARLY than from LATE. However, based on visual appraisal, a considerable portion of this forage mass was residual bermudagrass that grew after cattle removal and seeding of the EARLY forages. This will likely be validated when pending forage quality analyses are completed. Available forage mass did not differ ($P > 0.10$) between seeding dates or tillage intensity at the end of the grazing period.

No significant differences were detected ($P > 0.10$) among tillage intensity and seeding date combinations for heifer gains or daily gains (Table 2). Overall, heifer gains were good and averaged 2.14 lb/d across treatment combinations. Numerically, trends were for total heifer gains to be greatest from EARLY seeded pastures disked moderately and lowest from heifers grazing EARLY seeded pastures disked lightly. Numerical trends were for daily gains to be greatest numerically from heifers grazing LATE seeded pasture disked moderately.

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The EARLY seeding date allowed the winter annual forages time to produce greater quantities of forage earlier in the fall in year 2. This allowed heifers to begin grazing 15 d earlier on EARLY pastures in year 2. This earlier grazing initiation did not, however, increase total gain, but did increase the average number of grazing d/acre. Failure for improvements in total gain is likely because of the large amount of dormant bermudagrass contamination in the EARLY pastures.

## Implications

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

## Literature Cited

Coffey, K.P., et al. 2002. J. Anim. Sci. 80:926.

**Table 1. Winter annual forage mass (lb/acre) of sod-seeded winter annuals planted in early September (EARLY) or mid-October (LATE) after light (one) or moderate (two) diskings – 2-yr average.**

| | Light disking | | Moderate disking | | |
|---|---|---|---|---|---|
| | EARLY | LATE | EARLY | LATE | SE |
| Initial mass, lb/acre[ab] | 2,455 | 1,301 | 2,300 | 1,490 | 179.7 |
| Final mass, lb/acre | 1,662 | 1,926 | 2,152 | 1,658 | 471.2 |
| Average mass, lb/acre[c] | 1,653 | 1,252 | 1,740 | 1,272 | 162.5 |

[a] Grazing began on December 18, 2001 in year 1, on November 20, 2002 for early seeded pastures and December 5, 2002 for late seeded pastures in year 2.

[b] Differences were detected between seeding dates ($P < 0.05$).

[c] Differences were detected between seeding dates ($P < 0.10$).

**Table 2. Growth performance by heifers grazing sod-seeded winter annuals planted in early September (EARLY) or mid-October (LATE) after light (one) or moderate (two) diskings – 2-yr average[a].**

| | Light disking | | Moderate disking | | |
|---|---|---|---|---|---|
| | EARLY | LATE | EARLY | LATE | SE |
| Initial weight, lb[b] | 557 | 560 | 559 | 549 | 3.1 |
| Final weight, lb | 802 | 822 | 838 | 820 | 25.7 |
| Gain, lb | 244 | 262 | 279 | 271 | 23.1 |
| Daily gain, lb | 1.93 | 2.17 | 2.20 | 2.25 | 0.19 |
| Grazing days/acre | 136 | 128 | 136 | 128 | - |

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

[b] Grazing began on December 18, 2001 in year 1, on November 20, 2002 for early seeded pastures and December 5, 2002 for late seeded pastures in year 2.

# Growth Performance of Stocker Steers Grazing Bermudagrass

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## Story in Brief

Forty-five steers (BW = 541 ± 12 lb) were randomly allocated to one of three paddocks of bermudagrass to determine the effects of supplementation and the timing of steroid implantation on average daily gain and lactate dehydrogenase (LDH) activity. Steers received either no supplementation or 3 lb/steer daily of a corn-soybean meal supplement (12% CP). Steers were assigned to either no implant, one steroid implant (Synovex-S®) at d 0 and one steroid implant at d 56 (EI), or one steroid implant at d 56 (LI) only. Ultrasonography of steers was performed to determine rump fat (RF) and backfat (BF). Supplementation of steers increased ($P < 0.05$) ADG during 108 d of grazing (2.0 ± 0.01 vs 1.3 ± 0.01 lb/d for supplemented and non-supplemented steers, respectively). Steroid implants tended ($P = 0.13$) to increase ADG. Weight gain and ADG were similar ($P > 0.10$) between implant strategies. Both BF and RF were greatest ($P < 0.05$) in supplemented steers, and BF was increased ($P < 0.05$) in LI steers compared with EI steers. Lactate dehydrogenase activity with lactate as the substrate (LDHR) decreased ($P < 0.05$) in non-supplemented EI steers compared with LI steers with or without supplementation, but was similar ($P > 0.10$) to control steers with or without supplementation. Likewise, non-supplemented EI steers had decreased ($P < 0.05$) LDHF (lactate dehydrogenase with pyruvate as the substrate) compared with control and LI steers with or without supplementation. Altered LDH activity may be one mechanism by which supplementation and steroid implantation improve steer performance.


## Introduction

Almost 60 yr have past since the first bermudagrass (*Cynodon dactylon*) hybrid was released in Georgia by Glenn Burton. Bermudagrass remains a popular warm-season grass utilized in the southern U.S. for grazing systems and hay production. Supplemented steers grazing bermudagrass typically gain 1.25 lb/d but can gain as much as 2 lb/d (Aiken, 2002). Furthermore, providing supplemental energy to grazing animals can increase production performance but may alter forage intake and digestibility.

It is well recognized that steroid implants improve growth rate in cattle. Steroid implants may increase ADG by 9% to almost 18% in grazing cattle (Paisley et al., 1999). Lactate dehydrogenase (LDH) is an oxidoreductase that catalyzes the conversion of lactate to pyruvate and pyruvate to lactate in the glycolysis pathway (breakdown of glucose). Recent research suggests LDH may be used as a predictor of subsequent body composition in grain-fed cattle (Paria et al., 1997), as well as pelvic area and reproductive performance in growing heifers (Looper et al., 2002). The objective of this study was to determine the effects of supplementation and the timing of steroid implantation on average daily gain and lactate dehydrogenase activity in steers grazing bermudagrass.

## 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. Cross-bred (0 to 50% *Bos indicus*) steers (n = 45; BW = 541 ± 12 lb) grazed bermudagrass pastures for 108 d (June 14 to September 30, 2002). Prior to the grazing experiment, steers were randomly assigned to receive either no supplement (n = two paddocks; 30 steers) or 3 lb/steer daily (n = one paddock; 15 steers) of a corn-soybean meal diet (CP = 12%). Within each supplementation treatment, steers were assigned to receive no implant (C), one steroid implant (Synovex-S®, Fort Dodge Animal Health, Fort Dodge, IA) at d 0 and d 56 (EI) of the grazing period, or one steroid implant at d 56 only (LI). Blood serum samples were collected on d 0, 62 and 108 to determine LDH activity. Samples were allowed to clot and then centrifuged at 2,800 x g for 25 min. Serum was decanted and stored at -4°F until assayed. Total protein concentration was determined on serum samples using the Biuret method. Serum LDH activity was evaluated using a quantitative, colormetric assay (Sigma Diagnostics, St. Louis, MO) and was reported as I.U. of LDH activity/mg serum protein. Backfat and RF thickness were determined at the termination of the grazing period using an Aloka SSD-500V ultrasound unit (Aloka, Wallington, CT) equipped with a 3.5 MHz linear array transducer.

Forage availability was evaluated using a disk meter. Forage heights were determined on July 5th, August 15th, and October 15th of the 108-d grazing trial. The paddocks were grazed continuously with a stocking rate of 0.8 animals/acre, or 322 lb live weight/acre. Stocking rates were low to assess the influence of supplementation and implant on performance of steers without confounding these effects with forage availability. Steers were weighed at the initiation and termination of the grazing experiment following a 14 to 16 h shrink to determine weight gain.

Analyses of variance were performed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) to determine the effects of supplementation and timing of steroid implantation on serum protein and lactate dehydrogenase activity. Effects of supplementation, timing of steroid implantation, and their interaction on average daily gain, backfat (BF), and rump fat (RF) were determined by the MIXED procedure of SAS.

## Results and Discussion

Forage availability was not limiting during the experiment for the three bermudagrass paddocks. A supplementation x implantation interaction was not observed for performance characteristics ($P > 0.10$). Supplementation of 3 lb/steer daily of a corn:soybean meal ration increased ($P < 0.05$) overall weight gain, ADG, BF, and RF during 108 d grazing of bermudagrass (Table 1). Similarly, Aiken (2002) observed increased ADG in steers supplemented with 3 lb/d

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of corn, but not an additional increase of weight gain with feeding 5 lb/d of corn to steers.

Steroid implanted steers (EI and LI) had increased ($P < 0.05$) overall weight gain and tended ($P = 0.13$) to have increased ADG compared with non-implanted steers (Table 2). Similar to Paisley et al. (1999), implanted steers in the current study had a 14% increase in ADG compared with non-implanted steers. Performance in response to implantation of grazing cattle is likely due to pasture quality and forage availability.

Rump fat in implanted steers was not different ($P = 0.18$) than control steers (Table 2). In contrast, BF was less ($P < 0.05$) in EI steers (2 steroid implants) compared with LI (1 steroid implant). Johnson et al. (1996) reported carcasses from implanted steers had increased protein accumulation and a smaller percentage of kidney, pelvic, and heart fat than non-implanted steers.

Concentrations of serum protein were increased ($P < 0.05$) in supplemented steers (117.5 mg/mL) compared with non-supplemented steers (99.5 mg/mL; Table 1). Concentrations of plasma protein are a reliable indicator of long-term body protein status (Rowlands, 1980). Although the significance of increased serum protein in supplemented steers is unknown, increasing nutrients to the animal probably increases the mobility of nutrients for increased cellular growth and may increase concentrations of circulating lactate.

Lactate dehydrogenase activity was influenced by a supplementation x implantation interaction ($P < 0.05$). Average LDHR (lactate as the substrate) activity ranged from 429 to 563 IU/mg, while average LDHF (pyruvate as the substrate) activity ranged from 942 to 1126 IU/mg. Activity of LDHR was increased ($P < 0.05$) in EI steers that were supplemented compared with control steers with or without supplementation (Table 3). Non-supplemented EI steers had decreased activity of LDHF (pyruvate as the substrate) compared to all other animal groups (Table 3). Ruminants with greater weight gain had increased LDH activity in muscle tissues (Jurie et al., 1995). Lactate dehydrogenase activity may have a significant role in fat synthesis since growing cattle can utilize lactate as an energy source. We speculate that steroids may induce LDH gene transcription. Further research to completely understand the role of steroids on LDH gene transcription is needed.

The LDHF:LDHR ratio provides some indication of the balance of the conversion of lactate to pyruvate and pyruvate to lactate. Control steers had a higher ($P < 0.05$) ratio of LDHF:LDHR than implanted steers (Table 2). Our study suggests supplementation and steroid implants affect LDH activity. Further research to determine influence of supplementation and steroid implantation on specific LDH isoenzymes also is necessary.

## Implications

Supplementing steers grazing bermudagrass with 3 lb/d of a corn-based ration and implanting with steroids increased weight gains. Likewise, lactate dehydrogenase activity was influenced by supplementation and steroid implantation of steers. Further elucidation of the importance of altered lactate dehydrogenase activity is necessary to understand the physiological mechanisms that may increase performance efficiency in steers.

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**Table 1. Body weight gain, ADG, backfat (BF), rump fat (RF), and concentrations of serum protein of steers grazing bermudagrass and supplemented with or without 3 lb/steer daily of a corn-based ration (12% CP).**

| Item | BW gain (lb) | ADG (lb) | BF (in) | RF (in) | Serum Protein (mg/mL) |
|---|---|---|---|---|---|
| Supplemented | 218[a] | 2.0[a] | 0.30[a] | 0.21[a] | 117.5[a] |
| Non-supplemented | 133[b] | 1.3[b] | 0.23[b] | 0.17[b] | 99.5[b] |
| Pooled SE | 11.3 | 0.1 | 0.01 | 0.01 | 3.2 |

[a,b] Means in a column with no superscript in common differ ($P < 0.05$).

**Table 2. Body weight gain, ADG, backfat (BF), rump fat (RF), and ratio of LDHF (pyruvate as the substrate) to LDHR (lactate as the substrate) of steers grazing bermudagrass and implanted twice (EI; day 0 and day 56), implanted once (LI; day 56), or non-implanted control (C).**

| Implant protocol | BW gain (lb) | ADG (lb) | BF (in) | RF (in) | LDHF:LDHR |
|---|---|---|---|---|---|
| C | 160[a] | 1.5[c] | 0.26[a,b] | 0.18[a] | 2.4[a] |
| EI | 189[b] | 1.8[d] | 0.24[b] | 0.17[a] | 2.2[b] |
| LI | 179[b] | 1.7[d] | 0.30[a] | 0.21[a] | 2.1[b] |
| Pooled SE | 11.7 | 0.1 | 0.02 | 0.02 | 0.07 |

[a,b] Means in a column with no superscript in common differ ($P < 0.05$).

[c,d] Means in a column with no superscript in common differ ($P = 0.13$).

**Table 3. Influence of supplementation and steroid implantation [implanted twice (EI; day 0 and day 56), implanted once (LI; day 56), or non-implanted control (C)] on LDHR (lactate as the substrate) and LDHF (pyruvate as the substrate) activity in serum of steers grazing bermudagrass.**

| Item | LDHR (IU/mg) | SE | LDHF (IU/mg) | SE[1] |
|---|---|---|---|---|
| C/No supplement | 469[a] | 21 | 1063[a] | 26 |
| C/Supplement | 460[a] | 30 | 1083[a] | 37 |
| EI/No supplement | 429[a] | 21 | 942[b] | 26 |
| EI/Supplement | 563[b] | 31 | 1126[a] | 38 |
| LI/No supplement | 540[b] | 21 | 1080[a] | 26 |
| LI/Supplement | 547[b] | 30 | 1098[a] | 37 |

[a,b] Means in a column with no superscript in common differ ($P < 0.05$). Supplementation x implantation interaction ($P < 0.05$).

[1] Pooled standard error.

# Milk Production in Four Divergent Biological Types Grazing Common Bermudagrass or Endophyte-Infected Tall Fescue

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## Story in Brief

Milk yield and quality were measured on four divergent biological types resulting from Angus, Brahman, and reciprocal cross cows grazing either common bermudagrass or endophyte-infected tall fescue. Data were collected over a 4-yr period to evaluate the effect of biological type and forage on milk production traits. The growth curve parameters of mature weight (A) and rate of maturing (k) were estimated for 121 cows using the growth curve model as described by Brody (1945). Cows were assigned to one of four biological types: genetic potential for large mature size-late maturing (LL, A > 1254 lb, k < 0.047 %, n = 35), large mature size-early maturing (LE, A > 1254 lb, k ≥ 0.047 %, n = 19), small mature size-late maturing (SL, A ≤ 1254 lb, k < 0.047 %, n = 25), and small mature size-early maturing (SE, A ≤ 1254 lb, k ≥ 0.047 %, n = 42). Milk yield was estimated by milking machine, and milk fat, protein, and somatic cell counts were evaluated in a commercial laboratory. Included in the final models for milk yield and quality traits were the independent variables of forage, biological type, biological type x forage and residual error. Biological type was significant ($P < 0.10$) for average milk yield, average milk protein and average somatic cell count. Forage was a significant source of variation for average milk yield and butterfat percentage ($P < 0.05$). The cows grazing bermudagrass had higher ($P < 0.01$) milk yields and butterfat percentage than their counterparts grazing endophyte-infected fescue. These results suggest that biological type and forage have varying effects on milk production traits.


## Introduction

In the cow-calf business, maternal traits such as milk production and weaning weight have substantial economic implications. Increased weaning weights in turn increase economic returns. Weaning weights are a result of the genetic potential of the calves for growth as well as the maternal environment provided to them in the pre-weaning phase. A vital component in this pre-weaning environment is milk production. Milk production has been shown to account for 40% of the variation in 205-d weights (Robinson et al., 1978). How nutritional environment of the dam influences both quality and quantity of milk produced has been widely studied. Previous research has shown that cows grazing endophyte-infected fescue have decreased milk production compared to those grazing endophyte-free forages (Holloway and Butts, 1983).

The application of biological typing has seen limited use. Most biological type studies separate types by breed, relative to size, milking ability and various other traits. Separation of biological types by growth parameters is an option that has not been extensively explored. This may allow biological typing to help make the correct match of animal to production system. Therefore, the objective of this study was to evaluate milk production traits of four divergent biological types of cows grazing common bermudagrass or endophyte-infected tall fescue.

## Experimental Methods

One hundred twenty-one Angus (AA), Brahman (BB), Angus x Brahman (AB), and Brahman x Angus (BA) heifers born from 1988 to 1991 were evaluated in this study. The heifers were assigned to 40-acre endophyte-infected tall fescue pastures (100% infected) or 40-acre common bermudagrass pastures and were managed on these forages through their first four calf crops (1991 to 1994). Each pasture was stocked with approximately equal numbers of AA, BB, AB, and BA cows.

Heifers were bred as 2-yr-olds to calve at 3 yr of age to preclude introducing parity differences into the study due to the low percentage of purebred Brahman reaching sexual maturity at 15 mo of age. The breeding seasons were early May through mid-July of each year.

Milk yield was estimated using a single-cow portable milking machine. Milk production was estimated in all years at an average 61, 90, 117, 145, and 173 d postpartum. Dates of estimates were early May to late September. Cows and calves were separated at approximately 1700 h the evening before milking and held for 14 h overnight with hay and water provided. There was no milk-out prior to separation. Ten-minutes before milking, cows were sedated with 1.5 ml of acepromazine, and 1.0 ml of oxytocin also was administered immediately before milking to induce milk let-down. After milking was complete, milk was weighed and triplicate samples were taken for estimates of milk fat, milk protein, and somatic cell count. Milk fat, milk protein, and somatic cell counts were estimated by a commercial laboratory using a Milkoscan System 4000® (AOAC, 1990). Daily milk yield was estimated as twice the net weight of milk adjusted linearly to a 12-h basis ([milk weight/14] X 12). Somatic cell counts were transformed using natural logarithms prior to analysis.

The growth parameters of mature weight (A) and maturing rate (k) were estimated on cows using the three-parameter growth curve model as described by Brody (1945). Upon estimation of these parameters, cows were stratified into four biological types: large, late maturing (LL, A > 1,254 lb, k < 0.047%, n = 35); large, early maturing (LE, A > 1,254 lb, k ≥ 0.047%, n = 19); small, late maturing (SL, A ≤ 1,254 lb, k < 0.047%, n = 25); and small, early maturing (SE, A ≤ 1,254 lb , k ≥ 0.047%, n = 42). All breed types were represented in all biological types.

Data were analyzed by the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Data were averaged over month within year. The model included the dependent variables of overall average milk

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yield, butterfat, protein, and somatic cell count as well as individual records for 61, 90, 117, 145, and 173 d postpartum milk production.

## Results and Discussion

Presented in Table 1 are least-squares means and standard errors for average milk production (lb/24 h) by biological type. There were no differences ($P > 0.05$) in average milk yield between the two early maturing types or between the two late maturing types. There were also no differences ($P > 0.05$) between the large, late maturing and the small, early maturing types for average milk yield.

The cows grazing endophyte-infected fescue had lower ($P < 0.05$) average milk yield and butterfat percentage than their counterparts grazing bermudagrass (16.1 lb vs 24.0 lb and 3.39 vs 3.86 %, respectively). This decrease was somewhat expected due to the documentation of the negative effects on milk production caused by the endophyte-infected fescue forage.

The least-squares means and standard errors for average milk protein (%) by biological type are shown in Table 2. The two large mature size types had a higher ($P < 0.05$) mean milk protein percentage than did their small mature size counterparts (3.37 and 3.34 vs. 3.25 and 3.21 %, respectively). There were no significant differences ($P > 0.05$) for milk fat percentage for either biological type or forage.

Table 3 shows the least-squares means and standard errors for the interaction of biological types and forage for somatic cell count. This interaction likely resulted from a change in ranking between the two production systems. In the bermudagrass system the biological types ranked numerically: LE > LL > SL > SE and in the endophyte infected tall fescue grazing system they ranked: SL > LL > SE > LE.

For individual monthly records, forage was a significant ($P < 0.05$) source of variation for all individual milk yield records 145 and 173 d postpartum for milk fat percentage; 117, 145 and 173 d postpartum for milk protein percentage; and 117, 145 and 173 d for postpartum somatic cell counts. Biological type was a significant source of variation ($P < 0.05$) for individual records at 145 and 173 d postpartum for milk yield, 61 d postpartum for milk fat percentage, 145 d postpartum for milk protein percentage and somatic cell counts.

As the milking season lengthened, overall milk yield, milk fat percentage, milk protein percentage, and somatic cell counts tended to decrease from 61 d postpartum to 173 d postpartum with a few exceptions. The LE cows actually increased milk fat percentage (+ 0.78 %) and the LL cows had an increase (+ 0.04 %) in milk protein percentage over the milking period.

## Implications

These data suggest that biological type may have an effect on milk production and protein percentage, with early maturing types producing more milk than their later maturing counterparts and larger types having a higher percentage of protein. These results may aid in the use of biological type in determining the correct match of animal to production system. More research is needed to evaluate grazing systems involving both endophyte-infected fescue and common bermudagrass in an attempt to utilize both types of forage.

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**Table 1. Least-squares means and standard errors for average milk production (lb/24 h) by biological type[a].**

| Biological type | Milk production (lb/24 h) |
|---|---|
| LE | 22.3 ± 1.56[b] |
| LL | 19.73 ± 1.06[cd] |
| SE | 20.79 ± 0.95[bc] |
| SL | 17.40 ± 1.21[d] |

[a] LL= large mature size, late maturing; LE = large mature size, early maturing; SE = small mature size, early maturing; SL = small mature size, late maturing

[bcd] Means with differing superscripts differ (P = 0.06)

**Table 2. Least-squares means and standard errors for average milk protein (%) by biological type[a].**

| Biological type | Milk protein (%) |
|---|---|
| LE | 3.37 ± 0.054[b] |
| LL | 3.34 ± 0.036[b] |
| SE | 3.25 ± 0.033[c] |
| SL | 3.21 ± 0.42[c] |

[a] LL= large mature size, late maturing; LE = large mature size, early maturing; SE = small mature size, early maturing; SL = small mature size, late maturing

[bc] Means with differing superscripts differ (P = 0.06)

**Table 3. Least-squares means and standard errors for somatic cell count (loge count) for the interaction of biological typea and forage[b].**

| | Forage environment | |
|---|---|---|
| Biological type | BG | E+ |
| LE | 4.93 ± 0.42[cd] | 3.36 ± 0.25[efgh] |
| LL | 4.04 ± 0.20[bd] | 3.82 ± 0.26[defg] |
| SE | 3.84 ± 0.19[def] | 3.72 ± 0.22[defgh] |
| SL | 4.02± 0.29[bde] | 4.68 ± 0.25[cd] |

[a] LL= large mature size, late maturing; LE = large mature size, early maturing; SE = small mature size, early maturing; SL = small mature size, late maturing

[b] E+ = Endophyte-Infected Tall Fescue; BG = Common Bermudagrass

[cdefgh] Means with different superscripts differ (P < 0.01)

# 2002 Dairy Herd Improvement Herds in Arkansas

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## Story in Brief

During 2002, 79 of the 312 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. Seventy-two herds completed at least four DHI tests and averaged 9.3 tests per year with a rolling herd average of 16,581 lb milk, 621 lb and 3.6% fat, and 527 lb and 3.1% protein; mature equivalent averages were 18,490 lb milk, 3.6% fat, and 3.2% protein.

The Arkansas average for milk/cow was 12,281 lb/year on all cows in 2002, which indicates that non-DHIA herds averaged less than 12,000 lb/cow/year because 25% of the cows participated in the DHIA program, compared to the 16,581 lb/cow/year for herds on DHI. This difference of over 4,500 lb/cow/year affected income per cow by almost $550/cow or approximately $60,000/herd/year. The quartile data of milk production for the Holsteins with DHI records also reinforced that income over feed costs were $450/cow less than in 2001, due primarily to lower milk prices. Other records for health, reproduction, genetics, and inventory, as well as production, contributed to this difference in income/cow. Overall, 29.5% of the Holsteins left the herd, and 36.6% of those left because of injury, disease, or death, up from 31.4% last year and 24.1% in 2000. Opportunities exist for raising the level of milk production and profitability in the state by encouraging more producers to use DHI records.


## Introduction

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

Typically, herds on DHI produce 3,500 to 4,500 lb more milk per year nationally than herds not on DHI. Although many factors affect production per cow, this difference in production has a significant effect on net income for the dairies. Increased income over feed costs is associated with greater milk production per cow. The dairy herd summaries also allow a dairy producer to compare production, health, reproduction, and financial aspects of his dairy to other dairies, so that areas of management that need improvement can be detected.

## Experimental Procedures

Dairy cattle herds on test (n = 79) 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 percent of fat, protein and somatic cell count (SCC), plus recording of other management parameters as indicated in Table 1. Milk samples were analyzed at the Heart of America DHI Lab in Manhattan, KS. Records were processed at Dairy Records Management Services (DRMS), Raleigh, NC.

## Results and Discussion

In December 2002, 79 of the 312 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. Seventy-two herds completed at least four DHI tests and averaged 9.6 tests per year with a rolling herd average of 16,581 lb milk, 621 lb and 3.6% fat, and 527 lb and 3.1% protein; mature equivalent averages were 18,490 lb milk, 3.6% fat, and 3.2% protein.

Rolling herd averages for breeds of DHI herds with the 10 tests to be considered official herds are in Table 1. Income minus feed cost averaged $1,044/cow this year for the Holstein herds compared to $1,505/cow last year. The decrease in income minus feed cost primarily related to near-record high milk prices in 2001, which were much higher than in 2002. In 2000, Holstein herds averaged $1,184 in income minus feed costs. The Jersey herds averaged $1,253/cow/year for income minus feed costs; however, only three herds are included in the Jersey Summary. Few non-Holstein herds were on DHI in Arkansas, but the Jersey herds showed a similar trend in yield to reports from other states. In the United States, over 95% of the cows on test are Holsteins and almost 4% of cows on test are Jerseys. The average milk/cow for the 57 herds in Arkansas with at least six test periods during the year was 16,204 lb/year with 3.5% fat and 3.2% protein in 2002 compared to 16,075 lb milk, 3.6% fat, and 3.1% protein in 2001.

Table 2 shows the Holstein DHI averages for herds with 10 tests by quartile of milk production. The quartile data for the 35 Holstein herds illustrate the relationship of higher milk production to higher income minus feed costs. The high quartile of herds also had lower somatic cell scores than other herds and greater percentage of days in milk than herds in other quartiles. Table 3 shows that higher producing herds also used more proven sires, had fewer days dry, less days open, and lower calving intervals than lower producing herds, but lower producing herds had fewer services per pregnancy compared to higher producing herds.

Table 4 shows that 29.5% of Holstein cows left the herd last

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year. Only 7.5 % of the Holstein cows left the herd because of low production. This compares to 16.3 % of the cows leaving because they died and another 21.6 % of cows left because of reproduction. Injury, disease, or death accounted for 26.6 % of the Holstein cows leaving the herd compared to 31.4% in 2001 and 24.1% in 2000. However, the overall cull rate dropped to 29.5 % from 34.6% in 2001 and 32.5% in 2000. These data are similar to results from all states included in the Heart of America DHIA Summary for other years.

The 38 dairy cattle herds in Table 1 were less than the 79 dairy herds that were reported on DHI through other summaries. The primary reason for the difference in numbers was that herds reported in Table 1 had at least 10 test periods. For quartile data, the 35 Holstein herds were official herds with 10 tests during the year. There also were three goat herds on DHI, plus the list included any herd on DHI in 2002, including herds no longer on the DHI program. Additionally, one dairy cattle herd used the PC DART on-farm computer program for production testing and was not included in the 79 dairy cattle herds listed here that were processed through DRMS. Still, only 25% of the 312 herds in 2002 were involved in the DHI program. Herds on DHI averaged 16,581 lb milk/cow/year compared to the Arkansas average of 12,281 lb/milk/year, according to the Arkansas Agricultural Statistics Service. Omitting DHI herds from the state average indicated that the non-DHI herds averaged less than 12,000 lb milk/year. This difference of over 4,500 lb milk/cow/year affected income by almost $550/cow/year. This difference in milk income would be $60,000 per year in a 115-cow herd.

## Implications

DHI program participation affords dairy producers an opportunity to maintain records of milk production on individual cows and other management practices. Herds utilizing DHI records averaged 16,581 lb milk/cow/year versus less than 12,000 lb/cow for herds not on DHI test. We should continue to encourage producers to enroll in the DHI testing program.

**Table 1. 2002 Arkansas DHIA breed averages for selected traits.**

| | Breed[a] | |
|---|---|---|
| Trait | Holstein | Jersey |
| Number of herds | 35 | 3 |
| Rolling herd average, milk, lb | 17,301 | 14,546 |
| Peak milk, lb | 69.4 | 60.0 |
| Somatic cell count (SCC) average (x 1000) | 471 | 358 |
| Days to 1st service, total | 83 | 76 |
| Days open | 179 | 119 |
| Projected calving interval, mo | 15.1 | 13.1 |
| Income minus feed cost, $ | 1,044 | 1,253 |

[a] One mixed and no Ayshires, Brown Swiss, Milking Shorthorn, or Guernsey herds had 10 tests during 2002.

**Table 2. 2002 Arkansas DHI averages for official Holstein herds.**

| Production trait | Quartile 1[a] | Quartile 2 | Quartile 3 | Quartile 4 |
|---|---|---|---|---|
| Number of herds | 8 | 9 | 9 | 9 |
| Number of cows | 157 | 172 | 91 | 96 |
| Rolling herd average milk, lb | 21,501 | 17,920 | 16,139 | 13,495 |
| Rolling herd average fat, lb | 769 | 634 | 567 | 482 |
| Rolling herd average protein, lb | 662 | 554 | 495 | 418 |
| Average days in milk | 190 | 197 | 186 | 186 |
| Average test day milk (milking cows), lb | 67 | 58 | 53 | 44 |
| Average percent in milk | 87 | 85 | 84 | 83 |
| Average standardized 150-d milk, lb | 73 | 63 | 57 | 48 |
| 1st Lactation peak milk, lb | 75 | 60 | 57 | 50 |
| 2nd Lactation peak milk, lb | 92 | 77 | 70 | 62 |
| 3+ Lactation peak milk, lb | 98 | 80 | 76 | 65 |
| All lactation peak milk average, lb | 83 | 70 | 66 | 55 |
| Somatic cell count (SCC) x 1000 | 362 | 426 | 420 | 515 |
| 1st Lactation cows with SCC 0-3, % | 72 | 61 | 68 | 59 |
| 2nd Lactation cows with SCC 0-3, % | 62 | 57 | 61 | 62 |
| 3+ Lactation cows with SCC 0-3, % | 53 | 46 | 53 | 36 |
| All lactation cows with SCC 0-3, $ | 61 | 54 | 60 | 47 |
| Income minus feed cost, $ | 1,428 | 1,000 | 1,112 | 724 |

[a] Quartile 1 = top 1 – 25 percentile herds for milk production; Quartile 2 = top 26- 50 percentile herds; Quartile 3 = bottom 26- 50 percentile herds; and Quartile 4 = bottom 1- 25 percentile herds.

**Table 3. 2002 Arkansas DHI for official Holstein herds.**

| Breeding or reproduction trait | Quartile 1[a] | Quartile 2 | Quartile 3 | Quartile 4 |
|---|---|---|---|---|
| 1st Lactation AIPL[b] PTA$[c] – cows | 87 | 79 | 77 | 137 |
| 2nd Lactation AIPL PTA$ - cows | 67 | 84 | 107 | 71 |
| 3+ Lactation AIPL PTA$ - cows | 20 | 43 | 74 | -17 |
| All lactations AIPL PTA$ - cows | 52 | 61 | 63 | 0 |
| 1st Lactation AIPL[b] PTA$[c] – sires | 228 | 195 | 263 | 264 |
| 2nd Lactation AIPL PTA$ - sires | 207 | 206 | 219 | 189 |
| 3+ Lactation AIPL PTA$ - sires | 111 | 151 | 165 | 110 |
| All lactations AIPL PTA$ - sires | 177 | 179 | 210 | 137 |
| Days to 1st service, current | 90 | 96 | 49 | 80 |
| Days to 1st service, total | 89 | 103 | 63 | 77 |
| Services per pregnancy, pregnancy | 2.1 | 1.6 | 1.6 | 1.6 |
| Services per pregnancy, all | 3.5 | 2.4 | 2.1 | 2.2 |
| Average days dry | 68 | 72 | 74 | 79 |
| Days open | 153 | 196 | 194 | 185 |
| Projected calving interval, mo | 14.2 | 15.7 | 15.6 | 15.3 |
| % Successful first breedings | 36 | 49 | 24 | 38.8 |
| % Successful total breedings | 38 | 46 | 27 | 39.1 |
| Average percentage of heats reported | 36 | 29 | 43 | 29.1 |
| % Herds bred to proven sires | 73 | 34 | 37 | 19 |
| % Herds bred to AI young sires | 7 | 2 | 6 | 7 |
| % Herds bred to other sires | 21 | 52 | 22 | 51 |

[a] Quartile 1 = top 1 – 25 percentile herds for milk production; Quartile 2 = top 26- 50 percentile herds; Quartile 3 = bottom 26- 50 percentile herds; and Quartile 4 = bottom 1- 25 percentile herds.

[b] AIPL = From USDA's Animal Improvement Programs Laboratory

[c] PTA$ = Predicted Transmitting Ability Dollars

**Table 4. 2002 Arkansas DHIA reasons for cows entering and leaving herds from official Holstein herds[a].**

| Item | Quartile 1[b] | Quartile 2 | Quartile 3 | Quartile 4 | Average |
|---|---|---|---|---|---|
| Number left herd, all lactations | 47.9 | 53.7 | 29.3 | 29.1 | 40.0 |
| Total % left herd | 29.4 | 27.6 | 31.7 | 29.4 | 29.5 |
| % Left dairy | 5.3 | 14.2 | 9.2 | 30.0 | 14.9 |
| % Low production | 3.4 | 9.9 | 2.4 | 14.4 | 7.5 |
| % Reproduction | 57.5 | 17.5 | 28.0 | 13.4 | 21.6 |
| % Mastitis | 14.5 | 11.4 | 9.9 | 4.8 | 10.2 |
| % Udder | 1.1 | 0.0 | 0.3 | 4.1 | 1.4 |
| % Feet and legs | 12.6 | 6.7 | 2.0 | 2.7 | 6.0 |
| % Injury or other | 13.2 | 8.9 | 5.5 | 3.4 | 7.8 |
| % Disease | 5.9 | 1.5 | 0.0 | 2.4 | 2.5 |
| % Died | 15.8 | 16.4 | 11.3 | 21.6 | 16.3 |
| % Not reported | 1.7 | 14.9 | 31.7 | 2.1 | 12.6 |
| Number entered herd, all lactations | 57.3 | 72.9 | 37.6 | 24.3 | 48.0 |
| % Entered herd, all lactations | 36.5 | 42.4 | 38.3 | 26.4 | 35.0 |

[a] Some cows may have more than one reason for leaving herd.

[b] Quartile 1 = top 1 – 25 percentile herds for milk production; Quartile 2 = top 26- 50 percentile herds; Quartile 3 = bottom 26- 50 percentile herds; and Quartile 4 = bottom 1- 25 percentile herds.

# DairyMetrics for Arkansas Herds

*J.A. Pennington*[1]

## Story in Brief

DairyMetrics, a new benchmarking tool from Dairy Records Management Systems, can be used to compare 72 variables for dairy herds in the Dairy Herd Improvement (DHI) Program. The variables concern general herd traits, genetics, production, reproduction, and udder health for these herds, and they can be compared to other herds in the state or region. DairyMetrics was used to obtain the number of Arkansas herds in the comparison, average of herds, standard deviation, and highest and lowest herds of all breed. Additionally, averages for traits for Holstein herds in Arkansas are given as they are the predominant breed in the state.

DairyMetrics was also used to compare groups of Arkansas herds to illustrate the importance of genetic merit of cows, days open, calving interval, percentage of cows in milk, feed costs, and income-over-feed costs (IOF$ or income minus feed costs) on efficiency of producing high levels of milk. It showed that percentage of fat in milk had little effect on income-over-feed costs per cow. DairyMetrics also indicated that herds with conception rates above or below 44% at first service had similar income-over-feed costs.

## Introduction

DairyMetrics is a new benchmarking tool for herds on the Dairy Herd Improvement (DHI) program that can be used to compare 72 variables on DHI records to other herds in the state or region. Introduced in 2001 from Dairy Records Management Systems (DRMS) in Raleigh, North Carolina, DairyMetrics compares information concerning general herd traits, genetics, production, reproduction, udder health and genetics. These comparisons can be used to show individual dairy producers their herd average and percentile compared to other herds, which can indicate how they might improve the herd. The database for DairyMetrics includes herd summary information from almost 14,000 herds that are routinely processed by DRMS.

DairyMetrics can also 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 can be used for individual herd comparisons and also for group comparisons in extension meetings to illustrate the importance of recommended practices on the efficiency of producing milk, especially daily income-over-feed costs. Of the variables included in DHI records, income-over-feed cost (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 genetics, production, reproduction, and udder health parameters (Table 1) for herds of all breeds in Arkansas in April, 2003. Additional similar data were collected for herds of Holsteins but only the average of each parameter is presented for the Holstein herds.

DairyMetrics was also used to compare groups of Arkansas Holstein herds for selected variables (Table 2) to illustrate the importance of these variables on efficiency of milk production, using daily income-over-feed costs as the indicator of efficiency.

## Results and Discussion

The average, standard deviation, low herd, and high herd for 72 variables from DairyMetrics for all herds in Arkansas are shown in Table 1. Individual variables can be selected for comparison; however, each category must have at least six herds to assure anonymity of individual herds. If an individual herd comparison is conducted, the herd means for each trait and percentile is displayed. The percentile of each variable is relative to the variables that are selected for comparison (e.g., the cohort herds or selected group of herds).

As illustrated in Table 1, Holstein herds were the predominant herd on tests in Arkansas with 42 of the 57 herds on DairyMetrics; thus the averages for the Holstein herds are similar to the overall average of the traits. Compared to last year, one of the most significant changes in the averages showed that milk blend prices had decreased from $14.91/cwt to $11.68. This decrease in milk prices was the primary cause of daily income minus feed costs decreasing from $5.18/cow/day to $3.61. Feed cost/cow/day increased slightly from $2.97 to $3.15.

Table 2 shows the results of comparisons of groups of Arkansas Holstein herds using DairyMetrics. These summaries indicate the positive effect on daily income-over-feed costs of greater net genetic merit, fewer days' open, greater percent cows in milk, lower feed costs per day, greater rolling herd average for milk, and shorter calving intervals. Additionally, rolling herd average, calving interval, percentage of cows leaving the herd, and somatic cell count are shown to illustrate the importance of these independent variables on efficiency of producing milk. In total, these data illustrate the importance of having cows of high genetic merit, getting them bred back at a reasonable time, and keeping them in milk.

Table 2 also illustrates that daily income-over-feed costs per cow were not greatly affected by percentage of fat in the milk. Milk fat percentage may not have much effect on income-over-feed cost because milk per cow is often greater in lower fat herds. Additionally, herds with a conception rate less than 44% at first service had similar income-over-feed costs to herds with greater than 44% conception rate of first service; this can likely be explained by greater milk production in herds with lower conception rates.

DairyMetrics also allows further divisions of the data if more than six herds are in each category. As expected, herds with greater than $4 daily income-over-feed costs ($4.96) have greater IOF$ than

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herds with less than $4 income-over-feed costs ($3.04) (Table 2). The magnitude of this difference ($1.82/cow/day) indicates that these herds with higher IOF$ should be much more profitable. Although the effects on IOF$ of sound genetic selection, reproductive management, and feeding practices individually were less than $1.00/cow/day, DairyMetrics does illustrate their benefits.

## Implications

DairyMetrics can be used effectively by individual producers to compare their herds to other herds throughout the region. Additionally, it can be used in an educational activity to illustrate the importance of specific management practices on profitability and efficiency of milk production, as indicated by daily income-over-feed costs. As expected, most variables for routinely recommended management practices correlated with increased daily income-over-feed costs. Within the general herd traits, genetics, production, reproduction, and udder health variables indicated that cows of high genetic merit, shorter calving intervals, and lower feed costs were very important in maintaining an efficient level of milk production, as indicated by greater income-over-feed costs.

**Table 1. DairyMetrics summary for all herds on DHIA in Arkansas.**

| | All herds | | | | | |
|---|---|---|---|---|---|---|
| Item | No. of herds in avg | Avg of herds | SD | Lowest herd avg | Highest herd avg | Avg of Holstein herds |
| **GENERAL** | | | | | | |
| Number of cows | 57 | 115 | 75 | 23 | 413 | 122 |
| Change in herd size, % | 57 | 4 | 17 | -28 | 83 | 2 |
| Number of 1st lactation cows | 57 | 36 | 30 | 3 | 168 | 39 |
| Number of 2nd lactation cows | 57 | 27 | 20 | 2 | 89 | 28 |
| Number of 3rd+ lactation cows | 57 | 51 | 31 | 11 | 156 | 54 |
| Cows in milk on test day, % | 57 | 88 | 6 | 75 | 100 | 89 |
| Days in milk | 57 | 186 | 28 | 129 | 271 | 188 |
| Age of 1st lact cows, mo | 57 | 28 | 2 | 21 | 35 | 28 |
| Percent cows left herd, % | 56 | 30 | 10 | 16 | 56 | 32 |
| Percent cows died, % | 57 | 6 | 4 | 1 | 22 | 6 |
| Daily value prod (milk cows), $ | 57 | 6.61 | 1.24 | 3.70 | 10.18 | 6.86 |
| Daily feed cost (milk cows), $ | 45 | 3.15 | 0.07 | 2.09 | 5.78 | 3.24 |
| Daily inc(-)feed (milk cows), $ | 49 | 3.61 | 1.16 | 1.44 | 6.08 | 3.71 |
| Daily feed cost/cwt milk, $ | 50 | 5.39 | 1.54 | 2.40 | 12.48 | 5.49 |
| Milk blend price, $ | 57 | 11.68 | 0.74 | 10.00 | 14.00 | 11.64 |
| **GENETICS** | | | | | | |
| Percentile rank of proven AI bulls | 57 | 38 | 30 | 20 | 88 | 37 |
| Percentile rank of young AI bulls | 57 | 25 | 34 | 0 | 99 | 26 |
| Cows bred to proven AI bulls, % | 57 | 43 | 37 | 0 | 100 | 42 |
| Cows bred to young bulls, % | 57 | 8 | 12 | 0 | 58 | 3 |
| Cows bred to non-AI bulls, % | 57 | 36 | 38 | 0 | 100 | 37 |
| Net merit$ for 1st lactation cows | 42 | 71 | 88 | -132 | 250 | 97 |
| Net merit$ for heifers | 49 | 74 | 83 | -116 | 243 | 84 |
| Net merit$ for all cows | 47 | 24 | 102 | -262 | 162 | 49 |
| Percentile heifers identified by sire, % | 49 | 41 | 33 | 0 | 100 | 40 |
| **PRODUCTION** | | | | | | |
| RHA[a] -Milk yield/ year, lb | 56 | 16,204 | 3,116 | 10,205 | 23,979 | 16,873 |
| Year change in milk yield,lb | 55 | 147 | 1,485 | -3,073 | 9,855 | 211 |
| RHA-Protein yield, lb | 57 | 505 | 96 | 319 | 717 | 521 |
| RHA-Fat yield, lb | 57 | 576 | 118 | 338 | 494 | 590 |
| Daily milk for milk cows, lb | 57 | 57.1 | 10.3 | 33.3 | 90.5 | 59.7 |
| Daily milk for all cows, lb | 56 | 51.2 | 10.3 | 35.7 | 90.5 | 53.6 |
| Daily fat, % | 57 | 3.5 | 0.4 | 2.9 | 4.7 | 3.5 |
| Daily protein, % | 57 | 3.2 | 0.2 | 2.8 | 3.7 | 3.1 |
| Summit milk 1st lactation, lb | 57 | 54 | 8 | 38 | 78 | 56 |
| Summit milk 2nd lactation, lb | 57 | 67 | 12 | 43 | 101 | 70 |
| Summit milk 3rd+ lactation, lb | 57 | 72 | 13 | 46 | 103 | 75 |
| Projected 305-d ME[b] milk yield, lb | 57 | 18,198 | 3,203 | 12,385 | 26,499 | 19,929 |
| Standard 150-d milk yield, lb | 57 | 59.2 | 11 | 39.8 | 95.1 | 61.9 |

**Table 1. DairyMetrics summary for all herds on DHIA in Arkansas. (continued)**

| | All herds | | | | | |
|---|---|---|---|---|---|---|
| Item | No. of herds in avg | Avg of herds | SD | Lowest herd avg | Highest herd avg | Avg of Holstein herds |
| **REPRODUCTION** | | | | | | |
| Projected minimum calving interval, mo | 57 | 15.1 | 1.6 | 12.6 | 19.6 | 15.1 |
| Current actual calving interval, mo | 57 | 14.5 | 1.4 | 12.1 | 20.4 | 14.3 |
| Days open-projected minimum for total herd | 57 | 178 | 47 | 104 | 312 | 177 |
| Days open-projected minimum for 1st lactation | 57 | 184 | 58 | 106 | 414 | 190 |
| Days open-projected minimum for 2nd lactation | 56 | 181 | 66 | 88 | 321 | 181 |
| Days open-projected minimum for 3rd+ lactation | 57 | 173 | 51 | 99 | 353 | 170 |
| VWP[c], d | 51 | 50 | 7 | 45 | 60 | 49 |
| Days to 1st service (%herd<VWP) | 51 | 12 | 13 | 0 | 67 | 10 |
| Days to 1st service (%herd VWP to 100 d) | 51 | 51 | 17 | 0 | 85 | 52 |
| Days to 1st service (%herd>100 d) | 51 | 36 | 17 | 5 | 100 | 36 |
| Days to 1st service-total herd | 51 | 99 | 21 | 58 | 151 | 101 |
| Conception rate for past 12 mo-1st service, % | 57 | 39 | 23 | 0 | 98 | 39 |
| Conception rate for past 12 mo-2nd service, % | 57 | 38 | 22 | 0 | 100 | 37 |
| Conception rate for past 12 mo-3rd+ service, % | 57 | 40 | 24 | 0 | 100 | 40 |
| Heats observed for year, % | 47 | 34 | 14 | 5 | 65 | 31 |
| Number of abortions in past year | 57 | 0 | 0 | 0 | 2 | 0 |
| Number of calvings in past year | 57 | 87 | 74 | 0 | 450 | 91 |
| Percentage dry less than 40 d | 51 | 12 | 9 | 1 | 42 | 13 |
| Percentage dry more than 70 d | 57 | 37 | 17 | 6 | 92 | 35 |
| **UDDER HEALTH** | | | | | | |
| SCC[d] x 1000 | 65 | 468 | 239 | 104 | 1264 | 490 |
| SCC score (range) | 66 | 3.4 | 0.6 | 2.0 | 4.8 | 3.5 |
| Cows with SCC of 0-3, % | 66 | 53 | 12 | 25 | 91 | 52 |
| Cows (<41 d with SCC >4), % | 67 | 27 | 17 | 0 | 100 | 28 |
| 1st lactation cows with SCC of 0-3, % | 65 | 61 | 20 | 0 | 100 | 59 |
| 2nd lactation cows with SCC of 0-3, % | 66 | 58 | 18 | 0 | 100 | 57 |
| 3rd lactation cows with SCC of 0-3, % | 66 | 45 | 15 | 0 | 79 | 44 |
| Cows culled for mastitis, % | 63 | 2 | 4 | 0 | 14 | 2 |
| SCC score for 1st lactation cows | 34 | 3.0 | 0.5 | 2.1 | 4.1 | 3.0 |
| SCC score for 2nd lactation cows | 39 | 3.2 | 0.7 | 1.7 | 4.5 | 3.2 |
| SCC score for 3rd lactation cows | 52 | 3.9 | 0.6 | 2.3 | 5.1 | 4.0 |
| SCC score for cows 41-100 DIM[e] | 50 | 2.9 | 0.7 | 1.1 | 4.6 | 2.8 |
| SCC score for cows 101-199 DIM | 52 | 3.4 | 0.8 | 1.7 | 5.3 | 3.4 |
| SCC score for cows 200-305 DIM | 41 | 3.9 | 0.9 | 2.3 | 6.2 | 4.1 |
| SCC score for cows 306+DIM | 50 | 4.1 | 0.7 | 2.5 | 5.4 | 4.1 |
| Value production loss from SCC, % | 68 | 3 | 2 | 0 | 15 | 3 |

[a] RHA = Rolling herd average

[b] ME = Mature equivalent

[c] VWP = Voluntary waiting period

[d] SCC = Somatic cell count

[e] DIM = Days in milk

**Table 2. Comparison of Arkansas Holstein herds using DairyMetrics.**

| Trait | Trait Avg | RHA-Milk[a] (lb) | Daily IOF$[a] | Calving interval (mo) | Cows left herd (%) | SCC (x1000)[c] |
|---|---|---|---|---|---|---|
| Herds of 1-49 net merit $ | 49 | 16,871 | $3.71 | 14.3 | 31 | 509 |
| Herds of > 50 net merit $ | 98 | 17,927 | $4.23 | 14.1 | 34 | 393 |
| Herds < 149 days open | 146 | 17,980 | $4.02 | 13.7 | 34 | 431 |
| Herds > 150 days open | 213 | 15,645 | $3.38 | 14.8 | 29 | 591 |
| Herds of < 86% in milk | 79 | 16,097 | $3.96 | 14.5 | 31 | 528 |
| Herds > 85% in milk | 92 | 17,094 | $3.66 | 14.2 | 32 | 504 |
| Herds < $3.00 feed cost/day | 2.69 | 15,949 | $3.86 | 14.4 | 29 | 491 |
| Herds > $3.00 feed cost/day | 3.74 | 17,332 | $3.47 | 14.1 | 35 | 551 |
| Herds < 16,000 RHA milk | 13806 | 13,806 | $3.04 | 14.6 | 29 | 663 |
| Herds > 16,000 RHA milk | 18710 | 18,710 | $4.09 | 14.1 | 33 | 415 |
| Herds < 15 mo calving interval | 14.1 | 17,112 | $3.91 | 13.7 | 33 | 371 |
| Herds > 15 mo calving interval | 16.3 | 15,824 | $3.15 | 16.3 | 28 | 646 |
| Herds < 3.5% fat | 3.2% | 16,979 | $3.67 | 14.2 | 33 | 502 |
| Herds > 3.5% fat | 3.7 | 16,773 | $3.75 | 14.0 | 30 | 515 |
| Herds < 44% conception %[d] | 27 | 17,371 | $3.73 | 13.8 | 33 | 517 |
| Herds > 44% conception %[d] | 58 | 16,037 | $3.69 | 14.9 | 29 | 500 |
| Herds of 1-99 cows/herd | 65 | 15,475 | $3.14 | 14.3 | 32 | 582 |
| Herds > 99 cows/herd | 168 | 18,013 | $3.87 | 14.2 | 31 | 446 |
| Herds < $4 IOF$ | 3.04 | 15,718 | $3.04 | 14.2 | 31 | 568 |
| Herds > $4 IOF$ | 4.96 | 18,487 | $4.96 | 14.2 | 34 | 575 |

[a] Rolling herd average-milk

[b] Daily income-over-feed cost ($/cow/day) or income minus feed costs

[c] Somatic cell counts

[d] Conception rate at 1st service

# Comparisons of In Situ Nitrogen Disappearance Kinetics of Wheat Forages in Confined and Grazing Steers

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## Story In Brief

Wheat (*Triticum aestivum* L.) forages were harvested on three dates (March 6, March 27, and April 11, 2000) using five sampling techniques; these included three clipping techniques (whole plant, random pluck, and top half) and two evaluations of masticates (oven dried at 50°C or lyophilized). Disappearance kinetics of N for the 15 experimental forages were evaluated by the in situ technique using five 865 ± 120-lb crossbred steers that were offered an alfalfa-based (*Medicago sativa* L.) diet and were housed in confinement. Subsequently, this evaluation was repeated in five 986 ± 107-lb crossbred steers grazing wheat pasture during March 2001. Kinetic parameter estimates obtained from grazing steers were regressed on those obtained from confined steers; for fractions A and B, the slopes and intercepts did not differ ($P > 0.13$) from unity and zero, respectively. For disappearance rate, $K_d$, the slope (0.92) did not differ ($P = 0.41$) from unity, but the intercept (0.027) was greater than ($P = 0.026$) zero. The slope (1.23) and intercept (- 24.3% of N) for estimates of effective ruminal disappearance of N differed ($P < 0.033$) from unity and zero, respectively, but these differences were largely an artifact of the different passage rates used to determine effective disappearance. From a practical standpoint, the in situ disappearance kinetics of N for these wheat forages were not altered substantially when they were obtained from grazing steers.

## Introduction

Currently, most evaluations of disappearance kinetics are conducted with confined animals; this allows for close control of many factors, especially the composition and intake of the basal diet. The practice of using kinetic estimates derived from this traditional experimental approach to balance diets for grazing cattle has often been questioned. Previously, there has been little or no research designed to compare disappearance kinetics of forage N determined in grazing animals with similar estimates obtained from animals housed and fed in confinement. If the disappearance kinetics of N for masticate or clipped forages are similar or closely related for confined and pasture-based evaluations, then it may not be necessary to conduct these evaluations in grazing animals. Previous research (Coblentz et al., 2002a; 2002b) with this sample set has demonstrated that disappearance kinetics of dry matter (DM) were not altered substantially when they were evaluated in steers grazing wheat pasture.

Our objectives in this study were 1) to evaluate the effects of various sampling techniques and sampling date on the N disappearance kinetics and nutritive value of wheat forage, and 2) to compare kinetic parameter estimates for these forages obtained from fistulated steers housed in confinement with those obtained from steers grazing wheat pasture.

## Experimental Procedures

*Experimental Forages.* The 15 experimental wheat forages were collected on three dates (March 6, March 27, and April 11, 2000) with five sampling techniques (lyophilized- or oven-dried masticate, and top-half, whole-plant, and random-plucked samples clipped with garden shears). The establishment of the wheat plots, all associated agronomic management, a detailed description of the sampling techniques, and fiber composition for these wheat forages has been described in detail previously (Coblentz et al., 2002a).

*Laboratory Analyses.* Concentrations of N for each experimental forage and each in situ residue were determined by rapid combustion (1562°F), conversion of all N-combustion products to $N_2$, and subsequent measurement by thermoconductivity cell (LECO Model FP-428; LECO Corp., St. Joseph, MI). Concentrations of neutral detergent insoluble N (NDIN) and acid detergent insoluble N (ADIN) were determined similarly, following digestion of the experimental forages in neutral and acid detergent, respectively, using the batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). No sulfite or heat-stable α-amylase was included in the NDF solution.

*In Situ Procedures in Confined and Grazing Steers.* A complete description of the in situ procedures used for confined and grazing cattle has been described previously (Coblentz et al. 2002a; 2002b). All N disappearance data were fitted to the nonlinear regression model of Mertens and Loften (1980) using PROC NLIN (SAS Inst., Inc., Cary, NC). Forage N was partitioned into three fractions based on relative susceptibility to ruminal disappearance. Fraction A was defined as the immediately soluble fraction, or that portion of the forage N that disappears at a rate too fast to measure; fraction B was comprised of N that disappeared at a measurable rate; and fraction C was considered undegradable in the rumen. Typically, microbial contamination of in situ residues has been negligible when machine rinsing procedures similar to those used in this study (Coblentz et al. 2002a; 2002b) have been used. This was verified by the procedures of Zinn and Owens (1986) on a group ($n = 62$) of residues that represented a cross-section of all steers, forages, incubation periods, and basal diets (alfalfa or wheat pasture). No corrections for microbial contamination were made prior to calculating disappearance kinetics. The effective disappearance of N for the wheat forages was calculated as $A + B \times [K_d/(K_d + K_p)]$, where $K_d$ = ruminal disappearance rate and $K_p$ = passage rate (0.035 ± 0.009/h) that was determined experimentally in each confined steer using acid detergent insoluble ash as an internal marker. For grazing steers, a previously

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determined passage rate of 0.062/h for steers grazing wheat pasture (Lippke et al. 2000) was used in our calculations of effective disappearance of N.

*Statistics*. Indices of nutritive value were analyzed as a randomized complete block design with field blocks (4) as replications. Treatments were arranged as a split plot in time with sampling techniques as whole plots and sampling dates as the repeated measures term. Experimental forages were composited over field blocks prior to in situ analysis; therefore, disappearance kinetics for both confined and grazing cattle were evaluated as a randomized complete block design with a factorial arrangement of five sampling techniques and three harvest dates. The five steers served as replications (blocks). All analyses were conducted by PROC ANOVA (SAS Inst., Inc., Cary, NC). Parameters associated with disappearance kinetics determined in steers grazing wheat pasture were related to those determined in confined steers by linear regression; additional test statements were included to evaluate whether slope = 1 and intercept = 0 (PROC REG; SAS Inst., Inc., Cary, NC).

## Results and Discussion

*Nutritive Value of Wheat Forages*. Concentrations of N, NDIN, and ADIN were each affected ($P < 0.0001$) by sampling technique, sampling date, and the interaction of these main effects; therefore, only interaction means are described. Comparisons of subplots (sampling dates) within whole plots (sampling techniques) largely reflected changes in nutritive value that were associated with stem elongation and plant maturity. Within each sampling technique, concentrations of N generally decreased across sampling dates, and NDIN and ADIN concurrently made up a larger percentage of the total N in the forage. While these differences are important, they are fairly predictable, and will not be discussed further. Of more relevance are comparisons of whole plots (sampling techniques) within subplots (sampling dates; Table 1).

Within each sampling date, the greatest ($P < 0.05$) concentration of N was observed for the top-half clipping treatment, which ranged from 5.20% of DM on the initial sampling date down to 2.99% of DM on the final sampling date (Table 1). On the final sampling date, this concentration of N did not differ ($P > 0.05$) from either oven-dried or lyophilized masticate. Oven-dried masticate had a greater ($P < 0.05$) concentration of N than lyophilized masticate on the second harvest date, but also exhibited numerically higher levels on both other sampling dates.

The percentage of total N that is insoluble in neutral detergent (NDIN) was greatest ($P < 0.05$) in oven-dried masticate, ranging across sampling dates from 35.6 to 44.3% of total forage N. The NDIN concentrations in other treatments were generally less than 20% of total N. Concentrations of ADIN in masticate samples increased ($P < 0.05$) in response to oven-drying on both the March 27 and April 11 sampling dates, and numerical ($P > 0.05$) differences were observed for the March 6 date. Masticate samples, regardless of drying method, had greater ($P < 0.05$) concentrations of ADIN than clipping treatments on both the March 6 and 27 sampling dates. On the final sampling date, the concentration of ADIN was lowest ($P < 0.05$) in the top-half clipping treatment, which was only 39 and 45% of the concentration found in the random-pluck and whole-plant clipping treatments, respectively.

*Disappearance Kinetics of N in Confined Steers*. There was a strong interaction of main effects ($P \leq 0.001$) for kinetic parameters; therefore, only interaction means are discussed (Table 2). For each sampling date, fraction A comprised a smaller ($P < 0.05$) percentage of the total plant N in oven-dried masticate than in the other sampling techniques. Fraction A for lyophilized masticate exceeded that for oven-dried masticate by 11.9 to 14.2 percentage units over the three sampling dates, thereby illustrating a consistent reduction in N solubility in response to oven-drying. In contrast, fraction B was larger ($P < 0.05$) for oven-dried masticate than for lyophilized masticate on all sampling dates; these differences ranged from 11.3 to 14.1 percentage units. Fraction B for oven-dried masticate also was greater ($P < 0.05$) than observed for all clipping treatments on all sampling dates, except ($P > 0.05$) for the top half clipping treatment on the March 6 sampling date.

Fraction C, which is unavailable in the rumen, was very small for all treatments on each sampling date, never exceeding 10.3% of total N. While drying technique had a substantial effect on the percentage of total N in fractions A and B, oven-drying did not increase ($P > 0.05$) unavailable N relative to lyophilization on any sampling date. On the March 27 sampling date, fraction C for both oven-dried and lyophilized masticate was smaller ($P < 0.05$) than observed for the random pluck and whole-plant clipping treatments, and fraction C comprised a smaller ($P < 0.05$) percentage of total N for both masticate treatments than for all clipping treatments on the final sampling date.

Generally, $K_d$ was rapid on the initial sampling date, a trait consistent with expectations for lush, cool-season grasses, but slowed within sample collection method on subsequent dates, largely due to advancing plant maturity. The $K_d$ was most rapid ($P < 0.05$) for lyophilized masticate on all sampling dates; however, these rates did not differ ($P > 0.05$) from the top-half clipping treatment on either the March 6 or 27 sampling dates. Oven drying masticate samples reduced ($P < 0.05$) $K_d$ relative to lyophilization by 51.1, 35.7, and 47.4% on the March 6, March 27, and April 11 sampling dates, respectively. Oven-dried masticate had the slowest ($P < 0.05$) $K_d$ on all sampling dates, but did not differ ($P > 0.05$) from the random pluck or whole-plant clipping treatments on the March 27 sampling date, or from the whole-plant clipping treatment on the April 11 sampling date.

The effective disappearance of N decreased ($P < 0.05$) over sampling dates in response to advancing plant maturity (mean effective disappearances for the March 6, March 27, and April 11 sampling dates were 88.2, 84.3, and 80.8%, respectively). Effective disappearance was greatest ($P < 0.05$) for lyophilized masticate on all sampling dates, but these estimates did not differ ($P > 0.05$) from the top-half clipping treatment on the March 6 or 27 sampling dates. Oven-dried masticate exhibited the lowest ($P < 0.05$) effective disappearance of N on the first two sampling dates. On the final sampling date, effective disappearance for oven-dried masticate did not differ ($P > 0.05$) from either random pluck or whole-plant forage, but all of these forages exhibited poorer ($P < 0.05$) effective disappearance than the top-half clipping treatment or lyophilized masticate.

*Disappearance Kinetics of N in Grazing Steers*. When the 15 experimental wheat forages were evaluated for disappearance kinetics of N in steers grazing wheat pasture, the interaction of sampling technique and sampling date was significant ($P \leq 0.018$) for all response variables; therefore, only interaction means are presented (Table 3). While parameter estimates for disappearance kinetics of N determined in grazing steers varied somewhat from those observed for confined steers, these differences were generally minor, and patterns of mean separation were similar to those described for confined steers. Therefore, results obtained from grazing steers will not be discussed further.

*Regressions of Kinetics in Grazing Steers on Those in Confinement*. Linear regressions of all disappearance parameters determined in grazing steers on those determined in confined steers

(Table 4) had significant slopes ($P < 0.001$) and exhibited very high $r^2$ statistics ($r^2 \geq 0.881$) for all response variables. Ideally, a slope of unity and an intercept of zero would indicate that work in confined cattle could be applied directly to grazing cattle under the conditions and techniques used in this study. Slopes and intercepts for fractions A and B did not differ from unity ($P \geq 0.16$) and zero ($P \geq 0.13$), respectively. Fraction C exhibited a slope that was greater than unity (1.50; $P < 0.0001$), but an intercept that did not differ from zero ($P = 0.13$). In contrast, $K_d$ exhibited an intercept that differed from zero ($P = 0.026$), but the slope did not ($P = 0.41$). For the effective ruminal disappearance of N, both slope ($P = 0.033$) and intercept ($P = 0.009$) differed from unity and zero, respectively. However, these differences were largely an artifact of the different respective passage rates (0.035 vs. 0.062/h) used to calculate effective disappearance for confined and grazing cattle.

## Implications

Although fraction C, $K_d$, and effective disappearance of N, did not exhibit the ideal condition of slope = 1 and intercept = 0, our results for grazing steers did not represent a radical departure from those observed in confined steers consuming a basal diet of primarily alfalfa hay. This suggests that parameter estimates for disappearance kinetics of N obtained from confined steers may be relevant within a grazing context.

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**Table 1. Analysis of N components for wheat forage harvested by five sampling techniques on three dates in Fayetteville, AR, during Spring 2000.**

| Forage[1] | N[2] | NDIN | ADIN |
|---|---|---|---|
| | % of DM | % of N | |
| March 6 | | | |
| Lyophilized masticate | 3.68[c] | 16.5[b] | 4.45[a] |
| Oven-dried masticate | 3.86[c] | 35.6[a] | 4.72[a] |
| Random pluck | 4.62[b] | 12.1[c] | 1.69[b] |
| Top half | 5.20[a] | 13.1[c] | 1.07[b] |
| Whole plant | 3.75[c] | 11.7[c] | 2.29[b] |
| March 27 | | | |
| Lyophilized masticate | 2.70[c] | 24.2[b] | 6.03[b] |
| Oven-dried masticate | 3.07[b] | 39.7[a] | 8.14[a] |
| Random pluck | 2.70[c] | 17.3[c] | 4.31[c] |
| Top half | 3.95[a] | 12.9[d] | 3.24[c] |
| Whole plant | 2.90[bc] | 15.4[cd] | 3.57[c] |
| April 11 | | | |
| Lyophilized masticate | 2.89[a] | 16.7[c] | 3.88[c] |
| Oven-dried masticate | 3.00[a] | 44.3[a] | 7.25[a] |
| Random pluck | 2.15[b] | 19.3[bc] | 6.03[ab] |
| Top half | 2.99[a] | 17.6[bc] | 2.34[d] |
| Whole plant | 2.08[b] | 20.5[b] | 5.15[bc] |
| SEM[3] | 0.090 | 1.01 | 0.43 |

[a,b,c,d] Means within a column and sampling date without common superscripts differ ($P < 0.05$).

[1] Interaction means of sampling technique (whole plot) within harvest date (subplot). The appropriate LSD (0.05) for comparisons of harvest date within sampling technique are 0.29, 3.2, and 1.10 for N, NDIN, and ADIN, respectively; mean separation is not shown.

[2] Abbreviations: N, nitrogen; NDIN, neutral detergent insoluble N; and ADIN, acid detergent insoluble N.

[3] Standard error of the sampling technique (whole plot) within harvest date (subplot) interaction mean.

**Table 2. Characteristics of in situ disappearance of N for wheat forages harvested by five sampling techniques on three dates during Spring 2000 and evaluated in confined steers.**

| | N fraction | | | | Effective |
|---|---|---|---|---|---|
| Forage[1] | A[2] | B | C | $K_d$ | disappearance[3] |
| | % of N | | | /h | % of N |
| March 6 | | | | | |
| Lyophilized masticate | 59.3[a] | 37.9[c] | 2.8[ab] | 0.184[a] | 91.0[a] |
| Oven-dried masticate | 47.4[d] | 49.2[a] | 3.4[a] | 0.090[c] | 82.6[c] |
| Random pluck | 55.9[b] | 42.3[b] | 1.8[bc] | 0.127[b] | 89.0[b] |
| Top half | 51.4[c] | 47.1[a] | 1.4[c] | 0.184[a] | 90.9[a] |
| Whole plant | 54.8[b] | 42.0[b] | 3.2[a] | 0.126[b] | 87.6[b] |
| March 27 | | | | | |
| Lyophilized masticate | 53.7[b] | 42.7[b] | 3.6[b] | 0.126[a] | 86.7[a] |
| Oven-dried masticate | 40.2[c] | 56.0[a] | 3.9[b] | 0.081[b] | 79.3[c] |
| Random pluck | 61.0[a] | 32.6[c] | 6.4[a] | 0.077[b] | 83.4[b] |
| Top half | 54.0[b] | 43.0[b] | 3.0[b] | 0.129[a] | 87.6[a] |
| Whole plant | 61.3[a] | 32.6[c] | 6.1[a] | 0.089[b] | 84.6[b] |
| April 11 | | | | | |
| Lyophilized masticate | 54.6[b] | 42.0[b] | 3.5[d] | 0.135[a] | 87.9[a] |
| Oven-dried masticate | 40.4[c] | 56.1[a] | 3.5[d] | 0.071[bc] | 77.9[c] |
| Random pluck | 61.6[a] | 29.5[e] | 9.0[b] | 0.047[d] | 78.2[c] |
| Top half | 55.5[b] | 38.5[c] | 6.0[c] | 0.088[b] | 82.8[b] |
| Whole plant | 56.9[b] | 32.8[d] | 10.3[a] | 0.058[cd] | 77.3[c] |
| SEM[4] | 0.98 | 1.02 | 0.38 | 0.0085 | 0.58 |

[a,b,c,d] Means within a column and sampling date with different superscripts differ ($P < 0.05$).

[1] For clarity, only mean separations within a harvest date are shown; however, any two means within a column can be compared with a common LSD (0.05). The LSDs (0.05) for A, B, C, $K_d$, and effective disappearance (% of N) are 2.8, 2.9, 1.1, 0.024, and 1.6, respectively.

[2] Abbreviations: A = Immediately soluble fraction, B = fraction disappearing at a measurable rate, C = undegraded fraction, and $K_d$ = disappearance rate.

[3] Calculated as $A + B(K_d/K_d + \text{passage rate})$, where $K_d$ = disappearance rate. Passage rate for five steers housed in confinement was determined experimentally as 0.035 ± 0.0094/h.

[4] Standard error of the interaction mean.

**Table 3. Characteristics of in situ disappearance of N for wheat forages harvested by five sampling techniques on three dates during Spring 2000 and evaluated in grazing steers.**

| | N fraction | | | | Effective |
|---|---|---|---|---|---|
| Forage[1] | A[2] | B | C | $K_d$[2] | disappearance[3] |
| | % of N | | | /h | % of N |
| March 6 | | | | | |
| Lyophilized masticate | 57.4[a] | 39.6[c] | 3.0[b] | 0.182[a] | 86.6[a] |
| Oven-dried masticate | 42.5[c] | 53.0[a] | 4.5[a] | 0.094[c] | 73.6[c] |
| Random pluck | 58.1[a] | 39.4[c] | 2.5[b] | 0.175[ab] | 86.5[a] |
| Top half | 52.0[b] | 45.9[b] | 2.1[b] | 0.187[a] | 86.0[ab] |
| Whole plant | 56.1[a] | 39.9[c] | 4.0[ab] | 0.145[b] | 83.8[b] |
| March 27 | | | | | |
| Lyophilized masticate | 49.3[b] | 45.9[b] | 4.8[bc] | 0.144[ab] | 81.1[ab] |
| Oven-dried masticate | 40.0[c] | 54.6[a] | 5.4[b] | 0.080[c] | 70.5[c] |
| Random pluck | 60.2[a] | 30.4[c] | 9.4[a] | 0.113[bc] | 79.6[b] |
| Top half | 51.2[b] | 44.7[b] | 4.1[c] | 0.153[a] | 82.8[a] |
| Whole plant | 60.0[a] | 30.9[c] | 9.1a | 0.109[c] | 79.6[b] |
| April 11 | | | | | |
| Lyophilized masticate | 54.1[b] | 41.7[b] | 4.2[c] | 0.161[a] | 84.0[a] |
| Oven-dried masticate | 38.2[c] | 57.3[a] | 4.5[c] | 0.079[c] | 69.6[d] |
| Random pluck | 58.7[a] | 27.0[d] | 14.3[a] | 0.078[c] | 73.3[c] |
| Top half | 53.6[b] | 38.4[c] | 8.0[b] | 0.116[b] | 78.2[b] |
| Whole plant | 56.9[a] | 29.3[d] | 13.8[a] | 0.071[c] | 72.2[c] |
| SEM[4] | 0.81 | 0.83 | 0.37 | 0.0120 | 0.83 |

[a,b,c,d] Means within a column and sampling date with different superscripts differ ($P < 0.05$).

[1] For clarity, only mean separations within a harvest date are shown; however, any two means within a column can be compared with a common LSD (0.05). The LSDs (0.05) for A, B, C, $K_d$, and effective disappearance (% of N) are 2.3, 2.4, 1.0, 0.034, and 2.3, respectively.

[2] Abbreviations: A = Immediately soluble fraction, B = fraction disappearing at a measurable rate, C = undegraded fraction, and $K_d$ = disappearance rate.

[3] Calculated as $A + B(K_d/K_d + \text{passage rate})$, where $K_d$ = disappearance rate. Passage rate (0.062/h) for steers grazing wheat pasture was based on the work of Lippke et al., 2000).

[4] Standard error of the interaction mean.

**Table 4. Regressions of parameter estimates for disappearance kinetics of N obtained from in situ evaluations conducted in steers grazing wheat pasture on those obtained from in situ evaluations conducted in confinement.**

| Kinetic parameter | Slope[1] | $SE_{slope}$[2] | P > F[3] | Intercept[4] | $SE_{intercept}$[5] | P > F[6] | $r^2$ |
|---|---|---|---|---|---|---|---|
| Fraction A[7] | 1.03 | 0.082 | 0.742 | - 2.8 | 4.45 | 0.542 | 0.924 |
| Fraction B | 1.11 | 0.071 | 0.158 | - 4.9 | 2.98 | 0.126 | 0.950 |
| Fraction C | 1.50 | 0.065 | < 0.0001 | - 0.5 | 0.33 | 0.132 | 0.977 |
| $K_d$ | 0.92 | 0.094 | 0.408 | 0.027 | 0.0107 | 0.026 | 0.881 |
| Effective disappearance, % of N[8] | 1.23 | 0.094 | 0.033 | - 24.3 | 7.97 | 0.009 | 0.929 |

[1] Slope of regression line.

[2] Standard error of the slope.

[3] Probability that slope = 1.

[4] Intercept of regression line.

[5] Standard error of the intercept.

[6] Probability that intercept = 0.

[7] Abbreviations: A = immediately soluble fraction, B = fraction degradable at a measurable rate, C = undegraded fraction, and $K_d$ = ruminal disappearance rate.

[8] Calculated as $A + B(K_d/K_d + \text{passage rate})$, where Kd = disappearance rate. Passage rate (0.062/h) for grazing steers was based on the work of Lippke et al., 2000). The passage rate for five steers housed in confinement was determined experimentally as 0.035 ± 0.0094/h using acid detergent insoluble ash as an internal marker.

# Nutritive Value of Crabgrass Harvested on Seven Dates in Northern Arkansas

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## Story in Brief

Common crabgrass has been largely viewed as an unwanted weed because of its encroachment into field crops, gardens, and yards. It is undesirable in bermudagrass [*Cynodon dactylon* (L.) Pers.] hay fields because of slower drying which causes concerns about potential spontaneous heating and molding in hay. Visual observations and circumstantial evidence indicate that livestock prefer crabgrass to many other summer forages. Common crabgrass was harvested weekly between July 11 and August 22, 2001 to assess the nutritive value of leaf, stem and whole-plant tissue. The percentage of leaf decreased in linear ($P < 0.0001$), quadratic ($P = 0.0003$), and cubic ($P = 0.032$) patterns over sampling dates from 46.6% on July 11 to 28.4% on August 8. In general, concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, cellulose and lignin in whole-plant tissue increased linearly ($P \leq 0.013$) over sampling dates; a quadratic effect was observed for hemicellulose ($P = 0.006$), and a quartic effect ($P = 0.034$) was observed for lignin. Whole plant concentrations of N declined linearly ($P = 0.001$) from 3.36 to 2.55%. Crabgrass samples were evaluated for in situ disappearance of DM in five (843 ± 50 lb) ruminally cannulated steers. Crabgrass exhibited a more rapid ruminal disappearance rate than bermudagrass ($P < 0.0001$) and orchardgrass (*Dactylis glomerata* L.) hays ($P = 0.002$), but this rate was not as fast ($P < 0.0001$) as observed for alfalfa (*Medicago sativa* L.). The effective ruminal disappearance of DM was greater ($P < 0.0001$) for crabgrass than alfalfa, bermudagrass, and orchardgrass hays.


## Introduction

Crabgrass evolved in Africa, but was inadvertently brought to the United States by Europeans. It is believed that the United States Patent Office imported crabgrass in 1894 as a way to provide forage for farm animals. Crabgrass has been viewed largely as an unwanted weed because of its encroachment into field crops, gardens, and yards (Dalrymple, 1999). It is undesirable in bermudagrass fields because it dries slower than bermudagrass; this causes concerns about potential spontaneous heating and molding in hay, and bales with significant amounts of crabgrass are unacceptable to the equine industry. However, visual observation and circumstantial evidence indicate that livestock prefer crabgrass to many other summer forages, and cattle often exhibit good summer performance when consuming this forage. Our objectives in this study were to determine the nutritive value and in situ disappearance kinetics of DM for common crabgrass harvested on weekly intervals throughout the summer.

## Experimental Procedures

*Collection of Experimental Forages.* An existing stand of crabgrass was divided into four 12 x 24-ft field blocks and was fertilized with ammonium nitrate at a rate of 60 lb actual N/acre. In the summer of 2001, crabgrass was harvested by clipping two 0.25-$m^2$ frames per block to a 1-in stubble height with garden shears. For each frame, canopy height was measured at three random locations and three randomly selected plants were evaluated for growth stage. Forage samples were dried under forced air at 122°F and dry weights for each frame were converted to a per acre basis as an estimate of DM yield. Leaves were separated from the stem by separating each leaf at the collar. Crabgrass plots were clipped weekly beginning on July 11, 2001, and ending on August 22.

*Laboratory Analysis.* Dried crabgrass samples were ground through a 1 or 2-mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, PA). Subsamples ground through the 1-mm screen were analyzed sequentially for neutral-detergent fiber (NDF), acid-detergent fiber (ADF), cellulose, acid detergent lignin, and ash by the batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Sodium sulfate and α-amylase were omitted from the neutral detergent solution. Concentrations of N were determined by rapid combustion (1574°F; LECO Model FP-428; LECO Corp., St. Joseph,MI); CP was calculated as the percentage of N in the sample x 6.25. Plant ash was determined by combustion of 2-g samples of each forage at 932°F for 8 h in a muffle furnace. The subsamples ground through a 2-mm screen were retained for in situ analysis.

*In Situ Procedures in Confinement.* Five (843 ± 50 lb) ruminally cannulated crossbred (Angus x Brangus x Gelbvieh) steers were used to determine in-situ DM disappearance kinetics of common crabgrass. The cannulations and care of the steers were approved by the University of Arkansas Animal Care and Use Committee. Each steer was housed in individual 11 x 16-ft pens with concrete floors that were cleaned regularly. Steers were offered a diet of alfalfa hay (16.1% CP, 51.9% NDF, and 38.7% ADF) and a corn-based supplement (94.7% cracked corn, 3% molasses, and 2.3% trace mineral salt). On a DM basis, the basal diet contained 85.7% alfalfa hay and 14.3% supplement, and was offered in equal portions (0630 and 1430 h) at 2.0% of BW daily. Fresh water was offered on an ad libitum basis. Steers were adapted to the basal diet for 10 days prior to initiating the trial. The alfalfa, bermudagrass, and orchardgrass controls were harvested as small square bales at the Forage Research Area in Fayetteville. All bales were made during the spring and summer of 2002 and exhibited no evidence of spontaneous heating or molding. Slices were taken from the center of each bale and ground through a 2-mm screen prior to in situ analysis. In general, the bermudagrass hay (62.1% NDF, 27.0% ADF, and 17.1% CP) had excellent nutritional value, but the alfalfa (51.9% NDF, 38.7% ADF, and 16.1% CP) and orchardgrass (67.2% NDF, 34.9% ADF, and

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12.3% CP) had moderate nutritional value. In situ procedures were consistent with the standardized technique described by Vanzant et al. (1998). Five-g samples of each forage were placed into dacron bags and pre-incubated in tepid water at 102°F for 20 min. Samples were then incubated in the rumen for 3, 6, 9, 12, 24, 36, 48, 72, or 96 h, and subsequently rinsed in a top-loading washing machine (Coblentz et al., 1997). A separate set of bags were pre-incubated and rinsed without ruminal incubation (0 h).

Data were fitted to the nonlinear regression model of Mertens and Loften (1980) using PROC NLIN of SAS (SAS Inst., Inc., Cary, NC). Dry matter was partitioned into three fractions based on relative susceptibility to ruminal disappearance. The A fraction was defined as the immediately soluble portion; the B fraction represented that portion of DM that disappeared at a measurable rate; and fraction C was defined as the portion of DM that was undegradable in the rumen. Fractions B and C, disappearance rate ($k_d$), and the discrete lag time were determined directly by the nonlinear regression model. For each forage, fraction A was calculated as 100 – (B + C); similarly, the potential extent of disappearance was calculated as 100 – C. For all forages, the degradability of DM was calculated as A + B x $[k_d/(k_d + k_p)]$, where $k_p$ = passage rate (0.035/h).

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

## Results and Discussion

*Agronomic Characteristics of Crabgrass.* On July 11, stem elongation had reached the three-node stage with an associated DM yield of 3,079 lb/acre (Table 1). By July 25, the flag leaf sheath was swollen, and inflorescence was ready to emerge. At this time, the DM yield was 3,404 lb/acre. On the final harvest date, the average growth stage was the milk stage of seed development, and the associated DM yield was 3,752 lb/acre. Rainfall events in August triggered development of new tillers; therefore, the average growth stage on the final harvest date included fully mature tillers and other, less-developed tillers. Canopy height increased linearly ($P < 0.0001$) across harvest dates, ranging from a starting height of 11.2 inches to an ending height of 18.5 inches on August 22. The percentage of leaf decreased with significant linear ($P < 0.0001$), quadratic ($P = 0.0003$), and cubic ($P = 0.032$) trends over sampling dates from 46.6% on July 11 to 28.4% on August 8, but increased to 35.3% by August 22.

*Nutritive Value of Crabgrass.* In general, fiber contents (NDF, ADF, hemicellulose, cellulose and lignin) in whole-plant tissue increased linearly ($P \leq 0.013$) over sampling dates; a quadratic effect was observed for hemicellulose ($P = 0.006$), and a quartic effect ($P = 0.034$) was observed for lignin (Table 2). Leaf fiber contents (NDF, ADF, hemicellulose, cellulose and lignin) increased linearly ($P \leq 0.048$) over sampling dates; a quadratic effect was also observed for NDF, ADF, and cellulose ($P \leq 0.002$). In addition, a cubic effect was observed for NDF and hemicellulose ($P \leq 0.034$), and a quartic effect ($P = 0.002$) for hemicellulose. Concentrations of NDF, ADF, hemicellulose and lignin in the stem increased linearly ($P \leq 0.014$) over sampling dates; in addition, cubic effects ($P \leq 0.027$) were observed for NDF and ADF. Cubic and quadratic effects ($P = 0.049$) were observed for cellulose.

Leaf N (Table 2) declined linearly ($P < 0.0001$) throughout the harvest dates from 3.80 to 3.13%. On August 1, concentrations of N increased from 3.40 to 3.68%; this can probably be explained on the basis of new tiller development following a total of 1.3 in of rainfall that fell between July 25 and July 30. Concentrations of N in stem tissue declined linearly ($P = 0.002$) across the harvest dates, ranging from 3.31 to 2.42%. Whole plant concentrations of N declined linearly ($P = 0.001$) from 3.36 to 2.55% over the sampling dates.

*Disappearance Kinetics.* Fraction A declined in linear ($P = 0.001$), quadratic ($P = 0.001$) and quartic ($P = 0.012$) trends with harvest dates (Table 3). Fraction B decreased over harvest dates from 54.7 to 52.2% in linear, quadratic, and quartic ($P \leq 0.001$) trends. In contrast, fraction C increased from 12.2 to 16.2% over harvest dates in linear, quadratic, cubic, and quartic ($P \leq 0.043$) patterns. Crabgrass had a greater fraction A and B ($P < 0.0001$), and a smaller fraction C ($P < 0.0001$) than alfalfa. Alfalfa had a higher proportion of DM in fraction C which can potentially be explained on the basis of alfalfa having more lignin (7.6%), than crabgrass (overall range for whole plant = 1.89 to 2.90%; Table 2). Crabgrass had a more rapid disappearance rate than bermudagrass ($P < 0.0001$) and orchardgrass hays ($P = 0.002$); in contrast, alfalfa had a faster rate than crabgrass ($P < 0.0001$). The potential extent of disappearance was higher ($P < 0.0001$) for crabgrass than for alfalfa and orchardgrass hays, but there was no difference between crabgrass and bermudagrass ($P = 0.123$). The effective ruminal degradability of DM was greater ($P < 0.0001$) for crabgrass than for alfalfa, bermudagrass, and orchardgrass hays.

## Implications

The effective ruminal degradability of DM for crabgrass was between 3.1 to 9.3 percentage units greater than the bermudagrass hay utilized in this study. This indicates that crabgrass offers improved ruminal digestibility over bermudagrass hay and should support greater animal performance. Crabgrass appears to have good nutritive value and offers considerable promise as a forage alternative during the summer months in the upper South.

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**Table 1. Agronomic characteristics of crabgrass forages harvested during 2001 near Prairie Grove, AR.**

| Harvest date | Growth stage | DM yield | Canopy height | Leaf percentage |
|---|---|---|---|---|
| | | lb/acre | Inch | % |
| July 11 | stem elongation - 3 nodes | 3079 | 11.2 | 46.6 |
| July 18 | Flag leaf emerging | 2783 | 11.2 | 45.4 |
| July 25 | flag leaf sheath swollen | 3404 | 12.3 | 37.5 |
| August 1 | < 50% inflorescence emerged | 3463 | 14.3 | 38.0 |
| August 8 | < 50% inflorescence emerged | 3183 | 13.1 | 28.4 |
| August 15 | milk stage | 4138 | 17.8 | 35.0 |
| August 22 | milk stage | 3752 | 18.5 | 35.3 |
| SEM[1] | | 243 | 0.96 | 1.45 |
| Effect[2] | | L = 0.003 | L < 0.0001 | L < 0.0001 |
| | | | | Q = 0.0003 |
| | | | | C = 0.032 |

[1] Standard error of the mean.

[2] L, linear effect; Q, quadratic effect; C, cubic effect.

**Table 2. Nitrogen and fiber characteristics of leaf, stem, and whole-plant fractions for crabgrass forages harvested during 2001 near Prairie Grove, AR.**

| Harvest date | N[1] | NDF | ADF | Hemicellulose | Cellulose | Lignin |
|---|---|---|---|---|---|---|
| | | | % of DM | | | |
| **Leaf** | | | | | | |
| July 11 | 3.80 | 48.7 | 24.2 | 24.5 | 22.0 | 1.61 |
| July 18 | 3.62 | 48.7 | 22.9 | 25.8 | 21.1 | 1.54 |
| July 25 | 3.40 | 48.9 | 22.9 | 26.0 | 20.9 | 1.45 |
| August 1 | 3.68 | 51.0 | 24.6 | 26.4 | 21.7 | 2.30 |
| August 8 | 3.36 | 51.0 | 22.2 | 28.8 | 20.3 | 1.63 |
| August 15 | 3.21 | 54.6 | 25.0 | 29.6 | 22.5 | 2.51 |
| August 22 | 3.13 | 54.6 | 25.1 | 29.5 | 22.3 | 2.21 |
| SEM[2] | 0.110 | 0.37 | 0.30 | 0.28 | 0.29 | 0.197 |
| Effect[3] | L < 0.0001 | L < 0.0001 | L = 0.002 | L < 0.0001 | L = 0.048 | L = 0.002 |
| | | Q=0.002 | Q = 0.0002 | C = 0.031 | Q = 0.001 | |
| | | C = 0.034 | | Qu = 0.002 | | |
| **Stem** | | | | | | |
| July 11 | 3.31 | 59.5 | 31.7 | 27.8 | 29.2 | 2.15 |
| July 18 | 2.98 | 57.0 | 28.4 | 28.6 | 26.4 | 1.75 |
| July 25 | 2.61 | 60.1 | 30.4 | 29.7 | 27.4 | 2.62 |
| August 1 | 3.10 | 62.2 | 32.3 | 29.9 | 28.8 | 2.98 |
| August 8 | 2.81 | 61.3 | 30.0 | 31.3 | 27.1 | 2.60 |
| August 15 | 2.53 | 64.2 | 33.1 | 31.1 | 29.2 | 3.39 |
| August 22 | 2.42 | 63.7 | 32.0 | 31.7 | 28.7 | 3.02 |
| SEM[2] | 0.173 | 0.67 | 0.68 | 0.42 | 0.55 | 0.168 |
| Effect[3] | L = 0.002 | L < 0.0001 | L = 0.014 | L < 0.0001 | Q = 0.049 | L < 0.0001 |
| | | C = 0.026 | C = 0.027 | | C = 0.049 | |
| **Whole plant** | | | | | | |
| July 11 | 3.36 | 55.5 | 29.4 | 26.1 | 26.4 | 2.35 |
| July 18 | 3.07 | 55.6 | 27.5 | 28.1 | 25.2 | 1.89 |
| July 25 | 2.74 | 57.4 | 28.8 | 28.6 | 25.9 | 2.44 |
| August 1 | 3.05 | 60.8 | 31.2 | 29.6 | 27.4 | 2.89 |
| August 8 | 2.85 | 58.8 | 28.9 | 29.9 | 26.0 | 2.60 |
| August 15 | 2.68 | 61.9 | 31.3 | 30.6 | 27.2 | 2.90 |
| August 22 | 2.55 | 61.2 | 30.9 | 30.3 | 27.7 | 2.81 |
| SEM[2] | 0.148 | 0.76 | 0.60 | 0.42 | 0.54 | 0.151 |
| Effect[3] | L = 0.001 | L < 0.0001 | L = 0.001 | L < 0.0001 | L = 0.013 | L = 0.0003 |
| | | | | Q = 0.006 | | Qu = 0.034 |

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

[2] Standard error of the mean.

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

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

| | Fraction | | | | | | |
|---|---|---|---|---|---|---|---|
| Forage/harvest date | A[1] | B | C | Potential Extent | Lag time | $K_d$ | Degradability[2] |
| | % of DM | | | | H | /h | % of DM |
| Crabgrass (CRAB) | | | | | | | |
| July 11 | 33.1 | 54.7 | 12.2 | 87.8 | 1.57 | 0.081 | 71.1 |
| July 18 | 32.9 | 55.1 | 12.0 | 88.0 | 1.42 | 0.084 | 71.6 |
| July 25 | 33.9 | 51.0 | 15.1 | 84.9 | 1.62 | 0.082 | 69.4 |
| August 1 | 33.6 | 50.4 | 16.0 | 84.0 | 2.41 | 0.081 | 68.3 |
| August 8 | 33.8 | 50.8 | 15.4 | 84.6 | 1.36 | 0.071 | 67.5 |
| August 15 | 31.3 | 51.9 | 16.8 | 83.2 | 1.39 | 0.069 | 65.4 |
| August 22 | 31.6 | 52.2 | 16.2 | 83.8 | 1.73 | 0.076 | 67.2 |
| Alfalfa Hay (ALF) | 29.4 | 37.6 | 33.0 | 67.0 | 1.41 | 0.143 | 59.3 |
| Bermudagrass Hay (BER) | 27.2 | 58.4 | 14.4 | 85.6 | 2.68 | 0.054 | 62.3 |
| Orchardgrass Hay (OG) | 21.0 | 62.1 | 16.9 | 83.1 | 4.00 | 0.060 | 60.1 |
| SEM[3] | 0.42 | 0.55 | 0.23 | 0.23 | 0.273 | 0.0049 | 0.41 |
| Contrasts | P > F | | | | | | |
| CRAB Linear[4] | 0.001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.910 | 0.051 | < 0.0001 |
| CRAB Quadratic | 0.001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.415 | 0.906 | 0.052 |
| CRAB Cubic | 0.772 | 0.510 | 0.043 | 0.043 | 0.492 | 0.088 | 0.0002 |
| CRAB Quartic | 0.012 | 0.001 | 0.001 | 0.001 | 0.030 | 0.530 | 0.562 |
| CRAB vs. ALF | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.433 | < 0.0001 | < 0.0001 |
| CRAB vs. BER | < 0.0001 | < 0.0001 | 0.123 | 0.123 | 0.001 | < 0.0001 | < 0.0001 |
| CRAB vs. OG | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.002 | < 0.0001 |
| ALF vs. BER | 0.001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.002 | < 0.0001 | < 0.0001 |
| OG vs. BER | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.002 | 0.350 | 0.001 |

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

[2] Calculated as $A + B[(K_d/(K_d + \text{passage rate})]$, where $K_d$ = disappearance rate and the passage rate = 0.035/h.

[3] Standard error of the mean.

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

# Effect of N Fertilization Rate on the Degradability of Bermudagrass Protein Using *Streptomyces griseus* Protease

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## Story in Brief

This study was conducted to evaluate the effects of N fertilization rate and date on the degradability of protein from bermudagrass forages (*Cynodon dactylon* (L.) Pers.) using *Streptomyces griseus* protease (SGP). Twenty-eight 10 x 20-ft plots of common bermudagrass were established on two producer farms (Latta and Stephens) located near Lincoln, AR, in the early spring of 2000. The plots were fertilized with nitrogen applied as ammonium nitrate (34-0-0) in split applications of 0, 50, 100, and 150 lb N/acre at both sites on April 28, and July 19, 2000. Cumulative yearly rates of N fertilization were 0, 50, 100, 150, 200, 250, and 300 lb N/acre. Plots were harvested on May 30, July 7, and August 18 2000. Concentrations of N increased linearly ($P < 0.001$) with N fertilization at both sites on the first and third harvests, carryover effects from the first application did not affect ($P > 0.05$) concentrations of N for the second harvest. Concentrations of undegradable intake protein (UIP; DM basis) increased ($P < 0.002$) linearly on Harvest 1 for bermudagrass at the Stephens site, and at both sites on Harvest 3 with increasing N fertilization. Concentrations of degradable intake protein (DIP; DM basis) increased linearly at both sites on Harvests 1 and 3 ($P < 0.001$) with increasing N fertilization. Similarly, concentrations of DIP (% of total N) increased linearly ($P \leq 0.004$) with increasing N fertilization at both sites on Harvests 1 and 3. Nitrogen fertilization increased the proportion of total plant N that was degraded by SGP, indicating that ruminally degradable N is increased by N fertilization.

## Introduction

The determination of undegradable intake protein (UIP) has become increasingly important with the advent of new feeding systems, such as the Cornell Net Carbohydrate and Protein System (Sniffen et al., 1992). The use of these feeding systems has necessitated the development of a laboratory procedure that will accurately predict degradable intake protein (DIP) or UIP values for a wide array of feedstuffs. The *Streptomyces griseus* protease (SGP) method has been investigated as a means of determining UIP in a laboratory setting, allowing commercial laboratories to determine this N fraction without maintaining fistulated animals.

The relationship between N fertilization rate and concentrations of N in the forage is well known; however, the effects of N fertilization on proportions of DIP and UIP are not well established for bermudagrass. The objective of this study was to determine the impact of split applications of commercial N fertilizer on the concentrations of N, and fiber-bound N of bermudagrass forage harvested on three dates as well as UIP, and DIP determined by the SGP method.

## Experimental Procedures

*Sample Generation.* Twenty-eight 10 x 20-ft plots of common bermudagrass were established on two producer farms (Latta and Stephens) located near Lincoln, AR, in the early spring of 2000. The plots were fertilized with N applied as ammonium nitrate (34-0-0) in split applications of 0, 50, 100, and 150 lb N/acre at both sites on April 28 and July 19, 2000. Cumulative yearly rates of N fertilization were 0, 50, 100, 150, 200, 250, and 300 lb N/acre, with the application schedule shown in Table 1.

*Harvest Management.* Plots at each site were arranged in a randomized complete block design with four replications. Plots were harvested by cutting a single swath (3 x 20 ft) across the center of each plot at a 2-in stubble height with a self-propelled sickle-bar mower (Model Monarch) on May 30, July 7, and August 18 2000. Fresh weights were obtained from each plot in the field and representative subsamples (approximately 1 lb) were retained for subsequent laboratory analysis after they were dried under forced air at 131°F.

*Chemical Analysis.* The dry bermudagrass samples were ground through a Wiley mill fitted with a 1-mm screen and subsequently analyzed for N, neutral detergent fiber (NDF), acid detergent fiber (ADF), neutral detergent insoluble N (NDIN), and acid detergent insoluble N (ADIN). The NDF analyses were conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Sodium sulfite and heat-stable a-amylase were omitted from the neutral detergent solution. The concentration of N in the forage and in the NDF and ADF residues (NDIN and ADIN, respectively) was determined by rapid combustion procedure (Elementar Rapid N). Procedures for determination of NDIN and ADIN were consistent with the guidelines established by Licitra et al. (1996) with the exception that the ANKOM filter-bag method was used for digestion of forages in neutral and acid detergent solutions. Neutral-detergent soluble N (NDSN) was expressed as a percentage of total plant DM and was calculated as total N – NDIN.

*Streptomyces griseus Procedures.* The in vitro protease procedures used in this study were described previously by Coblentz et al. (2001). The SGP (P-5147; Sigma Chemical Co., St. Louis, MO) used in this study contained 5.5 enzyme activity units/mg of solid. Bermudagrass samples containing 15 mg of N were incubated for 1 h at 102°F in 40 mL of borate-phosphate buffer. One milliliter of sodium azide (1% wt/vol) was added to each incubation flask as an antimicrobial agent. Following the 1-h buffer incubation, 10 mL of prepared protease solution containing 0.33 activity units/mL of SGP were added to each flask, yielding a final enzyme activity concentra-

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tion of 0.066 activity units/mL in the incubation medium. Flasks were covered with aluminum foil and incubated at 102°F for 48 h with occasional hand swirling of the contents of each flask. Following incubation, samples were placed on ice to suspend enzymatic activity and then filtered through preweighed (dry basis) Whatman #541 filter paper. Residues were washed with 400-ml of deionized water and placed in a 212°F gravity convection oven until dry. The dry residue was subsampled, and the N content of each residue was determined by the rapid combustion procedure described previously. Single time point estimates of UIP were calculated as UIP (%) = residual N/total N x 100]. While DIP was calculated as DIP = 100 – UIP. Single samples were evaluated in each of two separate runs.

*Statistical Analysis*. For each individual harvest at each site, orthogonal contrasts using the PROC GLM option of SAS (SAS Inst., Inc., Cary, NC) were used to test forage N, NDIN, ADIN, DIP, and UIP for linear, quadratic and cubic responses to N fertilization. For each plot, the fertilization rate (0, 50, 100 or 150 lb N/acre) was not necessarily the same on both application dates (see Table 1); therefore, for the first and second harvest, contrast statements were constructed based on initial (April) application of ammonium nitrate. For the third harvest, contrast statements were based on the second application of fertilizer N. A combined analysis of the data from all three harvests at each site-year was conducted by similar methods. This analysis included seven cumulative annual fertilization rates (0, 50, 100, 150, 200, 250 and 300 lb N/acre), and a test for quartic effects was included in the model.

## Results and Discussion

Contrast statements for N and N components are presented in Table 2. Concentrations of N increased linearly ($P < 0.001$) with increasing fertilization N at both sites on Harvests 1 and 3 but were unaffected ($P > 0.07$) by N fertilization on the second harvest date. The linear increase in N concentration is related to the readily available N provided through fertilization. The concentrations of NDIN at both sites for Harvest 1, and at the Stephens site on Harvest 3 decreased linearly ($P < 0.05$), while concentrations of NDIN decreased in a quadratic pattern ($P < 0.02$) at the Latta site for Harvest 3. Concentrations of NDIN were unaffected ($P > 0.11$) by N fertilization at either site on Harvest 2. Concentrations of ADIN decreased linearly ($P < 0.01$) on Harvest 3 at both sites, while a cubic decline ($P < 0.0001$) was detected at the Stephens site for Harvest 1. Increasing levels of N fertilization decreased the proportion of N that was associated with the fiber components of the plant.

Contrast statements for UIP and DIP are presented in Table 3. Concentrations of UIP (DM basis) increased ($P = 0.0002$) linearly for Harvest 1 at the Stephens site, and at both sites ($P \leq 0.002$) on Harvest 3 with increasing rates of N fertilization. Previously other researchers (Johnson et al., 2001; Cuomo and Anderson, 1996) have reported similar linear responses in UIP with N fertilization. Concentrations of DIP (DM basis) increased linearly at both sites on Harvests 1 and 3 ($P < 0.001$). However, concentrations of both UIP and DIP were unaffected ($P > 0.08$) by N fertilization on Harvest 2 at both sites. Similarly, concentrations of UIP (N basis) decreased linearly ($P \leq 0.004$) at both sites on Harvests 1 and 3 with increasing N fertilization. Concentrations of UIP and DIP were unaffected ($P > 0.08$) by carryover effects of the initial application of N fertilizer on Harvest 2.

## Implications

Increasing levels of N fertilization produced higher proportions of DIP in these bermudagrass forages. The higher levels of DIP should help insure adequate ruminal microbial efficiency. Nitrogen fertilization results in a higher proportion of total N in the cell solubles, and a higher proportion of total N being degraded in the rumen.

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

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

[1] Total application for the entire growing season

[2] April 28, 2000

[3] July 19, 2000

**Table 2. Concentrations of N and N components for the bermudagrass forages harvested at two site (Latta and Stephens) on three dates.**

| Fertilization rate | N | | NDIN[1] | | ADIN | |
|---|---|---|---|---|---|---|
| lb N/acre | Latta | Stephens | Latta | Stephens | Latta | Stephens |
| **Harvest 1[2]** | ---------%------- | | ---------- % of N ---------- | | | |
| 0 | 2.97 | 1.78 | 29.8 | 44.5 | 4.74 | 11.49 |
| 50 | 3.19 | 2.26 | 28.4 | 39.8 | 5.02 | 9.56 |
| 100 | 3.33 | 2.47 | 26.3 | 39.6 | 4.60 | 9.17 |
| 150 | 3.53 | 2.89 | 24.4 | 35.4 | 4.43 | 8.32 |
| SE[3] | 0.048 | 0.100 | 1.50 | 1.26 | 0.225 | 0.363 |
| Effect | | | | | | |
| Cubic | 0.468 | 0.297 | 0.906 | 0.151 | 0.369 | <0.0001 |
| Quadratic | 0.854 | 0.767 | 0.909 | 0.860 | 0.374 | 0.201 |
| Linear | <0.0001 | <0.0001 | 0.033 | 0.001 | 0.276 | 0.242 |
| **Harvest 2** | ---------%------- | | ---------- % of N ---------- | | | |
| 0 | 2.56 | 1.94 | 29.8 | 38.6 | 4.74 | 7.22 |
| 50 | 2.65 | 1.99 | 28.4 | 35.2 | 5.03 | 5.79 |
| 100 | 2.65 | 2.08 | 26.3 | 37.7 | 4.60 | 5.89 |
| 150 | 3.16 | 2.10 | 24.4 | 37.5 | 4.43 | 5.67 |
| SE | 0.203 | 0.056 | 1.50 | 1.38 | 0.225 | 0.474 |
| Effect | | | | | | |
| Cubic | 0.532 | 0.661 | 0.565 | 0.187 | 0.313 | 0.406 |
| Quadratic | 0.356 | 0.774 | 0.112 | 0.312 | 0.524 | 0.269 |
| Linear | 0.112 | 0.066 | 0.897 | 0.934 | 0.915 | 0.089 |
| **Harvest 3** | ---------%------- | | ---------- % of N ---------- | | | |
| 0 | 2.11 | 1.81 | 36.4 | 36.1 | 7.92 | 8.58 |
| 50 | 2.45 | 2.11 | 34.6 | 34.4 | 6.29 | 8.07 |
| 100 | 2.75 | 2.33 | 32.7 | 33.7 | 5.91 | 7.38 |
| 150 | 2.69 | 2.63 | 35.4 | 32.7 | 5.91 | 6.81 |
| SE | 0.052 | 0.051 | 0.83 | 0.98 | 0.426 | 0.322 |
| Effect | | | | | | |
| Cubic | 0.181 | 0.513 | 0.243 | 0.764 | 0.660 | 0.832 |
| Quadratic | 0.003 | 0.957 | 0.022 | 0.723 | 0.101 | 0.937 |
| Linear | <0.0001 | <0.0001 | 0.271 | 0.047 | 0.011 | 0.002 |

[1] Abbreviation: NDIN, neutral-detergent insoluble N; ADIN, acid-detergent insoluble N.

[2] Harvest 1, May 30, 2000; Harvest 2, July 7, 2000; Harvest 3, August 18, 2000.

[3] SE = Standard error of the mean.

**Table 3. Concentrations of UIP and DIP of the bermudagrass forages harvested at two sites (Latta and Stephens) on three dates.**

| Fertilization rate | UIP[1] | | DIP | | UIP | |
|---|---|---|---|---|---|---|
| lb N/acre | Latta | Stephens | Latta | Stephens | Latta | Stephens |
| **Harvest 1[2]** | % of DM | | | | % of N | |
| 0 | 1.26 | 1.01 | 1.71 | 0.77 | 42.3 | 56.9 |
| 50 | 1.27 | 1.14 | 1.92 | 1.12 | 40.1 | 51.1 |
| 100 | 1.29 | 1.17 | 2.04 | 1.30 | 38.8 | 47.5 |
| 150 | 1.26 | 1.26 | 2.27 | 1.63 | 35.7 | 43.6 |
| SE[3] | 0.040 | 0.031 | 0.052 | 0.081 | 1.21 | 1.66 |
| Effect | | | | | | |
| Cubic | 0.744 | 0.251 | 0.350 | 0.415 | 0.627 | 0.741 |
| Quadratic | 0.653 | 0.529 | 0.859 | 0.917 | 0.732 | 0.596 |
| Linear | 0.986 | 0.0002 | <0.0001 | <0.0001 | 0.004 | <0.0001 |
| **Harvest 2** | % of DM | | | | % of N | |
| 0 | 1.05 | 1.09 | 1.35 | 0.84 | 47.0 | 56.9 |
| 50 | 1.09 | 1.03 | 1.32 | 0.97 | 50.2 | 51.7 |
| 100 | 1.09 | 1.06 | 1.31 | 1.03 | 51.4 | 51.0 |
| 150 | 1.12 | 1.08 | 1.73 | 1.03 | 45.5 | 51.4 |
| SE | 0.029 | 0.027 | 0.132 | 0.062 | 2.22 | 1.93 |
| Coefficients | | | | | | |
| Cubic | 0.671 | 0.365 | 0.515 | 0.986 | 0.625 | 0.719 |
| Quadratic | 0.912 | 0.151 | 0.142 | 0.379 | 0.083 | 0.212 |
| Linear | 0.193 | 0.808 | 0.132 | 0.078 | 0.786 | 0.110 |
| **Harvest 3** | % of DM | | | | % of N | |
| 0 | 1.18 | 1.06 | 0.93 | 0.75 | 55.9 | 58.4 |
| 50 | 1.25 | 1.12 | 1.19 | 0.99 | 51.3 | 53.3 |
| 100 | 1.33 | 1.23 | 1.42 | 1.10 | 48.4 | 52.7 |
| 150 | 1.36 | 1.21 | 1.32 | 1.42 | 51.0 | 46.0 |
| SE | 0.028 | 0.029 | 0.038 | 0.036 | 0.84 | 0.88 |
| Coefficients | | | | | | |
| Cubic | 0.799 | 0.219 | 0.101 | 0.064 | 0.348 | 0.015 |
| Quadratic | 0.550 | 0.218 | 0.0003 | 0.283 | 0.001 | 0.424 |
| Linear | 0.001 | 0.002 | <0.0001 | <0.0001 | 0.001 | <0.0001 |

[1] Abbreviation: UIP, undegradable intake protein; DIP, degradable intake protein.

[2] Harvest 1, May 30,; Harvest 2, July 7, 2000; Harvest 3, August 18, 2000.

[3] SE = Standard error of the mean.

# Effects of Management on the Voluntary Dry-Matter Intake and Dry-Matter Digestibility of Tall Fescue Hay

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## Story In Brief

A digestion trial utilizing a 4 x 4 Latin square design was initiated to determine the effects of management before baling on the voluntary DM intake (DMI), organic matter (OM) and DM digestibility, in situ disappearance kinetics, and rate of passage for tall fescue (*Festuca arundinacea* Schreb.) hays consumed by steers (average initial BW = 500.0 ± 45.1 lb). The four tall fescue hays utilized in this experiment were baled at 9.9 (low, L) and 22.5% (high, H) moisture prior to rainfall, and at 24.6% moisture after a 0.9-in. rainfall event (HR) and at 9.3% moisture after an accumulation of 2.8 in of rain (LR). Voluntary DM intake of hay and the total diet were greater ($P < 0.05$) for steers consuming the non-rain damaged hays than for those fed the HR hay. However, digestibilities of DM, OM, acid detergent fiber (ADF), and neutral detergent fiber (NDF) were greater ($P < 0.05$) for steers consuming the HR hay than for those fed the non-rain damaged hays. In situ disappearance kinetics of both DM and N indicated that the effective degradabilities of the HR and LR hays were poorer ($P < 0.05$) than either the H or L hays. The results of this study indicate that rain damage can reduce the voluntary intake of hay. Although rain-damaged hays may be inherently less digestible than non rained-on hays, these differences can be masked by reduced intakes and subsequent potential reductions in rates of passage.

## Introduction

Tall fescue is the predominant cool-season grass species harvested for hay in the eastern half of the United States. The recommended growth stage for harvest (boot stage to early heading) typically occurs during the spring, when there is a high probability of rainfall; this can delay harvest, thereby decreasing nutritive value and subsequent animal performance. The alternative to delaying harvest is to subject tall fescue hay crops to a higher probability of rain damage.

After the hay crop is mowed, rainfall events can reduce DM yields, and the entire crop can be lost if extended periods of rainfall occur. Collins (1982) determined that the primary materials leached from the rain-damaged forage are nonstructural carbohydrates. This reduces digestibility, while increasing the concentrations of the fibrous components within the forage.

There have been relatively few feeding studies designed to determine the influence of rain damage on hay intake and digestibility. The objectives of this study were to determine the influence of rainfall and spontaneous heating on the voluntary dry matter intake (DMI), apparent digestibility, rate of passage, ruminal fermentation characteristics, and in situ disappearance kinetics of tall fescue hays in steers consuming these forages.

## Experimental Procedures

*Diets.* The hay treatments were tall fescue hay baled without post-harvest rain exposure at 22.4 and 9.9% moisture (H and L respectively), at 24.6% moisture after a single 0.9 in rainfall event (HR), and at 9.3% moisture after a total accumulation of 2.8 in of rainfall (LR). The hay was harvested on May 22, 2000 at the boot stage of maturity. All hay treatments were chopped with a hay chopper to a 3.0-in particle length and offered three times a day (0630, 1230 and 1830 h) at 110% of the previous 3-day average voluntary intake. A grain supplement was offered in equal portions twice daily (0630 and 1830) at 0.2% of BW.

*Voluntary Intake and Digestibility.* Four ruminally cannulated Brangus x Angus x Gelbvieh steers (average initial BW = 500 ± 45.1 lb) were utilized in a 4 x 4 Latin square design to determine the effects of tall fescue hay management on voluntary DM intake, apparent total tract digestibility, rate of passage, and in situ DM disappearance kinetics of the four experimental hays. The University of Arkansas Animal Care and Use Committee approved the surgical procedures and animal care practices. Steers were housed in 11-ft x 16-ft individual pens in an open-air pole barn with fresh water available continuously. Pens had concrete floors and were cleaned regularly. A 12-h to 12-h light to dark photoperiod was maintained with the overhead lighting in the barn.

Each period consisted of a 10-day voluntary DM intake and adaptation phase, a 4-day total tract collection, a 4-day in situ evaluation of disappearance kinetics of DM, N and neutral detergent fiber (NDF), and 1 day of serial rumen sampling for a total period length of 19 days. Total tract diet digestion was assessed from day 9 to day 14 of each period; forage samples were collected from day 9 to day 12, ort samples were collected from day 10 to day 13, and total fecal output was collected from day 11 to day 14. Steers were fitted with fecal collection bags on day 11, and the fecal collection bags were emptied once daily at 0600 h and the contents weighed. Fecal, hay, and ort samples were weighed and then subsampled after thorough mixing. A subsample of approximately 0.01% of the daily hay fed, ort refusal, and fecal output was collected for further analysis. Daily hay, ort, and fecal subsamples were dried to a constant weight under forced air at 131°F and ground to pass a 1-mm screen. Hay, orts, and fecal samples were composited within animal and period prior to analysis.

*Rate of Passage.* A 2.2-lb aliquot of each experimental hay treatment was prepared for determination of rate of passage by lightly boiling the hay in NDF solution for 1 h and rinsing five times with

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water (203°F) for 5 min. The rinsed NDF residue was then placed in a 131°F forced-air oven until a constant weight was achieved. The NDF residues were then marked with ytterbium (Yb) using an immersion technique. Prior to feeding on day 10, each steer was pulse-dosed with 0.22-lb (DM basis) of Yb-labeled NDF residue from their respective treatment forage. The Yb-labeled forage was inserted into the rumen prior to the 0600 h feeding. Fecal grab samples were taken prior to inserting the labeled forage, and at 6, 12, 18, 24, 32, 40, 48, 60, 72, 84, and 96 h after pulse dosing to determine the rate of passage of each hay treatment. Fecal grab samples and labeled forage samples were dried in a forced air oven to a constant weight at 131°F, and ground in a Wiley mill to pass a 1-mm screen. Concentrations of Yb were determined using inductively coupled plasma spectroscopy. The concentrations of Yb were then fitted to a two-compartment model, and rates of passage of the two compartments and lag time were calculated using PROC NLIN of SAS (SAS Inst., Inc., Cary, NC).

*Diet and Fecal Analyses.* Dry hay, orts, and fecal samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) fitted with a 1-mm screen and subsequently analyzed for N, NDF, acid detergent fiber (ADF), neutral-detergent insoluble N (NDIN), acid-detergent insoluble N (ADIN), DM, and ash. The NDF and ADF analyses were conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Total N for fecal, hay and ort samples was quantified by combustion; the N concentrations in NDF (NDIN) and ADF (ADIN) residues were determined by procedures identical to those used to determine total N, and reported on the basis of total DM and N. Subsamples of hay, supplement, orts, and fecal material were dried for 24 h at 212°F in a convection oven to determine DM and then placed in a muffle furnace for 8 h at 932°F to determine concentrations of ash.

*Statistical Analyses.* The voluntary intake and digestibility measurements were analyzed as a 4 x 4 Latin square design using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Animal and period were considered to be blocking terms. Model sums of squares were separated into treatment, period, and animal effects. When significant ($P < 0.05$) treatment effects were detected, individual treatment means were compared using the protected least significant difference test.

## Results and Discussion

*Nutritive value of hays.* The nutritive values of the four tall fescue hays were of moderately low quality; quality characteristics of the hays and supplement are presented in Table 1.

*Voluntary intake.* Total voluntary dry matter intake and hay DMI, expressed as a percent of BW tended to be greater ($P < 0.10$) for steers consuming the non-rain damaged hays than for the steers consuming the HR hay, while intake of steers fed the LR hay was intermediate and did not differ ($P < 0.10$) from any other hay treatment (Table 2). Generally, intake of hay and total DM were relatively high considering the moderately low nutritional value of the forages. All other measures of intake were not affected ($P \geq 0.100$) by baling treatment.

*Digestibility.* Digestibilities of DM, organic matter (OM), NDF and ADF were greater ($P < 0.10$) when steers were consuming the HR hay diet compared to diets containing hays that were not rain-damaged (Table 2). Reasons for these observations remain unclear. Digestibilities of NDF and ADF were greater ($P < 0.10$) for the HR hay diet than for the H and L hay diets. Diets containing hays that were not subjected to rainfall had similar ($P > 0.10$) digestibilities of DM, OM, NDF, and ADF. Similarly, the diets containing hays that were subjected to rain-damage prior to baling had similar ($P > 0.10$) digestibilities for all measures of nutritive value. The digestibility of CP was unaffected ($P > 0.10$) by baling treatment.

*Rate of Passage.* Rate of passage and retention times of the four tall fescue hay diets are presented in Table 3. All measures of rate of passage and retention time for the four tall fescue hay treatments did not differ ($P \geq 0.256$).

*Disappearance Kinetics.* Kinetic parameters obtained from the ruminal in situ disappearance of the treatment hays are presented in Table 4. Dry matter, N, and NDF were partitioned into three fractions based on susceptibility to ruminal degradation. Fraction A was considered to be the immediately soluble portion. Fraction B was defined as the DM, N or NDF degraded at a measurable rate, while fraction C was undegradable in the rumen. Fractions B and C, lag time, and the fractional rate constant ($K_d$) were determined from the nonlinear model. Fraction A was calculated as [100 – (B + C)], and the potential extent of degradation was calculated as [100 – C]. The effective ruminal degradability was calculated as $A + B \times [K_d/(K_d + K_p)]$, where $K_p$ = passage rate (Orskov and MacDonald, 1979). For disappearance of DM, the L hay had a greater ($P < 0.05$) fraction A than the other hays that incurred rain-damage, spontaneous heating, or both. The HR had the least ($P < 0.05$) amount of its DM partitioned into fraction A; this may have been due to increased losses of nonstructural carbohydrates from leaching prior to baling and spontaneous heating during storage. Conversely, the HR hay had a greater ($P < 0.05$) proportion of its DM in fraction B, which disappears at a measurable rate, and the L hay had the smallest ($P < 0.05$) percentage of DM partitioned into this fraction. The undegradable fraction C was similar ($P > 0.05$) in all four hays, as was extent of disappearance and lag time. The disappearance rates of DM for all treatments were relatively slow ($\leq 0.039$/h). The rate of DM disappearance was greatest ($P < 0.05$) in the L hay, but differences between hays were relatively small, and probably not of great biological significance. The effective degradability was greater ($P < 0.05$) for the L hay than for the hays damaged by rain, spontaneous heating, or both.

In situ NDF disappearance followed trends that were similar to the disappearance of DM. Fraction A in all four hay treatments comprised a very small portion of the total NDF content. This has been attributed to the insoluble nature of cell wall components. The HR hay had a lower ($P < 0.05$) proportion of NDF in fraction A, and a greater ($P < 0.05$) proportion of NDF in fraction B than did the L and LR hays. The rate of NDF disappearance was greater ($P < 0.05$) in the hays that did not suffer rain damage than in LR hay. The HR hay exhibited an intermediate rate that did not differ ($P \geq 0.171$) from any other hay.

The LR hay had a lower ($P < 0.05$) proportion of N in fraction A than the other baling treatments but had a greater ($P < 0.05$) proportion of N in fraction B. The LR baling treatment had a greater ($P < 0.05$) proportion of N in fraction C than the hays that were baled prior to rainfall. This is may be explained on the basis of leaching of the soluble forage N components during rainfall events. Therefore, the N that remained in the forage was more likely to be bound within, or associated with, the fibrous portions of the forage. The H hay had a greater ($P < 0.05$) potential extent of disappearance than hays that were subjected to rainfall. Effective degradability of N was greatest ($P < 0.05$) for L hay, with the LR hay having the lowest ($P < 0.05$) effective degradability of N.

## Implications

The results of this study indicate that rain damage can reduce the voluntary intake of hay. Although damaged hays may be inher-

ently less digestible than non rained-on hays, these differences can be masked by reduced intakes and subsequent potential reductions in rates of passage.

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**Table 1. Nutritive value of four tall fescue hays made under different management conditions and grain supplement offered to four steers.**

| | Hay treatment | | | | |
|---|---|---|---|---|---|
| | H[1] | L | HR | LR | Supplement |
| | | % of DM | | | |
| CP | 8.7 | 8.0 | 7.8 | 8.1 | 21.5 |
| NDF | 79.0 | 74.3 | 82.8 | 81.3 | 40.32 |
| ADF | 45.9 | 45.0 | 49.0 | 48.6 | 29.44 |
| NDIN[2] | 0.86 | 0.65 | 0.82 | 0.66 | 0.48 |
| ADIN | 0.27 | 0.28 | 0.39 | 0.26 | 0.14 |
| | | % of N | | | |
| NDIN | 62.1 | 51.1 | 65.6 | 51.3 | 13.83 |
| ADIN | 19.6 | 22.0 | 31.0 | 20.5 | 4.12 |

[1] Abbreviations; H, high-moisture bales (22.5 % moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in total rainfall); L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in total rainfall); and supplement contained 60.9% soy hulls, 30.2% soybean meal, 3.0% molasses, 5.5% TM salt, 0.4% Vitamin ADE premix, and 0.03% trace mineral supplement.

[2] Abbreviations; NDIN, neutral detergent insoluble nitrogen; ADIN, acid detergent insoluble nitrogen.

**Table 2. Dry matter intake and digestibilities of the four tall fescue hays made under different management conditions when fed to steers.**

| | Hay treatment | | | | |
|---|---|---|---|---|---|
| | H[1] | L | HR | LR | SE |
| Total intake[2] | | | | | |
| Total DMI, % of BW[3] | 2.28$^{a}$ | 2.31$^{a}$ | 2.04$^{b}$ | 2.15$^{ab}$ | 0.057 |
| Hay DMI, % of BW | 2.10$^{a}$ | 2.10$^{a}$ | 1.85$^{b}$ | 1.93$^{ab}$ | 0.062 |
| Total DMI, kg/d | 5.26 | 5.15 | 4.69 | 4.73 | 0.162 |
| Total OMI, kg/d | 4.94 | 4.84 | 4.47 | 4.53 | 0.151 |
| Hay DMI, kg/d | 4.81 | 4.72 | 4.24 | 4.31 | 0.158 |
| Hay OMI, kg/d | 4.54 | 4.46 | 3.97 | 4.19 | 0.162 |
| Digestibility, % | | | | | |
| DM | 50.9$^{b}$ | 49.8$^{b}$ | 57.1$^{a}$ | 53.0$^{ab}$ | 1.70 |
| OM | 53.1$^{b}$ | 51.7$^{b}$ | 59.7$^{a}$ | 55.8$^{ab}$ | 1.63 |
| CP | 42.1 | 43.3 | 40.8 | 38.9 | 0.046 |
| NDF | 56.4$^{bc}$ | 52.3$^{c}$ | 63.8$^{a}$ | 59.4$^{ab}$ | 0.018 |
| ADF | 47.5$^{bc}$ | 44.8$^{c}$ | 57.8$^{a}$ | 53.0$^{ab}$ | 0.020 |

$^{a,b,c}$ Means in the same row with different superscripts differ ($P < 0.10$)

[1] Abbreviations; H, high-moisture bales (22.5 % moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in total rainfall).

[2] Total intake, the average intake over the entire 19-day period.

[3] Abbreviations; DMI, voluntary dry matter intake; OMI, voluntary organic matter intake.

**Table 3. Rates of passage[1] for the four tall fescue hay based diets when fed to steers.**

| | Hay treatment | | | | |
|---|---|---|---|---|---|
| Item | H[2] | L | HR | LR | SE |
| F[3] | 0.116[3] | 0.116 | 0.110 | 0.100 | 0.0097 |
| S | 0.048 | 0.039 | 0.046 | 0.045 | 0.0034 |
| TD | 15.20 | 14.33 | 15.64 | 15.12 | 1.101 |
| FMRT | 18.24 | 17.26 | 19.57 | 20.64 | 1.74 |
| RMRT | 21.68 | 26.36 | 22.32 | 23.01 | 1.57 |
| TMRT | 55.12 | 57.95 | 57.53 | 58.76 | 3.13 |

1 All measures of rate of passage and retention time were statistically similar ($P \geq 0.256$) for the four hay diets.

2 Abbreviations; H, high-moisture bales (22.5 % moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in total rainfall).

3 Abbreviations; F, fast compartment rate of passage; S, slow compartment rate of passage; TD, lag time; FMRT, fast compartment mean retention time; RMRT, ruminal mean retention time; TMRT, total mean retention time.

**Table 4. In situ digestion kinetics of DM, NDF and N, of four tall fescue hays made under different management conditions.**

| | Hay treatment | | | | |
|---|---|---|---|---|---|
| | H1 | L | HR | LR | SE |
| DM | | | | | |
| A[2], % | 16.2[b] | 20.9[a] | 13.2[c] | 17.0[b] | 0.39 |
| B, % | 55.8[b] | 50.7[c] | 57.7[a] | 55.8[b] | 0.43 |
| C, % | 28.0 | 28.4 | 29.1 | 27.3 | 0.56 |
| Potential extent, % | 72.0 | 71.6 | 70.9 | 72.7 | 0.56 |
| Kd, /h | 0.035[b] | 0.039[a] | 0.034[bc] | 0.031[c] | 0.0009 |
| Lag, /h | 4.00 | 3.58 | 3.63 | 2.89 | 0.298 |
| Effective degradability, % | 40.0[b] | 46.2[a] | 37.7[b] | 39.8[b] | 1.18 |
| NDF | | | | | |
| A, % of NDF | 3.5[de] | 5.2[d] | 0.9e | 5.9[d] | 1.15 |
| B, % of NDF | 65.9[de] | 62.3e | 68.1[d] | 63.3e | 1.25 |
| C, % of NDF | 30.7 | 32.5 | 31.3 | 29.3 | 0.89 |
| Potential extent, % of NDF | 69.3 | 67.5 | 69.0 | 69.2 | 1.26 |
| Kd, /h | 0.037[a] | 0.039[a] | 0.034[ab] | 0.032[b] | 0.0012 |
| Lag, /h | 4.53 | 4.22 | 3.97 | 3.86 | 0.386 |
| Effective degradability, % of NDF | 32.2 | 36.2 | 30.0 | 32.5 | 1.72 |
| N | | | | | |
| A, % of N | 24.6[a] | 24.1[a] | 18.8[b] | 2.8[c] | 1.32 |
| B, % of N | 51.4[b] | 48.8[b] | 52.1[b] | 65.3[a] | 1.07 |
| C, % of N | 23.9[c] | 27.0[bc] | 29.1[ab] | 31.9[a] | 1.16 |
| Potential extent, % of N | 76.1[a] | 73.0[ab] | 70.9[bc] | 68.1[c] | 1.16 |
| Kd, /h | 0.031 | 0.042 | 0.034 | 0.033 | 0.0028 |
| Lag, /h | 3.22 | 1.64 | 5.67 | 3.51 | 0.929 |
| Effective degradability, % of N | 44.9[b] | 49.7[a] | 41.1[b] | 30.7[c] | 0.772 |

[a,b,c] Means in the same row without common superscripts differ ($P<0.05$)

[d,e] Means in the same row without common superscripts differ ($P< 0.10$)

1 Abbreviations; H, high-moisture bales (22.5 % moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in total rainfall).

2 Abbreviations; A, immediately soluble portion of either the DM, NDF or N; B, DM, NDF or N degraded at a measurable rate; C, undegradable in the rumen; $K_d$, fractional rate constant; lag, lag time before measurable degradation occurred; potential extent, potential extent of degradation calculated as A + B; effective degradability, effective degradability calculated as $A + B \times [K_d/(K_d + K_p)]$, where $K_p$ = passage rate observed for each treatment by period combination.

# Using Orchardgrass and Endophyte-Free Fescue Versus Endophyte-Infested Fescue Overseeded on Bermudagrass for Cow Herds: Three-Year Summary of Forage Characteristics

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## Story in Brief

A trial was initiated in January 2000 to evaluate endophyte-free tall fescue (*Festuca arundinacea* Schreb.) or orchardgrass (*Dactylis glomerata* L.) overseeded into dormant common bermudagrass [*Cynodon dactylon* (L.) Pers.] sods for spring-calving cows. Two management systems were evaluated in an effort to help these cool-season grasses persist; these included rotations to new paddocks twice weekly or twice monthly. The grazing system x evaluation date interaction affected ($P = 0.08$) the percentage of desired cool-season species in each pasture. Generally, endophyte-free and endophyte-infested tall fescue remained stable over the entire study. Endophyte-free tall fescue managed with both a twice weekly and twice monthly rotation schedule had similar ($P > 0.1$) percentages of endophyte-free fescue on the June 2000 and November 2002 evaluation dates. In both endophyte-free systems, the percentage of fescue was greater than 55% on all dates after grazing was initiated. Through June of 2002, the orchardgrass systems maintained at least as high a percentage of orchardgrass as observed on the initial evaluation date (November 1999); however, the percentage of orchardgrass in pastures rotated twice monthly declined sharply ($P < 0.10$) from 34.1 to 14.7% between June and November 2002. We intend to monitor these pastures for at least one additional year prior to conducting a final summary because of annual variation.

## Introduction

Many cow-calf enterprises in the Ozarks are maintained on pasture systems that are mixtures of endophyte-infested tall fescue and common bermudagrass. The association of the fungus *Neotyphodium coenophialum* with tall fescue has a positive effect on plant persistence, but the toxins produced by this fungus affect livestock performance negatively. Generally, other perennial cool-season grasses, such as endophyte-free tall fescue and orchardgrass, have persisted poorly when subjected to the same types of management as endophyte-infested fescue. A trial was initiated in January 2000 to evaluate the effectiveness of overseeding endophyte-free tall fescue or orchardgrass into dormant common bermudagrass sods for spring-calving cows. Two management systems were used in an effort to help these cool season grasses persist; these included rotations to new paddocks either twice weekly or twice monthly. Our objective was to compare these forage management systems with a typical mixture of endophyte-infested tall fescue and common bermudagrass that was managed on a twice monthly rotation schedule. This report includes data from the initial 3 years of the study.

## Experimental Procedures

*Establishment and Maintenance of Pastures.* Nine 10-acre mixed-species pastures with a base sod of common bermudagrass were sprayed (Roundup Ultra®, Monsanto Co., St. Louis, MO) in the spring of 1998 to eliminate annual and perennial cool-season grasses. In the late-summer of 1998, cattle were used to remove summer growth of forage that was primarily bermudagrass. Cattle were used to remove available forage because many of the pastures were not suitable for haying.

In September and early October 1998, thirteen 10-acre pastures (including the nine pastures sprayed in the spring) were fertilized to soil test recommendations of the Arkansas Cooperative Extension Service, and 'Benchmark' orchardgrass and 'Kentucky 31' endophyte-free tall fescue were overseeded into five and four of these pastures, respectively. The remaining four pastures had mixtures of endophyte-infested tall fescue and bermudagrass that had been established previously, and these were retained as controls that represented typical pastures in the southern Ozarks. In April 1999, three independent observers evaluated each overseeded pasture for continuous row coverage by cool-season seedlings. During the 1999 growing season, pastures were grazed lightly to control forage growth. All pastures were fertilized with urea (46-0-0) at a rate of 60 lb N/acre on September 9 or 10, 1999. Similar applications were made each subsequent year in mid February, early June, and early September; therefore a total of 180 lb N/acre were applied annually. Soil tests were obtained each year in August and any needed potassium, phosphorus, or lime was applied based on soil test recommendations each September. All 13 pastures were evaluated initially (November 1999; prior to initiating the trial) for basal cover and species composition by the modified step-point method (Owensby, 1973). In this method, a modified pointer is placed randomly throughout the pasture; at each pointer placement the species of the nearest plant is identified, and species composition can be calculated on a percentage basis. These procedures were repeated in June and November of each subsequent year to assess the effects of grazing on the species composition and basal cover of the experimental pastures.

Each 10-acre pasture was subdivided into either eight (1.25-acre) or two (5-acre) paddocks using electric fencing to supplement existing permanent fences. Orchardgrass and endophyte-free tall fescue mixtures with bermudagrass were managed with either a twice weekly rotation to a fresh 1.25-acre paddock or a twice-monthly rotation to fresh 5-acre paddock. The endophyte-infested pastures were managed on a twice monthly rotation schedule. There were two replications of the orchardgrass pastures managed with the twice monthly rotation system, and three replications of the twice weekly rotation system. There were two replicates of both the twice weekly

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and twice monthly rotation systems for the endophyte-free tall fescue pastures. Pastures were evaluated monthly for forage availability using a rising-plate disk meter. To protect the non-toxic forages from trampling and overgrazing when forage was limiting, cattle were fed bermudagrass hay on single 1.25-acre paddocks in the twice weekly rotation system and on an area of comparable size constructed with electric wire for the twice monthly rotation system.

*Cattle Management.* Sixty-five spring-calving cows (1208 ± 150 lb) were stratified by weight, age, and breeding and assigned randomly to one of the 13 pastures (five per pasture) on January 11, 2000. Cows initially assigned to each pasture remained on their assigned pasture continuously throughout the trial to assess the cumulative effects of each grazing system on animal performance. Cows were checked for pregnancy by rectal palpation in January of each year, and any open cows were replaced with pregnant first-calf heifers. Similarly, any cows without calves at the end of the calving season (May 1) were replaced with a primiparous cow and her calf. In an effort to control the flush of forage growth that occurs in the spring, extra "thin" cows were placed on these pastures in order to improve their body condition. This technique was used because all pastures were not suitable for harvesting extra forage as hay. Extra cows were assigned to a specific 10-acre pasture and remained there as long as forage availability permitted. Within each pasture, cows were co-mingled and managed with the same rotation schedule as the five permanently assigned cows. Additional grazing days for these extra cows were tabulated for each pasture and analyzed as a response variable.

Forage species composition and basal cover data were analyzed as a repeated measures design with grazing systems as the whole-plot term and evaluation date as the repeated measures term. Forage availability and data from extra spring grazing cows were analyzed similarly. Significance was declared at $P = 0.1$ unless otherwise indicated.

## Results and Discussion

Visual evaluation of continuous row coverage by cool-season seedlings in April 1999 indicated that there were no differences ($P = 0.81$) between orchardgrass and endophyte-free tall fescue pastures. The overall mean was 68.4%, indicating that establishment was relatively good. In some small areas, establishment was poor because the bermudagrass sod was particularly vigorous and competitive, and the cattle did not remove the entire existing bermudagrass canopy adequately prior to seeding.

The percentages of basal cover, bermudagrass, and other species in our experimental pastures (Table 1) were affected by evaluation date ($P < 0.001$), but not by grazing system ($P > 0.46$) or the interaction of grazing system and evaluation date ($P > 0.14$). Basal cover ranged from 36.3 to 47.7%, and was lowest ($P < 0.10$) on the November 2000 and June 2001 evaluation dates. Percentage of bermudagrass was the lowest ($P < 0.10$) on the June 2000 and June 2001 evaluation dates, but the overall range across all dates was relatively narrow (29.2 to 39.0%). The grazing system x evaluation date interaction affected ($P = 0.08$) the percentage of desired cool-season species in each pasture. Generally, the endophyte-free and endophyte-infested tall fescue remained stable over the entire study (Table 2). For endophyte-free tall fescue, both rotation systems had similar ($P > 0.10$) percentages of endophyte-free tall fescue on the June 2000 and November 2002 evaluation dates. In both endophyte-free tall fescue systems, the percentage of fescue was greater than 55% on all dates after grazing was initiated (Table 2). Through June of 2002, the orchardgrass systems maintained at least as high a percentage of orchardgrass as observed on the initial evaluation date (November 1999); however, the percentage in pastures rotated twice monthly declined sharply ($P < 0.10$) from 34.1 to 14.7% between June and November 2002.

The sampling date main effect affected forage availability ($P < 0.0001$), but grazing system and the interaction of grazing system and sampling date did not ($P > 0.12$). Seasonal trends for forage availability are shown in Figure 1. Extra grazing cows were used to control the flush of spring forage growth (Table 3). There were no differences ($P > 0.10$) across grazing systems for animal grazing days, initial weight, final weight, or final body condition score. The total weight gain per grazing animal was greater ($P < 0.10$) for the orchardgrass systems than for endophyte-infested fescue or endophyte-free fescue rotated twice weekly. Extra grazers on both orchardgrass systems gained approximately twice as much weight as cattle grazing endophyte-infested pastures (151 or 146 vs. 72 lb/head). The respective average daily gains for cattle grazing orchardgrass pastures managed with twice weekly and twice monthly rotations were 3.1 and 2.9 lb/head/day, which were greater ($P < 0.1$) than gains observed for extra grazers consuming endophyte-infested pastures (1.3 lb/head/day). The average daily gain for all cattle was greater ($P < 0.1$) in 2000 (3.2 lb/head/day) than for either 2001 or 2002 (2.2 and 1.6 lb/head/day, respectively).

## Implications

Endophyte-free tall fescue overseeded into common bermudagrass sods has persisted well over a three-year period, regardless of rotation schedule. Orchardgrass pastures maintained stands that were at least comparable to initial levels through June 2002, but stands appeared to decline in late 2002.

## Literature Cited

Owensby, C.E. 1973. J. Range Manage. 26:302-303.

**Table 1. Percentage of basal cover, bermudagrass, and other species for pastures at Batesville, AR, from November 1999 through 2002.[1]**

| | Evaluation date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Nov 99 | June 00 | Nov 00 | June 01 | Nov 01 | June 02 | Nov 02 | SE |
| Basal cover | 44.5$^{ab}$ | 45.2$^{ab}$ | 36.3$^{c}$ | 36.8$^{c}$ | 47.7$^{a}$ | 42.5$^{b}$ | 43.9$^{ab}$ | 1.6 |
| Bermudagrass | 36.9$^{a}$ | 31.5$^{b}$ | 37.7$^{a}$ | 29.2$^{b}$ | 36.3$^{a}$ | 38.7$^{a}$ | 39.0$^{a}$ | 1.8 |
| Other species | 21.8$^{a}$ | 12.7$^{cd}$ | 18.1$^{b}$ | 18.3$^{b}$ | 14.4$^{c}$ | 9.2$^{d}$ | 12.9$^{c}$ | 1.5 |

$^{a,b,c}$ Means in a row without common superscripts differ ($P < 0.1$).

[1] Data were determined by the modified step-point method (Owensby, 1973). Grazing system and the grazing system x evaluation date interaction did not affect ($P > 0.14$) any of these response variables.

**Table 2. Percentage of desired cool-season grasses within the sward at Batesville, AR, from November 1999 through 2002.[1]**

| | Evaluation date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| System[2] | Nov 99 | June 00 | Nov 00 | June 01 | Nov 01 | June 02 | Nov 02 | SE |
| OG - HM | 36.9$^{c}$ | 52.1$^{ab}$ | 32.9$^{c}$ | 50.4$^{ab}$ | 52.9$^{ab}$ | 56.9$^{a}$ | 42.7$^{bc}$ | 4.7 |
| OG - LM | 36.3$^{ab}$ | 48.6$^{a}$ | 34.4$^{b}$ | 40.7$^{ab}$ | 31.9$^{b}$ | 34.1$^{b}$ | 14.7$^{c}$ | 5.8 |
| FF - HM | 45.1$^{b}$ | 63.5$^{a}$ | 55.4$^{ab}$ | 60.3$^{a}$ | 64.1$^{a}$ | 58.1$^{ab}$ | 61.3$^{a}$ | 5.8 |
| FF - LM | 53.0$^{b}$ | 68.8$^{a}$ | 59.1$^{ab}$ | 72.5$^{a}$ | 67.2$^{a}$ | 64.7$^{ab}$ | 68.5$^{a}$ | 5.8 |
| IF - LM | 49.0 | 52.6 | 54.6 | 54.2 | 48.6 | 46.9 | 53.4 | 4.1 |

$^{a,b,c}$ Means in a row without common superscripts differ ($P < 0.1$).

[1] Data were determined by the modified step-point method (Owensby, 1973). The grazing system x evaluation date interaction affected species composition at $P = 0.08$.

[2] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

**Table 3. Performance of extra grazing cows added to control spring forage growth at Batesville, AR, from 2000 through 2002.**

| Main effect | Extra grazing days[1] | Total Initial weight | Final weight | Initial BCS[2] | Final BCS | Total weight gain | Average daily gain |
|---|---|---|---|---|---|---|---|
| System[3] | Days | ------- lb ------- | | | | lb/head | lb/head/day |
| OG - HM | 252 | 1082 | 1234 | 5.5$^{b}$ | 7.0 | 151$^{a}$ | 3.1$^{a}$ |
| OG - LM | 206 | 1078 | 1224 | 5.5$^{b}$ | 7.0 | 146$^{ab}$ | 2.9$^{ab}$ |
| FF - HM | 203 | 1145 | 1244 | 5.7$^{ab}$ | 6.9 | 100$^{cd}$ | 2.0$^{bc}$ |
| FF - LM | 170 | 1107 | 1217 | 6.1$^{a}$ | 7.1 | 110$^{bc}$ | 2.2$^{abc}$ |
| IF - LM | 198 | 1120 | 1192 | 6.0$^{a}$ | 7.0 | 72$^{d}$ | 1.3$^{c}$ |
| SE | 26 | 30 | 30 | 0.2 | 0.1 | 13 | 0.4 |
| Year | | | | | | | |
| 2000 | 267$^{a}$ | 1092 | 1272 | 5.8 | 7.1$^{a}$ | 180$^{a}$ | 3.2$^{a}$ |
| 2001 | 115$^{b}$ | 1117 | 1188 | 5.9 | 7.1$^{a}$ | 71$^{b}$ | 2.2$^{b}$ |
| 2002 | 236$^{a}$ | 1110 | 1207 | 5.6 | 6.8$^{b}$ | 97$^{c}$ | 1.6$^{b}$ |
| SE | 16 | 34 | 37 | 0.2 | 0.1 | 9 | 0.3 |

$^{a,b,c,d}$ Means within a column and main effect without common superscripts differ ($P < 0.1$).

[1] Grazing days by extra cows to control spring growth.

[2] BCS = body condition score (1 = emaciated, 9 = obese).

[3] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

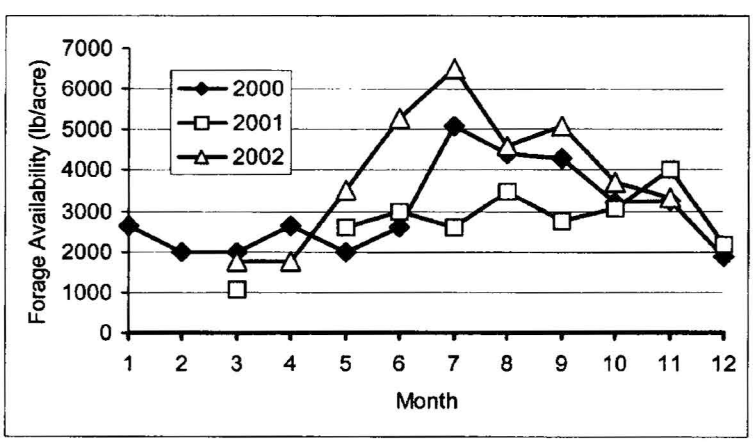


**Figure 1. Forage availability (SE = 189 lb/acre) for Batesville pastures.**

# Using Orchardgrass and Endophyte-Free Fescue Versus Endophyte-Infested Fescue Overseeded on Bermudagrass for Cow Herds: Three-Year Summary of Cattle Performance

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## Story in Brief

A trial was initiated in January 2000 to evaluate endophyte-free tall fescue (*Festuca arundinacea* Schreb.) or orchardgrass (*Dactylis glomerata* L.) overseeded into dormant common bermudagrass [*Cynodon dactylon* (L.) Pers.] sods for spring-calving cows. Two management systems were evaluated in an effort to help these cool-season grasses persist; these include rotations to new paddocks twice weekly or twice monthly. To serve as controls, pastures (n = 4) containing approximately 50% endophyte-infested fescue, with the balance mainly in bermudagrass and other warm- and cool-season annuals, were evaluated concurrently. This type of pasture, with approximately 50% dilution of fescue, represents a common grazing situation in northern Arkansas. Actual weaning weight, adjusted 205-day weaning weight, total gain from birth to weaning, and average daily gain from birth to weaning were greater ($P < 0.04$) for calves on non-toxic forages (endophyte-free fescue or orchardgrass) than for those on endophyte-infested fescue pastures. Calves raised on both orchardgrass grazing systems and endophyte-free fescue rotated twice monthly exhibited a 51- to 62-lb advantage in actual weaning weight over those on endophyte-infested fescue pastures. It is not clear why calves raised on endophyte-free fescue pastures rotated twice weekly did not exhibit this type of advantage. Cows grazing orchardgrass and endophyte-free fescue pastures exhibited higher ($P < 0.10$) body weights and body condition scores at calving, breeding, and weaning than cows grazing endophyte-infested fescue pastures. We intend to monitor these pastures for at least one additional year prior to conducting a final summary.

## Introduction

Many cow-calf enterprises in the Ozarks are maintained on pasture systems that are mixtures of endophyte-infested tall fescue and common bermudagrass. The association of the fungus *Neotyphodium coenophialum* with tall fescue has a positive effect on plant persistence, but the toxins produced by this fungus affect livestock performance negatively. A trial was initiated in January 2000 to evaluate the effectiveness of overseeding endophyte-free fescue or orchardgrass into dormant common bermudagrass sods for spring-calving cows. Orchardgrass and endophyte-free tall fescue pastures were rotated either twice monthly or twice weekly in an effort to help these forages persist. Our objective was to compare the cattle performance on these forage management systems with a typical mixture of endophyte-infested fescue and common bermudagrass that was managed on a twice monthly rotation schedule. This report includes data from the initial 3 years of the study.

## Experimental Procedures

A detailed description of the establishment of endophyte-free fescue and orchardgrass forages and all forage management practices are reported in a companion report (Coblentz et al., 2003). Sixty-five spring-calving cows (1208 ± 150 lb) were stratified by weight, age, and breeding and assigned to one of the thirteen pastures (five per pasture) on January 11, 2000. Initially, at least one cow per pasture had a Hereford sire and Brahman x Angus dam; the balance of the cows were purebred Angus. Cows and calves were not supplemented other than with hay when forage was limiting, but a commercial mineral mix was offered free choice throughout the trial. From mid-May through mid-July of each year, one Gelbvieh bull was assigned to each pasture. Cows were weighed and evaluated for body condition score on a monthly basis. Calves were weighed monthly and weaned in early October. Actual and 205-day adjusted weaning weights were obtained and analyzed as response variables. Milk production was evaluated by the weigh-suckle-weigh method in May and July of each year.

Cows initially assigned to each pasture remained on their assigned pasture continuously throughout the trial in order to assess the cumulative effects of each grazing system on animal performance. Cows were checked for pregnancy by rectal palpation in January of each year, and any open cows were replaced with pregnant first-calf heifers. Similarly, any cows without calves at the end of the calving season (May 1) were replaced with a primiparous cow and her calf. All data presented are 3-year averages, except for milk production and pregnancy rate, which include data from the 2000 and 2001 seasons only. Means were compared with four contrast statements that evaluated: 1) endophyte-infested fescue vs. non-toxic forages (orchardgrass and endophyte-free fescue); 2) endophyte-free fescue vs. orchardgrass; 3) twice weekly vs. twice monthly rotation (excluding endophyte-infested fescue); and 4) the interaction of #2 and #3.

## Results and Discussion

Birth weight of calves (Table 1) was not affected by grazing system ($P \geq 0.17$). Actual weaning weight, adjusted 205-day weaning weight, total gain from birth to weaning, and average daily gain from birth to weaning were greater ($P \leq 0.041$) for calves on non-toxic forages than for those on endophyte-infested fescue pastures. No other contrast was significant ($P \geq 0.13$) for any of these response variables. Calves raised on orchardgrass pastures managed with either system and endophyte-free fescue rotated twice monthly

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exhibited a 51- to 62-lb advantage in actual weaning weight over those on endophyte-infested pastures. It is not clear why calves raised on endophyte-free pastures rotated twice weekly did not exhibit this advantage. Generally, calves raised on endophyte-infested pastures with 50% dilution (Coblentz et al., 2003) exhibited a level of performance that may be quite acceptable to the many part-time producers operating in northern Arkansas, but this performance was poorer than observed for calves raised on non-toxic forages.

Cow weights (Table 2) and body condition scores (Table 3) at calving, breeding, and weaning were lower ($P < 0.10$) for cows grazing endophyte-infested pastures than for those grazing orchardgrass and endophyte-free pastures. At breeding, body condition scores were higher ($P < 0.001$) for cows grazing non-toxic pastures rotated twice monthly than for those grazing non-toxic pastures rotated twice weekly. In addition, the interaction of rotation frequency and non-toxic forage also was significant ($P = 0.011$), largely due to the difference in body condition score (0.6 units) that was observed between twice monthly and twice weekly rotation schedules for endophyte-free fescue pastures, but was not observed for orchardgrass systems. Generally, milk production in May and July showed little response to treatment; respective 2-year averages were 11.7 and 7.9 lb/cow/day. Similarly, pregnancy rate exhibited little response to treatment, and the 2-year mean was 84%.

## Implications

To date, calf weaning weights and cow weights and body condition scores at calving, breeding, and weaning for cattle grazing non-toxic forage systems have been greater than observed for cattle grazing endophyte-infested pastures with approximately 50% dilution. However, these differences have been marginal. Based on the returns demonstrated in this study, it remains unclear whether cow-calf producers will be willing to make the commitments necessary to establish and maintain these non-toxic forages.

## Literature Cited

Coblentz, W.K., et al. 2003. Arkansas Anim. Sci. (submitted).

**Table 1. Summary of calf performance at Batesville, AR, from 2000 through 2002.**

| System[1] | Birth weight | Actual weaning weight | 205-day adjusted weaning weight | Total gain, birth to weaning | Average daily gain, birth to weaning |
|---|---|---|---|---|---|
| | ---------- lb ---------- | | | | lb/head/day |
| OG - HM | 79.8 | 557 | 536 | 477 | 2.2 |
| OG - LM | 78.7 | 552 | 543 | 473 | 2.3 |
| FF - HM | 77.6 | 505 | 494 | 428 | 2.0 |
| FF - LM | 78.5 | 546 | 541 | 468 | 2.3 |
| IF - LM | 76.5 | 495 | 481 | 418 | 2.0 |
| SE | 1.6 | 21 | 16 | 9 | 0.1 |
| Contrast | | | | | |
| IF vs. FF and OG | 0.171 | 0.038 | 0.010 | 0.041 | 0.010 |
| FF vs. OG | 0.485 | 0.199 | 0.190 | 0.202 | 0.191 |
| HM vs. LM[2] | 0.939 | 0.404 | 0.140 | 0.381 | 0.125 |
| Interaction[3] | 0.534 | 0.288 | 0.228 | 0.291 | 0.233 |

[1] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

[2] The IF treatment is not included with LM systems.

[3] Interaction of non-toxic forages (OG and FF) and grazing management (LM and HM). The LM grazing treatment does not include IF forage.

**Table 2. Summary of cow weights at Batesville, AR, from 2000 through 2002.**

| System[1] | Calving weight | Breeding weight | Weaning weight | Weight change, calving to breeding | Weight change, calving to weaning |
|---|---|---|---|---|---|
| | ---------- lb ---------- | | | lb/head | lb/head |
| OG - HM | 1243 | 1172 | 1192 | - 67 | - 64 |
| OG - LM | 1297 | 1249 | 1261 | - 25 | - 30 |
| FF - HM | 1286 | 1198 | 1185 | - 73 | - 110 |
| FF - LM | 1318 | 1267 | 1245 | - 39 | - 78 |
| IF - LM | 1179 | 1103 | 1067 | - 62 | - 105 |
| SE | 34 | 34 | 34 | 14 | 17 |
| Contrast | | | | | |
| IF vs. FF and OG | 0.004 | 0.040 | 0.035 | 0.579 | 0.169 |
| FF vs. OG | 0.314 | 0.547 | 0.799 | 0.642 | 0.103 |
| HM vs. LM[2] | 0.192 | 0.071 | 0.179 | 0.109 | 0.235 |
| Interaction[3] | 0.718 | 0.925 | 0.926 | 0.841 | 0.971 |

[1] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

[2] The IF treatment is not included with LM systems.

[3] Interaction of non toxic forages (OG and FF) and grazing management (LM and HM). The LM grazing treatment does not include IF forage.

**Table 3. Summary of cow body condition score[1] at Batesville, AR, from 2000 through 2002.**

| System[2] | BCS at calving | BCS at breeding | BCS at weaning |
|---|---|---|---|
| OG - HM | 6.6 | 6.6 | 6.8 |
| OG - LM | 6.8 | 6.8 | 6.9 |
| FF - HM | 6.8 | 6.5 | 6.7 |
| FF - LM | 6.9 | 7.1 | 6.9 |
| IF - LM | 6.6 | 6.4 | 6.1 |
| SE | 0.1 | 0.1 | 0.1 |
| *Contrast* | | | |
| IF vs. FF and OG | 0.095 | 0.003 | 0.004 |
| FF vs. OG | 0.239 | 0.184 | 0.793 |
| HM vs. LM[3] | 0.132 | < 0.001 | 0.238 |
| Interaction[4] | 0.631 | 0.011 | 0.418 |

[1] BCS = body condition score (1 = emaciated, 9 = obese).

[2] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

[3] The IF treatment is not included with LM systems.

[4] Interaction of non toxic forages (OG and FF) and grazing management (LM and HM). The LM grazing treatment does not include IF forage.

# Sampling Requirements for Determining Forage Quality

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## Story in Brief

Large, round hay bales from two farms in the Arkansas River Valley were individually analyzed for chemical composition to determine the optimum (or minimum) sampling rate to achieve an accurate forage analysis for either uniform grass hays or non-uniform, mixed grass hays. The monoculture field consisted of approximately 8 acres of Tipton 44 bermudagrass, which was determined through forage inventory to be 90% of the stand. A 12-acre mixed grass field was also inventoried and was highly variable ($P < 0.0001$) in species composition. Fifty-one bermudagrass and 73 mixed grass large round bales were individually core sampled six times with a 0.75-in internal diameter, 18-in-long Star Multi-Forage Sampler. Wet chemistry was used to determine crude protein, acid detergent fiber, and neutral detergent fiber concentrations of each bale. From these factors, percentage TDN (total digestible nutrients) was calculated using equations developed and currently used in Arkansas. For each hay lot, a computer program was used to generate 10,000 random hay samples for sampling rates ranging from 5 to 75% of the lot in increments of 5%. Potential sampling outcomes for each sampling rate were generated. Results indicate that forage samples should include one core from at least 30% of all bales of a monoculture or pure forage stand and 35% of all bales when sampling a mixed/native grass field to achieve a representative hay sample useful for ration balancing.


## Introduction

Controlling input costs and achieving desired animal production levels are two goals of most livestock producers. Supplemental feeding is where these two factors generally collide and profitability is decreased. Dry hay is most often the primary source of nutrients for livestock during winter months, and to maintain desired production levels, many producers provide supplemental feed.

Forage testing is the first step, and possibly the most overlooked factor, in balancing a ration to meet livestock nutrient requirements. Techniques for hay sampling vary widely from hand-grabbed samples out of the windrow to core sampling multiple bales by lot. However, it is vital that each hay sample be truly representative of the particular lot of hay. Due to the time and labor involved in obtaining forage samples it is also important to know the minimum percentage of bales from a lot of hay to be core sampled to achieve a representative forage analysis. It is suspected that monoculture hay lots, such as those containing primarily bermudagrass, will require fewer core samples than lots with a large variation among forage species, and both will likely require more cores than are currently being obtained by most producers. Therefore, the objective of this study was to demonstrate the inaccuracies that could occur with too small a sample size, and to determine an appropriate sampling rate for hay bales from two types of fields (monoculture and mixed grass).

## Experimental Procedures

Two fields on farms in the Arkansas River Valley were selected; these included an 8-acre field of Tipton 44 bermudagrass and a 12-acre field of mixed/native grass. Each field was divided into four quadrants ranging from 2 to 4 acres, and forage inventories were performed for each section using a step-point identification method to identify the species mix in the entire field and to show the random distribution of the various species across the entire field. Forage inventories were performed for both fields on June 20, 2002. The bermudagrass field was cut, tedded, raked, and then baled on July 12. The mixed grass field was cut, tedded, raked, and then baled on July 27. Fifty-one bermudagrass and 73 mixed grass bales were harvested. Hay bales were 5.0 by 5.5-ft round bales, weighing approximately 1000 lb. Within one week of baling, while bales were still in the fields, all bales were cored with a 0.75-in internal diameter, 18-in-long Star Multi-Forage Sampler (Star Quality Samplers, Edmonton, AB, Canada). Each bale was cored three times on each rounded side, and these six cores were composited, in order to gain the necessary sample amount for each bale.

Forage samples were dried at 131°F and ground through a Wiley mill fitted with a 1-mm screen (Arthur H. Thomas, Philadelphia, PA). Crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) were determined on the composite sample from each bale. Crude protein was determined by rapid combustion (Elementar Americas, Inc., Mt. Laurel, NJ); and ADF and NDF were conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY).

*Statistical Analysis.* Chi Square analysis was performed on forage inventories. Analyses were conducted for each field using PROC Survey Select of SAS (SAS Inst., Inc., Cary, NC), to generate 10,000 random samples for each population size. Population size (sampling rate) ranged from 5 to 75% of the total lot in increments of 5%. Descriptive statistics (mean, standard error, minimum and maximum) were generated with the MEANS procedure.

## Results and Discussion

Chi Square analysis indicated that there were no differences ($P = 0.30$) among the four quadrants in species composition in the bermudagrass field (Figure 1), and there were differences ($P < 0.0001$) in the species composition among the quadrants in the mixed grass field (Figure 2). The number of bales harvested and the mean forage quality data from each field are shown in Table 1.

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In order to interpret the results in a practical and useful manner, it was decided that the primary function of the forage analysis, in most applications, is balancing supplemental feed rations for livestock. It was determined that evaluating forages for total digestible nutrients (TDN) and CP is the primary purpose of testing; therefore, a baseline with an acceptable degree of error within the samples was set at a two percentage unit variation in TDN and a two percentage unit variation in CP (i.e. the mean ± one percentage unit).

The variables used in the Arkansas bermudagrass TDN equation include CP, ADF, and NDF [TDN = 111.8 + 0.95(%CP) – 0.36(%ADF) – 0.7(%NDF)]; however, the variables used in the Arkansas mixed/native grass TDN equation are CP and ADF only [TDN = 73.5 + 0.62(%CP) – 0.71(%ADF)]. Based on these TDN equations it was determined that variation in NDF would have the largest impact when calculating TDN for the bermudagrass field, and the variation in ADF would have the largest impact for the mixed grass field. These variables were considered the limiting factors and recommendations for sampling were based on meeting the acceptable range for these limiting factors.

Holding ADF and CP constant and using the minimum and maximum observations for NDF at each sampling rate, TDN was calculated for the bermudagrass lot. At the lowest sampling rate (5% of bales), calculated TDN ranged from 59.4 to 64.2% (Figure 3). As sampling rate increased, the range in observed TDN values (i.e. the difference between minimum and maximum values) became smaller. A sampling rate of 30% resulted in an acceptable, less than a two-percentage unit difference between the calculated TDN concentrations (Figure 3). This is the point (30%) at which sampling recommendations were determined to be the minimum acceptable for the bermudagrass field. The 30% sampling rate for 51 bermudagrass bales would require core sampling 15 bales.

For mixed grasses, ADF was the limiting factor in the TDN equation. Holding CP constant and using the minimum and maximum observations for ADF at each sampling rate, TDN was calculated. At the lowest sampling rate (5% of bales), calculated TDN ranged from 46.3 to 52.3% (Figure 4). As sampling rate increased, the difference between minimum and maximum observed TDN values became smaller. A sampling rate of 35% resulted in an acceptable, less than a two-percentage unit difference between the calculated TDN concentrations (Figure 4). This is the point (35%) at which sampling recommendations were determined to be the minimum acceptable for the mixed grass field. For the 73 bales of mixed grass, a minimum of 26 bales would be core sampled to reach the 35% sampling rate. At these sampling rates, CP concentration varied less than two percentage units (Figure 5) for both uniform and mixed grass hay meadows.

## Implications

Livestock producers and industry professionals generally recognize the benefits of forage testing, but often overlook the importance of attaining a truly representative hay sample. In order to develop useful feed rations, forages must be sampled at a minimum level of 30 to 35% of the bales or greater depending on the variability of the forage stand.

## Acknowledgements

The authors thank John Jennings for assisting with collecting the forage inventories, Blair Griffin for assisting with hay sampling, and Jack Thomas and Steve Morgan for cooperating in providing the sampling sites.

**Table 1. Characteristics of the forage from the two fields that were used (dry-matter basis).**

| | Number of bales | CP, % | ADF, % | NDF, % | TDN, %[1] |
|---|---|---|---|---|---|
| Bermudagrass field | 51 | 13.0 | 36.0 | 71.1 | 61.5 |
| Mixed grass field | 73 | 11.0 | 43.2 | 69.9 | 49.6 |

[1] Calculated

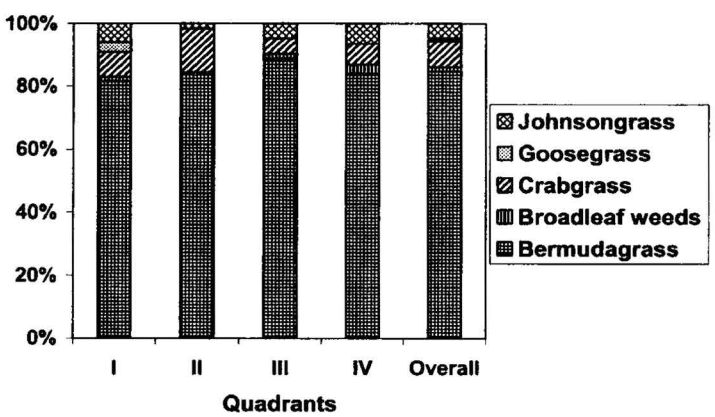


**Fig. 1. Bermudagrass field forage inventory, from four areas within the field and overall.**

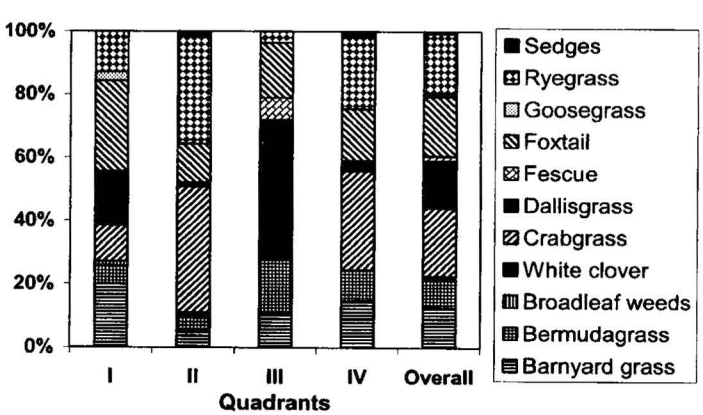


**Fig. 2. Mixed grass field forage inventory, from four areas within the field and overall.**

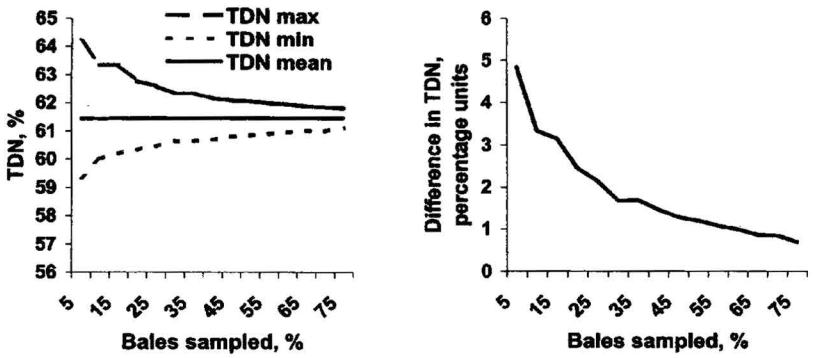


**Fig. 3. Variation in calculated TDN based on sampling rate for the bermudagrass field.**

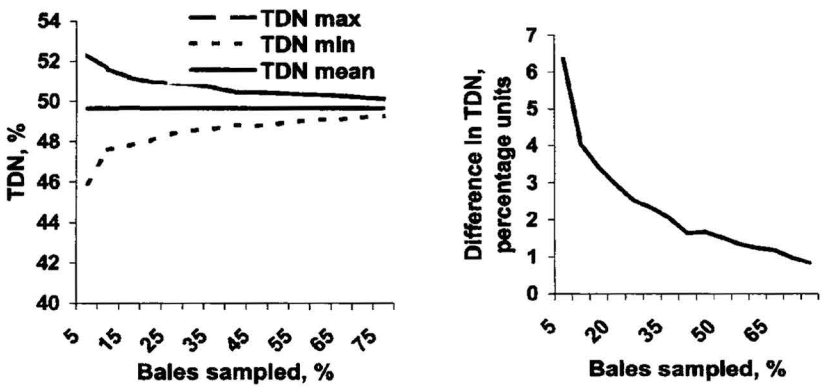


**Fig. 4. Variation in calculated TDN based on sampling rate for the mixed grass field.**

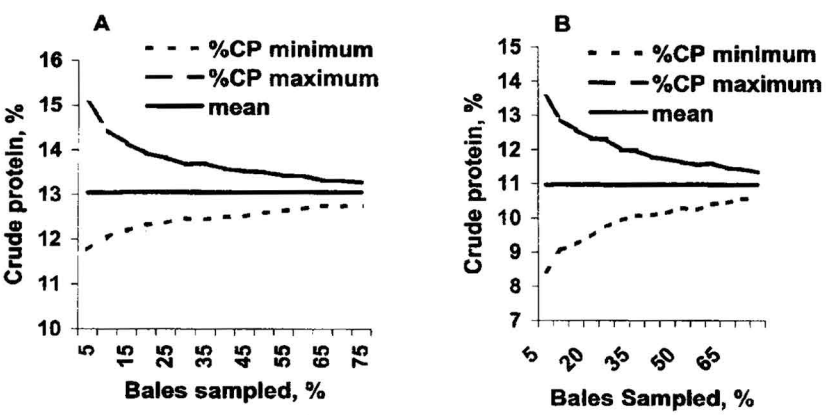


**Fig. 5. Variation in crude protein due to sampling rate for bermudagrass (A) and mixed grass (B) hay.**

# Effects of Iron Supplementation Level in Diets of Growing-Finishing Swine. I. Pig Performance and Carcass Characteristics

*J.K. Apple[1], W.A. Wallis[2], C.V. Maxwell[1], L.K. Rakes[1], and J.D. Stephenson[1]*


## Story in Brief

A total 210 crossbred barrows and gilts were used to test the effects of supplementation level (50, 100, or 150 ppm) of iron (Fe) from Availa-Fe (an iron-amino acid complex) on performance and carcass characteristics of growing-finishing pigs. During the starter phase, ADG decreased linearly ($P < 0.02$) as supplementary Fe levels increased from 0 to 150 ppm; however, during the grower-I phase, ADG tended to increase linearly ($P < 0.10$) as supplemental Fe from Availa-Fe increased. Pig performance during the grower-II and finisher phases, as well as over the entire trial, was not ($P > 0.10$) affected by supplemental Fe. Carcass muscling and fatness measures were similar ($P > 0.10$) among dietary treatments. The redness of the longissimus muscle (LM) increased linearly ($P < 0.03$) with increasing levels of supplemental Fe. Furthermore, the LM tended to become darker (linear effect; $P < 0.15$), and American color scores tended to increase (linear effect; $P < 0.10$), as dietary Fe from Availa-Fe increased from 0 to 150 ppm. Even though ADG was affected during the early feeding phases, increasing the dietary Fe level had no effects on pig performance or carcass composition. Yet, modest improvements in pork color suggest that feeding diets supplemented with 150 ppm of Fe from Availa-Fe may enhance pork quality.


## Introduction

The newborn pig is born with approximately 50 mg of iron (Fe), most of which is as hemoglobin, and sow's milk contains only 1 mg Fe per liter. Therefore, pigs receiving only milk rapidly become anemic, and it is common practice in swine production to supply the newborn pig with Fe, typically via intramuscular injections of 100 to 200 mg of Fe. Post-weaning dietary Fe requirement for pigs is approximately 80 ppm (Pickett et al., 1960), and declines with advancing age and weight (NRC, 1998). Similarly, Harmon et al. (1969) reported that ADG was reduced in pigs fed diets containing less than 29 ppm of Fe, but not at dietary levels ranging from 34 to 147 ppm, indicating the requirement may be somewhat lower than suggested. On the other hand, supplementing diets of weanling and grower pigs with higher (100 to 7,000 ppm) levels of Fe also fails to impact on ADG, ADFI, or F/G (Dove and Ewan, 1990).

Most of the literature focuses on the Fe requirements of newborn and weanling pigs, and very little information is available concerning the effects of supplemental Fe on carcass characteristics. Abdelrahim et al. (1983) indicated that the addition of 5 ppm Fe in the diet of veal calves produced significantly darker meat; however, there are no published reports on the effects of supplemental Fe on pork quality and composition traits. Therefore, the objective of this study was to determine the effect of dietary Fe supplementation level on the performance and carcass characteristics of growing-finishing swine.

## Experimental Procedures

A total of 210 crossbred barrows and gilts (DeKalb Choice Genetics, St. Louis, MO), with an average initial live weight of 67 lb, were blocked by weight into seven blocks of 30 pigs/block. Pigs within each block were allotted randomly to pens (six pigs/pen) and stratified across gender and litter origin. Within each block, pens were randomly assigned to one of five treatments, including a negative control, corn-soybean meal-wheat middlings starter, grower, and finisher diets with no Fe present in the vitamin-mineral premix; a positive control, corn-soybean meal-wheat middlings starter, grower, and finisher diets with iron sulfate present in the vitamin-mineral premix; or the positive control diets supplemented with either 50, 100, or 150 ppm Fe from Availa-Fe (an iron-amino acid complex produced by Zinpro Corp., Eden Prairie, MN). Pigs were fed a four-phase diet with transition from starter to grower-I, from grower-I to grower-II, and grower-II to finisher diets when mean weight of each block was 120, 150, and 200 lb, respectively. Additionally, diets were formulated to be isolysinic (1.00, 0.86, 0.72, and 0.64% lysine in the starter, grower-I, grower-II, and finisher diets, respectively) and isocaloric (1554.3, 1573.6, 1579.4, and 1569.0 Kcal/lb in the starter, grower-I, grower-II, and finisher diets, respectively), and Availa-Fe was added to the trace mineral premix (0, 100, 150, 200, and 250 ppm Fe in the negative control, positive control, 50 ppm supplemental Fe, 100 ppm supplemental Fe, and 150 ppm supplemental Fe diets, respectively; Table 1). All diets were formulated to meet, or exceed, NRC (1998) amino acid, energy, and other nutrient requirements for growing-finishing swine. Individual pig weights were measured weekly, and feed disappearance was recorded at 7-d intervals during each phase to calculate ADG, ADFI, and feed:gain (F/G).

When the lightest block of pigs weighed approximately 260 lb, all pigs were transported approximately 416 miles to a commercial pork packing plant (Bryan Foods, Inc., West Point, MS). After a 12-hr rest period, pigs were electrically-stunned, and harvested according to industry-acceptable procedures. Hot carcass weight was recorded, and 10th rib fat and loin eye depths were measured on-line with a Fat-O-Meater automated probe (SFK Technology A/S, Cedar Rapids, IA). Following a 24-h conventional spray-chill, loins were marked between the 10th and 11th ribs in order to measure loin eye area upon arrival at the University of Arkansas Red-Meat Abattoir. During carcass fabrication, bone-in pork loins from right sides were captured, wrapped in parchment paper, boxed, and transported back

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to the University of Arkansas for pork quality data collection.

At approximately 48 h postmortem, each loin was separated at the mark between the 10th and 11th ribs, and each loin eye was traced onto acetate paper and loin eye area was measured using a compensating planimeter. Then, two 1.5-in thick and one 1-in thick chops were cut anterior to the 11th rib. The two 1.5-in thick chops were used for drip loss determination. A 1.5-in diameter core was removed from each 1.5-in thick chop, weighed, and suspended on a fishhook (barb removed) mounted to the lid of a plastic container (18 in deep x 15 in wide x 24 in long), and stored at 34°F. After 48 h, each core was blotted dry on paper towels and re-weighed. The loss in weight due to drip and evaporation was divided by the initial core weight, multiplied by 100, and reported as drip loss percentage. After a 30-min bloom period, American (1 = pale pinkish gray to 6 = dark purplish red) and Japanese color (Nakai et al., 1975) scores, as well as marbling (1 = devoid to 10 = abundant) and firmness (1 = very soft/very watery to 5 = very firm/very dry) scores, were evaluated by a three-person panel on the 1-in thick loin chop. Also, L* (measure of darkness to lightness; higher number indicates a lighter color), a* (measure of redness; higher number indicates a redder color), and b* (measure of yellowness; higher number indicates a more yellow color) values were determined from the mean of three random readings from a Hunter MiniScan XE (Hunter Associates Laboratory, Inc., Reston, VA) using illuminant C.

All data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was performned using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Least-squares means were computed and orthogonal contrasts were used to accurately compare the positive and negative control diets, as well as test the linear, quadratic, and cubic responses to the dietary inclusion level of Availa-Fe.

## Results And Discussion

Even though ADFI and F/G were not ($P > 0.10$) affected by dietary treatments during the starter phase, ADG decreased linearly ($P = 0.02$) as supplementary Fe levels increased from 0 (positive control) to 150 ppm (Table 2). During the grower-I phase, however, ADG tended to increase linearly ($P < 0.10$) as supplemental Fe from Availa-Fe increased from 0 (positive control) to 150 ppm, with pigs fed diets supplemented with 150 ppm Fe gaining 0.41 lb/d more than pigs fed the negative control diets. There was also a tendency for F/G to decrease (linear effect; $P = 0.13$) as Fe from Availa-Fe increased in the diet. There were no ($P > 0.10$) differences in ADG, ADFI, or F/G among dietary treatments during the grower-II and finisher phases, as well as over the entire length of the feeding trial. Interestingly, pigs fed the negative control diets tended to have lower F/G values than pigs fed the positive control diets during the grower-II phase ($P = 0.06$) and across the entire trial ($P = 0.07$). The lack of an effect of dietary Fe on performance during the late grower and finisher phases is consistent with the results of Harmon et al. (1969) and Dove and Ewan (1990), who demonstrated that supplementing pig diets with Fe, at levels greater than NRC (1998) requirements, had no appreciable effects on pig performance.

Supplementing diets with Fe from Availa-Fe did not ($P > 0.10$) affect hot carcass weight, 10th rib fat depth, loin eye depth and area, or fat-free lean yield (Table 3). American color scores tended to improve linearly ($P = 0.10$) as supplemental Fe concentrations increased from 0 to 150 ppm; however, dietary Fe did not ($P > 0.10$) affect Japanese color, marbling, or firmness scores. There was a non-significant ($P = 0.15$) linear relationship between L* values and dietary Fe inclusion level, with loin eye muscle becoming darker (lower L* values) as Fe from Availa-Fe increased from 50 to 150 ppm. Pork from pigs fed the negative control diets was redder (higher a* values; $P = 0.03$) than that from pigs fed the positive control diets, and the loin eye became redder (linear effect; $P = 0.04$) as supplemental Fe increased from 0 (positive control) to 150 ppm. Neither b* values (yellowness) or drip loss percentages were affected ($P > 0.10$) by any dietary treatment.

Results from the present study are in line with those of Abdelrahim et al. (1983), who reported that supplementing veal-calf diets with Fe resulted in darker colored veal. Moreover, the linear increase in the redness of pork from Availa-Fe-supplemented pigs confirms the reported increase in redness of skin as dietary Fe, from Availa-Fe, increased from 30 to 120 ppm (Yu et al., 2000).

## Implications

Even though daily gain was improved by iron-supplementation during the early-grower phase, results from the present study indicated that increasing the dietary iron content had no appreciable effects on pig performance or carcass composition. However, moderate improvements in pork color were noted, suggesting that feeding diets supplemented with 150 ppm of iron from Availa-Fe may enhance pork quality.

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**Table 1. Composition (as-fed basis) of finisher diets (fed from 200 to 260 lb) supplemented with 50, 100, or 150 ppm iron (Fe).**

| | Negative | Positive | Iron, ppm | | |
|---|---|---|---|---|---|
| Ingredient, % | control | control | 50 | 100 | 150 |
| Corn | 70.525 | 70.525 | 70.442 | 70.358 | 70.275 |
| Wheat middlings | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Soybean meal (48% CP) | 8.50 | 8.50 | 8.50 | 8.50 | 8.50 |
| Fat | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| Calcium carbonate | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Lysine hydrochloride | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Vitamin premix[a] | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Mineral premix[b] | --- | 0.09 | 0.09 | 0.09 | 0.09 |
| Mineral premix[c] | 0.09 | --- | --- | --- | --- |
| Availa-Fe | --- | --- | 0.083 | 0.167 | 0.25 |
| Phytase | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Ethoxyquin | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Tylosin-40 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| | | | | | |
| Calculated composition, % | | | | | |
| CP | 12.39 | 12.39 | 12.39 | 12.39 | 12.39 |
| Lysine | 0.64 | 0.64 | 0.64 | 0.64 | 0.64 |
| Methionine + cysteine | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| Threonine | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Tryptophan | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| Fe from ferrous sulfate, ppm | 0 | 100 | 100 | 100 | 100 |
| Fe from Availa-Fe, ppm | 0 | 0 | 50 | 100 | 150 |
| Calcium | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Phosphorus | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| ME, Kcal/lb | 1569.0 | 1569.0 | 1569.0 | 1569.0 | 1569.0 |

[a] Vitamin premix contained 14,551 IU of vitamin A, 2,182 IU of vitamin $D_3$ (D-activated animal sterol), 57 IU of vitamin E, 5.7 mg of vitamin K (menadione sodium bisulfite complex), 36.3 mg of pantothenic acid (D-calcium pantothenate), 65.3 mg of niacin, 11 mg of riboflavin, and 50.6 µg of vitamin $B_{12}$ per pound of feed (Nutra Blend Corp., Neosho, MO).

[b] Mineral premix contains calcium carbonate, 100 ppm Fe (ferrous sulfate), 100 ppm Zn (zinc sulfate), 0.18 ppm Se (sodium selenite), 24 ppm Mn (manganous sulfate), 9.9 ppm Cu (copper sulfate), and 0.18 ppm I (calcium iodate) (Nutra Blend Corp., Neosho, MO).

[c] Mineral premix devoid of ferrous sulfate (Nutra Blend Corp., Neosho, MO).

**Table 2. Effects of iron-supplementation level on performance of growing-finishing swine.**

| Item | Negative control | Positive control | Supplemental iron, ppm 50 | 100 | 150 | SE |
|---|---|---|---|---|---|---|
| Starter phase (67 to 120 lb) | | | | | | |
| ADG, lb[1] | 1.96 | 1.99 | 1.93 | 1.95 | 1.86 | 0.033 |
| ADFI, lb | 4.36 | 4.50 | 4.52 | 4.48 | 4.22 | 0.136 |
| F/G | 2.22 | 2.28 | 2.33 | 2.38 | 2.27 | 0.058 |
| Grower I phase (120 to 150 lb) | | | | | | |
| ADG, lb[2] | 1.73[y] | 1.88[xy] | 1.92[xy] | 1.92[xy] | 2.14[x] | 0.097 |
| ADFI, lb | 5.34 | 5.55 | 5.40 | 5.44 | 5.56 | 0.198 |
| F/G[3] | 3.12 | 2.98 | 2.90 | 2.90 | 2.60 | 0.164 |
| Grower II phase (150 to 200 lb) | | | | | | |
| ADG, lb | 2.26 | 2.18 | 2.32 | 2.13 | 2.09 | 0.081 |
| ADFI, lb | 6.00 | 6.29 | 6.43 | 6.25 | 6.30 | 0.191 |
| F/G[4] | 2.66 | 2.99 | 2.80 | 2.95 | 3.02 | 0.118 |
| Finisher phase (200 to 260 lb) | | | | | | |
| ADG, lb | 1.97 | 2.02 | 2.00 | 1.94 | 2.01 | 0.053 |
| ADFI, lb | 5.98 | 6.33 | 6.34 | 6.24 | 6.22 | 0.156 |
| F/G | 3.04 | 3.15 | 3.17 | 3.21 | 3.10 | 0.059 |
| Overall trial (67 to 260 lb) | | | | | | |
| ADG, lb | 2.00 | 2.01 | 2.04 | 1.98 | 2.00 | 0.024 |
| ADFI, lb | 5.39 | 5.62 | 5.66 | 5.57 | 5.52 | 0.119 |
| F/G[5] | 2.70 | 2.81 | 2.76 | 2.84 | 2.76 | 0.040 |

[1] Linear effect of supplemental iron (P = 0.02).

[2] Linear effect of supplemental iron (P = 0.10).

[3] Linear effect of supplemental iron (P = 0.13).

[4] Negative control is different from the positive control (P = 0.06).

[5] Negative control is different from the positive control (P = 0.07).

**Table 3. Effects of iron-supplementation level on carcass characteristics of growing-finishing swine.**

| Item | Negative control | Positive control | Supplemental iron, ppm 50 | 100 | 150 | SE |
|---|---|---|---|---|---|---|
| Hot carcass wt, lb | 197.7 | 203.5 | 201.4 | 206.6 | 199.1 | 3.33 |
| 10th rib fat depth, in | 0.77 | 0.78 | 0.81 | 0.82 | 0.80 | 0.052 |
| Loin eye depth, in | 2.2 | 2.3 | 2.3 | 2.2 | 2.2 | 0.05 |
| Loin eye area, sq in | 8.2 | 7.6 | 7.4 | 8.0 | 7.3 | 0.29 |
| Fat-free lean yield, % | 52.89 | 53.06 | 52.64 | 52.16 | 52.71 | 0.893 |
| American color score[a,1] | 3.2 | 3.2 | 3.0 | 3.3 | 3.4 | 0.13 |
| Japanese color score[b] | 3.3 | 3.2 | 3.4 | 3.4 | 3.4 | 0.12 |
| Marbling score[c] | 1.9 | 1.8 | 1.9 | 1.9 | 2.1 | 0.14 |
| Firmness score[d] | 3.2 | 3.3 | 3.4 | 3.4 | 3.4 | 0.10 |
| Lightness (L*)[e,2] | 51.18 | 50.87 | 51.54 | 50.63 | 50.20 | 0.438 |
| Redness (a*)[e,3,4] | 8.11 | 7.63 | 7.41 | 7.95 | 7.94 | 0.149 |
| Yellowness (b*)[e] | 14.83 | 14.42 | 14.54 | 14.41 | 14.32 | 0.232 |
| Drip loss, % | 2.4 | 2.4 | 2.6 | 3.1 | 2.9 | 0.39 |

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

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

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

[d] Firmness score: 1 = very soft/very watery and 5 = very firm/very dry (NPPC, 1991)

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

[1] Linear effect of supplemental iron (P = 0.10).

[2] Linear effect of supplemental iron (P = 0.15).

[3] Negative control is different from the positive control (P = 0.03).

[4] Linear effect of supplemental iron (P = 0.04).

# Effects of Iron Supplementation Level in Diets of Growing-Finishing Swine. II. Pork Quality Traits During Retail Display

*W.A. Wallis[1], J.K. Apple[2], C.V. Maxwell[2], L.K. Rakes[2], S. Hutchison[3], and J.D. Stephenson[2]*


## Story in Brief

Bone-in pork loins (n = 80) from pigs fed diets devoid of iron (negative control), 100 ppm iron (Fe) from ferrous sulfate (positive control), or the positive control diets supplemented with an additional 50, 100, or 150 ppm Fe from Availa-Fe were used to determine the effect of dietary Fe concentration on pork quality during 7 d of retail display. Briefly, loin chops were cut, placed on foam trays, overwrapped with an oxygen-permeable PVC film, and placed under 1600 lx of warm white light in chest-type display cases for 7 d. Loin chops from pigs fed diets supplemented with 50 Fe from Availa-Fe had less ($P < 0.05$) moisture loss during retail display than chops from pigs fed either the negative or positive control diets and diets supplemented with 150 ppm Fe. Even though L* values were similar among dietary treatments during the first 4 d of retail display, chops from pigs fed diets supplemented with 50 ppm Fe were darker (lower L* values) than chops from pigs fed the negative control diet (dietary treatment x display day interaction; $P = 0.03$). Neither b* values nor estimated oxymyoglobin content (630/580 nm) were affected ($P > 0.10$) by dietary Fe level; however; chops from pigs fed the negative control and 100 ppm Fe from Availa-Fe diets tended to be a more ($P < 0.10$) vivid, redder ($P < 0.10$) color than chops from pigs fed diets supplemented with 50 ppm Fe. Although there was a dietary treatment x display day interaction ($P = 0.002$) for 2-thiobarbituric acid reactive substances (TBARS) values, values were quite small, implying that dietary inclusion of Availa-Fe had no appreciable effects on the development of oxidative rancidity. Results from the present study indicate that supplementing the diets of growing-finishing swine with 100 ppm Fe from Availa-Fe may enhance pork color, without negatively impacting oxidative rancidity, during retail display.


## Introduction

Myoglobin is the primary pigment in meat; however, other heme proteins, such as hemoglobin and cytochrome C, also contribute to meat color. Myoglobin content of muscle varies greatly between muscles and species, and has been shown to increase with increasing age and elevation. Supplementing swine diets with iron (Fe) has been shown to increase muscle concentrations of heme (Yu et al., 2000) and non-heme (Miller et al., 1994b) Fe. The response of increasing muscle Fe content on meat color, however, may be source dependent. For example, elevating dietary Fe content with an inorganic source resulted in detrimental effects on visual color of pork (O'Sullivan et al., 2002); whereas, feeding increased levels of a more bioavailable, organic source (Availa-Fe; Zinpro Corp., Eden Prairie, MN) of Fe increased the redness of pigskin (Yu et al., 2000) and longissimus muscle (unpublished data), and reduced the percentage of pale, soft and exudative pork (unpublished data).

Miller et al. (1994a; b) reported that supplementing swine diets with ferrous sulfate resulted in increased rancidity in cooked ground pork and pork chops stored for up to 12 weeks; however, dietary Fe did not affect lipid oxidation in raw, whole-muscle pork. Additionally, O'Sullivan et al. (2002) reported that supplementing swine diets with 3,000 mg/kg of ferrous sulfate resulted in greater oxidation of oxymyoglobin (bright red color) to metmyoglobin (brown color), adversely impacting visual color scores of pork from pigs fed the Fe-supplemented diet. However, there is no available information concerning the effects of supplementing swine diets with an organic-source of Fe (Availa-Fe) on the shelf-life of pork. Therefore, the objectives of this experiment were to test the effect of Availa-Fe supplementation level on pork quality characteristics of the longissimus muscle during 7 days of retail display.

## Experimental Procedures

Bone-in pork loins (n = 80) were randomly selected from pigs fed either: corn-soybean meal-wheat middlings starter, grower, and finisher diets devoid of supplemental Fe in the vitamin-mineral premix (negative control; NC); corn-soybean meal-wheat middlings starter, grower and finisher diets with an inorganic Fe-source in the vitamin-mineral premix (positive control; PC); or the PC starter, grower and finisher diets supplemented with 50, 100, or 150 ppm Fe from Availa-Fe. Description of pigs, diets and feeding protocols, rearing conditions, and harvest are presented in detail in the companion article (Apple et al., 2003).

Twenty-four hours after harvest, pork loins were collected during fabrication at a commercial pork packing plant (Bryan Foods, Inc., West Point, MS). Loins were wrapped in parchment paper, boxed, and shipped back to the University of Arkansas Red-Meat Abattoir under refrigeration. At approximately 48 h postmortem, each loin was processed into four, 1-in thick loin chops, cut perpendicular to the length of the loin. Chops (4 chops/loin) were weighed, placed on foam trays, over-wrapped with an oxygen-permeable PVC film, and allotted randomly to 0, 1, 4, or 7 days of retail display (chest display cases with an average temperature of 34°F, and under 1,600 lx of warm, white light). On each day of display, L* (a measure of darkness to lightness; a larger number indicates a lighter color), a* (a measure of redness; a larger number indicates a redder color), and b* (a measure of yellowness; a larger number indicates a more yellow color) values were determined from a mean of three random readings made with a Hunter MiniScan XE (model 45/0-L; Hunter Associates Laboratory, Reston, VA) using illuminant C. Additionally, the hue angle (a measure of the distance, in degrees, from the true red axis) was calculated as: $tan^{-1}$ ($b^*/a^*$); whereas, chroma (a measure of the total color, or vividness of color) was cal-


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culated as: $(a^{*2} + b^{*2})^{1/2}$. The ratio of reflectance measured at 630 nm to 580 nm was used to estimate oxymyoglobin concentration of chops during retail display.

After color data collection on each day of retail display, chops were removed from the packaging material, re-weighed, and the difference between chop weights was divided by the initial (day-0) weight to calculate moisture loss percentage. Also, approximately 2 g of pulverized longissimus muscle were used to measure 2-thiobarbituric acid reactive substances (TBARS; a measure of lipid oxidation) according to the procedures of Witte et al. (1970). Values for TBARS are reported as mg of malenaldehyde/kg of muscle.

Data were analyzed as a repeated measures design using the mixed-model procedure of SAS (SAS Inst., Inc., Cary, NC) with loin as the experimental unit. Fixed effects included in the model were dietary treatment, display day, and the treatment x display day interaction, and block and the block x pen x loin x treatment were included in the model as random effects. Least squares means were generated for the main effects and the two-way interaction, and separated statistically by pairwise t-test (PDIFF option of SAS) when $P \leq 0.10$.

## Results and Discussion

The effect of Fe supplementation level on pork quality characteristics of loin chops during retail display is presented in Table 1. Loin chops from pigs fed diets supplemented with 50 Fe from Availa-Fe had less ($P < 0.05$) moisture loss during retail display than chops from pigs fed either the negative or positive control diets and the positive control diet supplemented with 150 ppm Fe. These results conflict with those of O'Sullivan et al. (2002), who failed to note a difference in drip loss percentage of chops from pigs fed diets supplemented with Fe, vitamin E, or Fe and vitamin E.

Lightness (L*) values were similar among dietary treatments on d-0, 1, and 4 of retail display; however, on d-7, chops from pigs fed 50 ppm Fe from Availa-Fe were darker (lower L* values) than chops from pigs fed the negative control diet (dietary treatment x display day interaction; $P = 0.03$; Fig. 1). Even though dietary treatments did not ($P > 0.10$) affect yellowness (b*) or estimated oxymyoglobin content (630/580 nm), chops from pigs fed the negative control diets and diets supplemented with 100 ppm Fe tended to have a more vivid (higher chroma values; $P < 0.10$), redder (higher a* values; $P < 0.10$) color than chops from pigs consuming diets supplemented with 50 ppm Fe (Table 1).

There was a treatment x display day interaction ($P = 0.07$) for hue angle, indicating that loin chops from pigs fed diets supplemented with 100 ppm Fe were redder (lower hue angles) than chops from pigs fed the positive control diets or diets supplemented with 50 ppm Fe on d-0 of retail display (Fig. 2). Hue angles were similar among dietary treatments on d-1 of retail display; however, loin chops from pigs fed diets supplemented with 50 ppm Fe had higher hue angles than chops from pigs fed the negative control diet on d-4 of display, and remained higher on d-7 of display than pork from pigs fed either the negative or positive control diets and diets supplemented with 150 ppm Fe. Interestingly, the hue angle values of chops from pigs fed 100 ppm Fe from Availa-Fe were numerically lower at each time during retail display.

Recent, unpublished information indicated that subjective and objective measures of color of the loin muscle were improved by supplementing swine diets with Fe from Availa-Fe (I. Lecaros, personal communication). O'Sullivan et al. (2002), on the other hand, reported that pork from pigs fed diets supplemented with Fe became less red and more brown in color after 5 d of retail display whereas chops from vitamin E-supplemented pigs was less red and less brown on d-5 of display compared to values collected on d-1. The authors concluded that supplementing swine diets with Fe lead to increased pigment oxidation from oxymyobloin (bright red pigment) to metmyoglobin (brown pigment).

Although TBARS values were quite small, chops from pigs fed 150 ppm Fe from Availa-Fe had higher TBARS values than chops from all other dietary treatments after one day of retail display; however, on d-4 of display, TBARS values were lower in chops from pigs fed diets supplemented with 150 ppm Fe than chops from pigs fed the negative control diets or diets supplemented with 100 ppm Fe (dietary treatment x display day interaction; $P = 0.002$; Fig. 3). On d-0 and 7 of display, the degree of oxidative rancidity was similar among the dietary treatments. Increasing dietary Fe content of finishing pigs was shown to increase lipid oxidation in cooked ground pork and pork loin chops stored for up to 12 weeks (Miller et al., 1994a, b); however, dietary Fe did not affect TBARS of fresh, uncooked, whole-muscle pork (Miller et al., 1994a), which is consistent with results from the present study.

## Implications

Results from the present study indicate that pork color may be enhanced during retail display by supplementing swine diets with 100 ppm iron from Availa-Fe. Moreover, dietary inclusion of Availa-Fe had no effect on the development of oxidative rancidity. Even though more research is need to thoroughly investigate the effects of dietary iron on pork quality, the supplementation of swine diets with iron may be an effective way of improving pork color during retail display.

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**Table 1. Effects of iron-supplementation level on pork quality characteristics during retail display.**

| | | | Supplemental iron, ppm | | | |
|---|---|---|---|---|---|---|
| Item | Negative control | Positive control | 50 | 100 | 150 | SEM |
| Moisture loss, % | 3.10[g] | 3.01[g] | 2.47[f] | 2.77[fg] | 3.26[g] | 0.190 |
| Lightness (L*)[a] | 50.72 | 50.55 | 50.32 | 50.42 | 50.16 | 0.526 |
| Redness (a*)[a] | 10.05[i] | 9.64[hi] | 9.27[h] | 10.21[i] | 9.78[hi] | 0.230 |
| Yellowness (b*)[a] | 16.04 | 15.88 | 15.57 | 16.04 | 15.80 | 0.185 |
| Hue angle[b] | 58.18 | 58.93 | 59.59 | 57.75 | 58.45 | 0.530 |
| Chroma[c] | 18.97[i] | 18.61[hi] | 18.17[h] | 19.05[i] | 18.63[hi] | 0.240 |
| 630/580 nm[d] | 2.68 | 2.69 | 2.55 | 2.61 | 2.72 | 0.106 |
| TBARS, mg/kg[e] | 0.13 | 0.14 | 0.13 | 0.14 | 0.15 | 0.008 |

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

[b] Hue angle represents the change from the true red axis (larger number indicates a shift from red to yellow).

[c] Chroma represents the total color of the sample (larger number indicates a more vivid color).

[d] 630/580 nm is an estimate of the quantity of oxymyoglobin (larger number indicates more oxymyoglobin).

[e] TBARS are representative of lipid oxidation (larger number indicates greater oxidative rancidity).

[f,g] Within a row, least-squares means lacking a common superscript letter differ ($P < 0.05$).

[h,i] Within a row, least-squares means lacking a common superscript letter differ ($P < 0.10$).

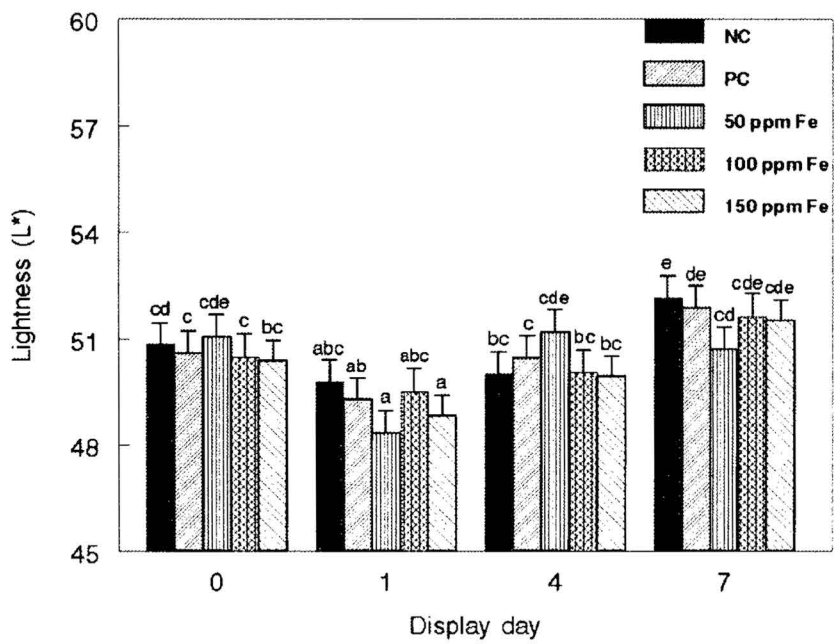


**Fig. 1. Effect of dietary iron level on the lightness (L*) value of pork loin chops during seven days of retail display (dietary treatment x display day; P = 0.03). A larger L* value indicates a lighter color. Within a display day, bars lacking a common letter differ (P < 0.05).**

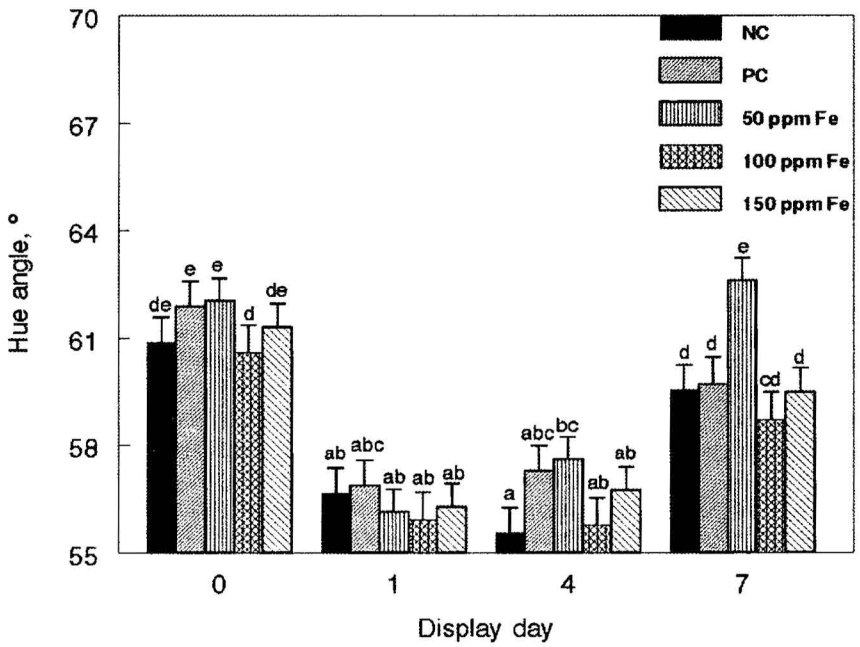


**Fig. 2. Effect of dietary iron level on the hue angle of pork loin chops during seven days of retail display (dietary treatment x display day; P = 0.07). A larger hue angle indicates a greater distance from the true red axis (less red, more yellow). Within a display day, bars lacking a common letter differ (P < 0.05).**

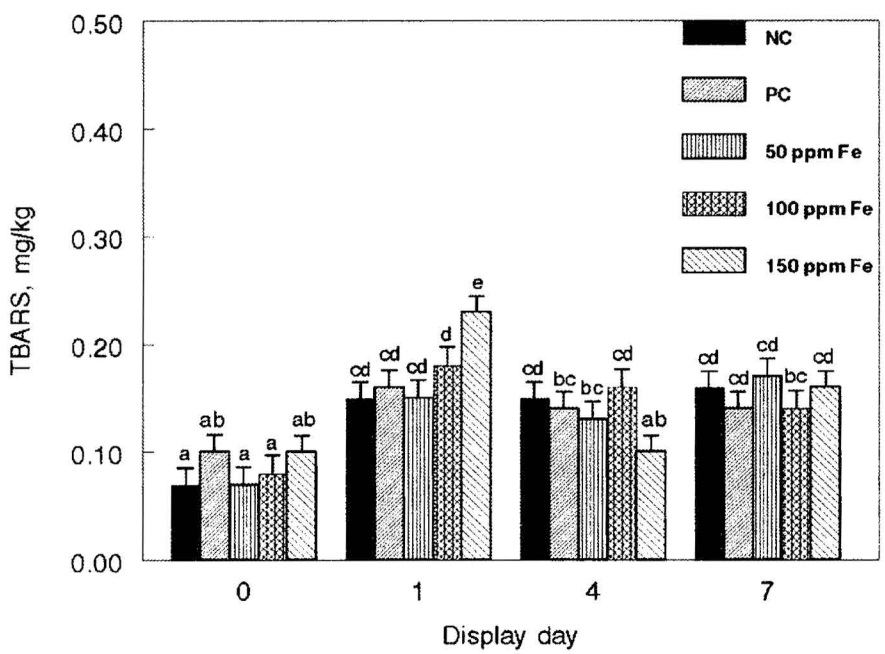


**Fig. 3. Effect of dietary iron level on 2-thiobarbituric acid reactive substances (TBARS) values of pork loin chops during seven days of retail display (dietary treatment x display day; P = 0.002). Within a display day, bars lacking a common letter differ (P < 0.05).**

# Effect of Dietary Manganese Inclusion Level on Performance and Carcass Characteristics of Growing-Finishing Swine

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## Story in Brief

Crossbred pigs (n = 216) were blocked by BW, assigned to pens (six pigs/pen) within blocks, and pens (six pens/block) were allotted randomly to either a corn-SBM starter (52.0 to 80.0 lb), grower I (80.0 to 150.0 lb), grower II (150.0 to 200.0 lb), and finisher (200.0 to 235.0 lb) diet with no supplemental manganese (Mn) or diets supplemented with 20, 40, 80, 160, or 320 ppm Mn from Availa-Mn. When the lightest block averaged 235.0 lb, pigs were harvested, and boneless pork loins were captured during fabrication. Loin chops fabricated from each loin, and subjective and instrumental measures of color were collected. Pigs fed 40, 80, and 320 ppm Mn consumed less ($P < 0.02$) feed than pigs fed unsupplemented diets or 20 ppm Mn during the starter phase. Although dietary Mn had no ($P \geq 0.71$) effect on performance during the early grower phase, pigs fed 40 and 320 ppm Mn had higher ADG, and lower F/G, than pigs fed the control diet or diets fortified with 20, 80, and 160 ppm Mn (cubic effect; $P < 0.02$ and $P < 0.05$, respectively) during the late grower phase. Across the entire trial, there was a trend (cubic effect; $P = 0.08$) for F/G to be less in pigs fed diets containing 320 ppm than those fed the control diets or diets containing 20, 80, and 160 ppm Mn. Dietary Mn did not affect ($P \geq 0.18$) pork carcass composition or loin muscle quality characteristics. Even though Mn supplementation had no appreciable effects on pork quality during display in the present study, results indicate that supplementing diets with 40 or 320 ppm Mn from Availa-Mn may enhance pig performance, especially feed efficiency.


## Introduction

The dietary requirements for manganese (Mn) in swine diets are quite low and not well established, and are largely based on research conducted 30 years ago with inorganic sources of Mn. Grummer et al. (1950) observed improvements in growth rate and feed efficiency in pigs fed supplemental manganese. Conversely, neither Plumlee et al. (1956), Leibholz et al. (1962), nor Roberts et al. (2001) reported differences in daily gain and efficiency between pigs fed diets supplemented with, or without, Mn. Although not statistically significant, Svajgr et al. (1969) noted that feed efficiency was improved by inclusion of 100 ppm Mn in swine finishing diets.

In the only trial to measure pork carcass composition and quality, Roberts et al. (2002) reported that loin chops from pigs supplemented with 350 ppm of Mn from Availa-Mn received higher Japanese and American color scores than pigs fed unsupplemented diets or diets supplemented with 700 ppm from Availa-Mn, 350 and 700 ppm Mn sulfate. Furthermore, these authors demonstrated that loin chops from pigs fed 350 ppm Mn from Availa-Mn tended to be darker and less yellow than chops from pigs fed the control diets or diets supplemented with 700 ppm Availa-Mn (Roberts et al., 2001). They concluded that supplementing diets with 350 ppm Mn could enhance pork quality, but inclusion of 700 ppm Mn, regardless of source, had no beneficial effects on pork quality or composition. There is no available information concerning the effects of supplementing Mn at inclusion levels less than 350 ppm; therefore, the objectives of this research were to assess the effects of dietary inclusion level of Availa-Mn on performance, carcass composition, and pork quality of growing-finishing swine.

## Experimental Procedures

Two hundred and sixteen crossbred barrows and gilts (EB-348 line; DeKalb Choice Genetics, St. Louis, MO) with an initial BW of 52.4 ± 7.5 lb were sorted into six weight blocks of 36 pigs/block. Pigs within each block were allotted randomly to pens (six pigs/pen) and stratified across pens according to gender and litter origin. A total of 36 pens were assigned randomly to one of six dietary treatments consisting of control corn-wheat middlings-soybean meal starter, grower and finisher diets with no supplemental Mn, and the control diets supplemented with either 20, 40, 80, 160, or 320 ppm Mn from Availa-Mn (a manganese-amino acid complex produced by Zinpro Corporation, Eden Prairie, MN). Pigs were fed a four-phase dietary program with transition from starter to grower-I, grower-I to grower-II, and grower-II to finisher phases occurring when average block weight reached 80, 150, and 200 lb, respectively. Additionally, diets were formulated to be isolysinic and isocaloric (Table 1). Although the mineral premix incorporated in all diets was devoid of Mn, feedstuffs supplied between 44 and 50 ppm of Mn, and, Availa-Mn was added at the expense of corn starch. All diets were formulated to meet, or exceed, NRC (1998) amino acid, energy, and other nutrient requirements for growing-finishing swine. Individual pigs weights were measured weekly, and feed disappearance was recorded at 7-d intervals during each phase to calculate ADG, ADFI, and feed:gain (F/G).

When the mean weight of pigs was 235 lb, all pigs were transported approximately 472 miles to a commercial pork harvest/fabrication plant (Bryan Foods, Inc., West Point, MS). Pigs were harvested after a 12-h rest period at the plant, and 10th rib fat and loin eye depths were measured online with a Fat-O-Meater automated probe (SFK Technology A/S, Cedar Rapids, IA), and hot carcass weight was recorded. Carcasses were subsequently subjected to a conventional spray-chilling system for 24 h. Prior to carcass fabrication, midline backfat depths were recorded to calculate average backfat depth. Boneless pork loins were captured during fabrication, vacuum-packaged, boxed, loaded onto a refrigerated truck, and transported to the University of Arkansas for pork quality data collection.

At approximately 48 h postmortem, pork loins were cut between the 10th and 11th ribs, and two 1-in thick loin chops were removed from the posterior portion of the loin. After a 45-min bloom period at 34°F, chops were visually evaluated for marbling (1 =

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devoid [1% intramuscular fat] to 10 = abundant [10% intramuscular fat]; NPPC, 1999) and color based on both the American (1 = pale, pinkish gray to 6 = dark purplish red; NPPC, 1999) and Japanese color standards (Nakai et al., 1975). Also, L* (measure of darkness to lightness; larger number indicates a lighter color), a* (measure of redness; larger number indicates a redder color), and b* (measure of yellowness; larger number indicates a more yellow color) values were determined from a mean of four random readings (two readings for each chop) made with a Hunter MiniScan XE (model 45/0-L; Hunter Associates Laboratory, Reston, VA) using illuminate C. The saturation index, or chroma (C*), was calculated as $C^* = (a^{*2} + b^{*2})^{1/2}$, and is a measure of the total color or vividness of the color of the longissimus muscle (LM).

A 2-g sample of LM was homogenized in 20 mL of distilled, deionized water, and the pH of the homogenate was measured with a temperature-compensating combination electrode (model 300731.1; Denver Instrument Co., Arvada, CO) attached to a pH/ion/FET-meter (model AP25; Denver Instrument Co., Arvada, CO). After color data collection, chops were weighed, placed on foam trays with an absorbent diaper, overwrapped with an oxygen-permeable PVC film, and stored at 34°F for 48 h. After the 48-h storage period, chops were removed from their packages and re-weighed. The difference between pre- and post-storage chop weights was divided by the initial chop weight to calculated moisture loss percentage.

Data were analyzed as a randomized complete block design, with blocks based on initial BW. Analysis of variance was generated using the mixed-model procedure (PROC MIXED) of SAS (SAS Inst., Inc., Cary, NC). The experimental unit for all performance data was pen; however, carcass was considered as the experimental unit in the analysis of pork carcass composition and pork quality data. Dietary treatment was included in the model as the lone fixed effect, and block and the block x pen x treatment (performance data) or block x pen x carcass x treatment (carcass data) was included in the models as random effects. Least-squares means were computed for the dietary treatments, and orthogonal comparisons of controls vs Mn-fed pigs and the highest inclusion level (320 ppm) vs all other inclusion levels (20, 40, 80, and 160 ppm) were included in the statistical model. Additionally, linear, quadratic, and cubic polynomials were used to detect the response to dietary inclusion level (20, 40, 80, 160, and 320 ppm) of Mn from Availa-Mn.

## Results and Discussion

Pigs fed the control diet consumed more ($P < 0.01$) feed during the starter phase than pigs fed Mn-supplemented diets (Table 2). Additionally, pigs fed diets with 40, 80, and 320 ppm Mn consumed less ($P < 0.02$) feed than pigs fed 20 ppm Mn during the starter phase (cubic effect; $P < 0.10$); however, dietary Mn did not ($P > 0.10$) affect either ADG or F/G (Table 2). Even though dietary Mn level had no ($P > 0.10$) effect on performance during the grower-I phase or finisher phase, pigs fed 40 and 320 ppm Mn had higher ADG, and lower F/G, than pigs fed diets fortified with 20, 80, and 160 ppm Mn (cubic effect; $P < 0.02$ and $P < 0.05$, respectively) during the grower-II phase. Over the entire study (52.0 to 235.0 lb), neither ADG nor ADFI were affected ($P > 0.10$) by dietary Mn, but there was a trend (cubic effect; $P < 0.08$) for F/G to be less in pigs fed diets containing 320 ppm than those fed the control diets or diets containing 20, 80, and 160 ppm Mn. Albeit different Mn sources, our results concur with those of Grummer et al. (1950), who reported improvements in ADG and F/G in pigs fed supplemental Mn. On the other hand, previous results from our laboratory failed to note differences in pig performance among pigs supplemented with 350 or 700 ppm from either Mn-sulfate or Availa-Mn (Roberts et al., 2001).

The effects of dietary inclusion level of Mn on pork carcass composition are presented in Table 3. In agreement with previous results from our laboratory (Roberts et al., 2001), dietary Mn did not ($P > 0.10$) affect hot carcass weight, average backfat thickness, loin eye and 10th rib fat depths, and fat-free lean yield. However, carcasses from pigs fed 80 ppm Mn were trimmer at the last lumbar vertebrae than carcasses from pigs fed 20 or 320 ppm Mn (quadratic effect; $P < 0.03$).

Ultimate (48-h) pH of the LM decreased linearly ($P < 0.01$) as dietary Mn inclusion level increased from 20 to 320 ppm (Table 4). Reductions in muscle pH are typically associated with lower water-holding capacity and a lighter, paler lean color; however, dietary Mn did not ($P > 0.10$) affect moisture loss percentage, American and Japanese color scores, or L* and b* values. Roberts et al. (2001) reported that muscle pH, subjective color scores, and drip loss percentage was not affected by dietary Mn inclusion level or source; however, when chops (from randomly selected loins) from these pigs were subjected to 7 d of retail display, loin chops from pigs 350 ppm of Mn from Availa-Mn received higher Japanese and American color scores than pigs fed unsupplemented diets or diets supplemented with 700 ppm from Availa-Mn, 350 and 700 ppm Mn sulfate (Roberts et al., 2002).

There was a trend for loin chops to become redder (linear effect; $P < 0.10$) as the dietary Mn inclusion level increased from 20 to 320 ppm (Table 4). Finally, the color of chops from pigs fed diets containing 40 and 320 ppm Mn from Availa-Mn was more vivid than chops from pigs fed the control, 20 ppm, 80 ppm or 160 ppm Mn (cubic effect; $P < 0.03$). Roberts et al. (2001) demonstrated that pork from pigs fed 350 ppm Mn from Availa-Mn was darker (lower L* values) than pork from pigs fed diets supplemented with 700 ppm Mn from Availa-Mn, and tended to be less yellow than chops from pigs fed the control diets or diets supplemented with 700 ppm Availa-Mn (Roberts et al., 2002).

## Implications

Results from the present study indicate that supplementing swine diets with 40 or 320 ppm manganese from Availa-Mn may enhance pig performance, in particular feed efficiency. Even though pork loin chops tended to become redder as the level of dietary manganese increased from 20 to 320 ppm, the lower dietary manganese inclusion levels (less than 350 ppm) used in the present study may have contributed to the lack of any appreciable effects on pork quality during retail display.

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**Table 1. Composition of control starter, grower I, grower II, and finisher diets.**

| Ingredient, %[a] | Starter phase | Grower I phase | Grower II phase | Finisher phase |
|---|---|---|---|---|
| Corn (Exp. 2) | 65.27 | 68.48 | 77.84 | 76.945 |
| Soybean meal, 48% (Exp. 2) | 28.86 | 20.30 | 11.85 | 5.55 |
| Wheat middlings | --- | 7.50 | 7.50 | 15.00 |
| Fat | 2.30 | 0.65 | --- | --- |
| Calcium carbonate | 0.92 | 1.00 | 0.88 | 0.90 |
| Corn Starch[b] | 0.40 | 0.40 | 0.40 | 0.40 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 |
| Monocalcium phosphate | 0.75 | 0.68 | 0.55 | 0.25 |
| Lysine | 0.15 | 0.15 | 0.15 | 0.15 |
| Vitamin premix[c] | 0.15 | 0.15 | 0.15 | 0.125 |
| Mineral premix[d] | 0.10 | 0.10 | 0.10 | 0.10 |
| Tylan 40 | 0.05 | 0.05 | 0.05 | 0.05 |
| Ethoxyquin | 0.03 | 0.03 | 0.03 | 0.03 |
| Theronine | 0.02 | 0.01 | --- | --- |
| Methionine | 0.02 | --- | --- | --- |
| | | | | |
| CP, % | 19.28 | 16.61 | 13.36 | 11.49 |
| Lysine, % | 1.16 | 0.95 | 0.72 | 0.57 |
| Methionine + cysteine, % | 0.66 | 0.57 | 0.49 | 0.44 |
| Threonine, % | 0.74 | 0.62 | 0.48 | 0.40 |
| Tryptophan, % | 0.23 | 0.19 | 0.14 | 0.11 |
| Calcium, % | 0.60 | 0.60 | 0.51 | 0.45 |
| Phosphorus, % | 0.54 | 0.54 | 0.48 | 0.44 |
| Basal manganese, ppm | 44.0 | 48.0 | 45.0 | 50.0 |
| ME, Mcal/kg | 3.41 | 3.32 | 3.31 | 3.30 |

[a] Ingredients reported on an as-fed basis.

[b] Corn starch was replaced by 0.025, 0.05, 0.10, 0.20, and 0.40% Availa-Mn for the 20, 40, 80, 160, and 320 ppm Mn treatments, respectively.

[c] Premix contained 909,091 IU of vitamin A, 136,364 IU of vitamin D, 3,636 IU of vitamin E, 3.6 mg of vitamin B12, 364 mg of vitamin K, 818 mg of riboflavin, 2,727 mg of D-pantothenic acid, and 4,546 mg of niacin per kilogram (Nutra Blend Corp., Neosho, MO).

[d] Premix contained 11.0% Iron, 11.0% Zinc, 1.1% Copper, 0.02% Iodine, and 0.02% Selenium (Nutra Blend Corp., Neosho, MO).

**Table 2. Effect of dietary supplementation level of manganese on growth performance of growing-finishing swine.**

| | | Manganese, ppm | | | | | |
|---|---|---|---|---|---|---|---|
| Item | Control | 20 | 40 | 80 | 160 | 320 | SEM |
| Starter phase (52.0 to 80 lb) | | | | | | | |
| ADG, lb | 1.41 | 1.41 | 1.34 | 1.34 | 1.36 | 1.36 | 0.066 |
| ADFI, lb[1,2] | 2.73 | 2.71 | 2.53 | 2.55 | 2.57 | 2.55 | 0.090 |
| F/G | 1.93 | 1.91 | 1.93 | 1.89 | 1.94 | 1.89 | 0.061 |
| Grower I phase (80.0 to 150.0 lb) | | | | | | | |
| ADG, lb | 1.91 | 1.89 | 1.91 | 1.87 | 1.94 | 1.96 | 0.084 |
| ADFI, lb | 4.99 | 5.04 | 4.97 | 4.95 | 4.93 | 5.04 | 0.165 |
| F/G | 2.57 | 2.65 | 2.60 | 2.67 | 2.55 | 2.57 | 0.073 |
| Grower II phase (150.0 to 200.0 lb) | | | | | | | |
| ADG, lb[3] | 1.74 | 1.85 | 1.98 | 1.83 | 1.72 | 1.87 | 0.073 |
| ADFI, lb[4] | 6.25 | 6.36 | 6.31 | 6.18 | 5.90 | 6.09 | 0.209 |
| F/G[5,6] | 3.60 | 3.46 | 3.18 | 3.39 | 3.47 | 3.24 | 0.118 |
| Finisher phase (200.0 to 235.0 lb) | | | | | | | |
| ADG, lb | 1.21 | 1.28 | 1.28 | 1.21 | 1.25 | 1.32 | 0.099 |
| ADFI, lb | 6.25 | 6.23 | 6.31 | 6.47 | 6.60 | 6.07 | 0.279 |
| F/G | 5.24 | 5.31 | 5.01 | 5.38 | 5.41 | 4.72 | 0.325 |
| Overall (52.0 to 235.0 lb) | | | | | | | |
| ADG, lb | 1.61 | 1.63 | 1.67 | 1.58 | 1.61 | 1.67 | 0.048 |
| ADFI, lb | 5.19 | 5.21 | 5.15 | 5.17 | 5.15 | 5.08 | 0.198 |
| F/G[7] | 3.23 | 3.21 | 3.11 | 3.25 | 3.20 | 3.05 | 0.059 |

[1] Pigs fed control diets differ from pigs fed manganese-supplemented diets ($P < 0.01$).

[2] Cubic effect of manganese-supplementation level ($P < 0.10$).

[3] Cubic effect of manganese-supplementation level ($P < 0.02$).

[4] Linear effect of manganese-supplementation level ($P = 0.11$).

[5] Pigs fed control diets differ from pigs fed manganese-supplemented diets ($P < 0.06$).

[6] Cubic effect of manganese-supplementation level ($P < 0.05$).

[7] Cubic effect of manganese-supplementation level ($P < 0.08$).

**Table 3. Effect of dietary supplementation level of manganese on pork carcass cutability characteristics.**

| | | Manganese, ppm | | | | | |
|---|---|---|---|---|---|---|---|
| Item | Control | 20 | 40 | 80 | 160 | 320 | SEM |
| Hot carcass wt, lb | 175.8 | 178.2 | 178.6 | 174.2 | 176.2 | 178.2 | 5.39 |
| Backfat depth, in | | | | | | | |
| First rib | 1.48 | 1.54 | 1.39 | 1.45 | 1.43 | 1.42 | 0.050 |
| Last rib | 0.82 | 0.83 | 0.78 | 0.81 | 0.83 | 0.80 | 0.046 |
| Last lumbar vertebrae[1] | 0.77 | 0.83 | 0.73 | 0.70 | 0.75 | 0.77 | 0.070 |
| Average | 1.03 | 1.07 | 0.97 | 0.99 | 1.00 | 1.00 | 0.042 |
| Loin eye depth, in | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.7 | 0.05 |
| 10th rib fat depth, in | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 | 0.9 | 0.04 |
| Fat-free lean yield, %[a] | 50.13 | 48.95 | 49.00 | 49.87 | 50.55 | 49.84 | 0.720 |

[a] Fat-O-Meater equation: ((15.3098 – (31.2796 _ 10th rib fat depth, in.) + (3.8132 _ loin eye depth, in.) + (0.5096 _ hot carcass wt, lb.)) ÷ hot carcass wt, lb) x 100.

[1] Quadratic effect of manganese-supplementation level ($P < 0.03$).

**Table 4. Effect of dietary supplementation level of manganese on pork quality characteristics.**

| | | Manganese, ppm | | | | | |
|---|---|---|---|---|---|---|---|
| Item | Control | 20 | 40 | 80 | 160 | 320 | SEM |
| 48-h muscle pH[1] | 5.94 | 5.91 | 5.92 | 5.89 | 5.84 | 5.73 | 0.090 |
| Moisture loss, % | 3.31 | 2.82 | 2.90 | 2.96 | 3.64 | 3.38 | 0.417 |
| American color score[a] | 3.7 | 3.8 | 3.7 | 3.8 | 3.7 | 3.7 | 0.09 |
| Japanese color score[b] | 3.4 | 3.7 | 3.5 | 3.5 | 3.4 | 3.5 | 0.10 |
| Lightness (L*)[c] | 51.38 | 51.53 | 53.20 | 51.18 | 51.64 | 51.70 | 0.586 |
| Redness (a*)[c,2] | 6.43 | 6.27 | 6.54 | 6.58 | 6.60 | 6.70 | 0.202 |
| Yellowness (b*)[c] | 13.90 | 14.17 | 14.69 | 14.00 | 13.89 | 14.08 | 0.187 |
| Chroma[d,3] | 15.34 | 15.52 | 16.12 | 15.48 | 15.40 | 15.61 | 0.217 |
| Marbling score[e] | 2.1 | 1.9 | 2.0 | 2.0 | 2.0 | 1.9 | 0.10 |

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

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

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

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

[e] Marbling: 1 = 1% intramuscular fat (devoid) to 10 = 10% intramuscular fat (abundant; NPPC, 1999).

[1] Linear effect of manganese-supplementation level ($P < 0.01$).

[2] Linear effect of manganese-supplementation level ($P < 0.10$).

[3] Cubic effect of manganese-supplementation level ($P < 0.03$).

# Potential for Fish Meal Analog as a Replacement for Fish Meal in Early-Weaned Pig Diets

*C.V. Maxwell*[1], *M.E. Davis*[1], *D.C. Brown*[1], *P. Bond*[2], *and Z.B. Johnson*[1]


## Story in Brief

A total of 288 pigs (20 d of age; 7.9 ± 0.08 kg BW) were fed one of four dietary treatments to determine the potential for an animal-based protein with similar composition to fish meal (fish analog) to replace fish meal in early-weaned pig diets. Pigs were sorted into nine weight blocks, and pigs within each weight block were randomly assigned to pens of eight pigs each. Four dietary treatments fed from d 0 to 14 (Phase 1) after weaning consisted of: 1) positive control with 8% fish meal, 2) negative control with soybean meal and lysine replacing fish meal, 3) positive control with fish analog replacing 50% of the fish meal, and 4) positive control with fish analog replacing 100% of the fish meal. Fish meal was replaced in each diet on an equal lysine basis. Dietary treatments fed from d 14 to 28 (Phase 2) after weaning were similar to those in Phase 1, although the positive control diet contained 6% fish meal during Phase 2. A common Phase 3 diet was fed from d 28 to 42 after weaning. From d 0 to 7, d 7 to 14, and d 0 to 14, pigs fed the positive control diet and those fed fish analog replacing 100% of fish meal had similar ADG. From d 0 to 28, pigs fed the negative control diet had the highest ADG, while there were no differences in ADG between pigs fed the positive control diet and those fed fish analog at either replacement level. Gain:feed ratio from d 0 to 7 was highest when pigs were fed the positive and negative control diets compared to pigs fed fish analog at either replacement level. Although average body weights of pigs fed fish analog at the 100% replacement level was lower than that observed in pigs fed the negative control diet at the end of Phase 1 and Phase 2, there were no differences between body weight of pigs fed fish analog at the 100% replacement level and the positive control. This study indicates that fish analog protein results in comparable gain to fish meal when added to Phase 1 and Phase 2 diets for early-weaned pigs.


## Introduction

Pigs produced in conventional intensively managed swine production systems are routinely weaned as early as 19 to 21 days of age and as early as 10 to 14 days of age in off-site segregated early-weaning systems. At these ages, pigs are very sensitive to the source of dietary protein. Many dietary proteins produce allergic reactions in which diarrhea, reduced growth, and increased mortality can occur (Bimbo and Crowther, 1992). Various protein sources have been tested in early-weaned pig diets in an attempt to overcome these problems and to decrease diet cost. Select grade menhaden fish meal has been one of the most widely utilized protein sources due to a combination of consistent quality and competitive price. Increased demand and decreased supply of fish meal has resulted in increased price volatility and periodic high prices. Spray dried plasma protein is another protein source that has consistently been shown to improve performance of early-weaned pigs when included in Phase 1 (d 0 to 14 postweaning) diets at the expense of dried skim milk (Hansen et al., 1993; Kats et al., 1994; de Rodas et al., 1995), soybean meal (Fakler et al., 1993; Coffey and Cromwell, 1995; de Rodas et al., 1995), and whey (Hansen et al., 1993). However, the supply of these proteins is limited and, therefore, these protein sources are expensive.

Mid-South Milling Co., Inc., Memphis, TN, has produced a product based on animal proteins that has a composition very similar to fish meal and should be an excellent protein and amino acid source for young pigs. This may provide a high quality protein and amino acid source for use in early weaning pig diets at costs lower than those associated with fish meal. This study was conducted to determine the potential for fish analog as a replacement for fish meal in early weaning pig diets.

## Experimental Procedures

*Allotment of pigs*: A total of 288 weanling pigs (20 days of age; 7.9 ± 0.08 kg body weight; Dekalb 348 mated to Dekalb EB sires) were transported to the University of Arkansas wean-to-finish facilities, sorted by weight, and divided into weight groups (blocks). Pigs within each weight group were allotted into equal subgroups (eight pigs per pen) with stratification based on litter and sex. Then treatments were randomly assigned to pens (subgroups) within each of the weight groups.

*Dietary Treatments*: This study was conducted to determine the efficacy of fish analog as a replacement for fish meal in Phase 1 and Phase 2 nursery diets in pigs weaned at 20 ± 2 days of age and reared in a wean-to-finish nursery.Diets during the first 14 days postweaning (Phase 1) consisted of the following:

1) A positive control Phase 1 diet containing 8.00% fish meal (Table 1).
2) A negative control diet devoid of fish meal with 48% soy bean meal and lysine added at the expense of fish meal on an equal lysine basis (requires 12.00% soybean meal and 0.05% lysine).
3) The positive control diet with fish meal analog replacing 50% of the fish meal on an equal lysine basis (replaces 4.00% fish meal).
4) The positive control diet with fish meal analog replacing 100% of the fish meal on an equal lysine basis (replaces 8.00% fish meal).

Substitutions in all diets were made at the expense of corn. Dietary metabolizable energy was maintained constant by adding fat. Diets were formulated to contain 1.50% lysine, 0.86% methionine plus cystine, 0.90% Ca, 0.80% P, and 14.85% lactose.

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Diets during the second 14 days postweaning (Phase 2) consisted of the following:

1) A positive control Phase 1 diet containing 6.00% fish meal (Table 2).
2) A negative control diet devoid of fish meal with 48% soybean meal and lysine added at the expense of fish meal on an equal lysine basis (requires 8.60% soybean meal and 0.05% lysine).
3) The positive control diet with fish meal analog replacing 50% of the fish meal on an equal lysine basis (replaces 3.0% fish meal).
4) The positive control diet with fish meal analog replacing 100% of the fish meal on an equal lysine basis (replaces 6.0% fish meal).

Upon completion of Phase 2, a common phase-3 corn-soybean meal-based diet (1.20% lysine) was fed from day 28 to 42 postweaning.

*Housing, Equipment & Environment:* Pigs were housed in a wean-to-finish facility in totally slatted pens (1.52 m x 3.05 m) equipped with radiant heaters, a two-hole nursery feeder and wean to finish cup waterers. Ambient room temperature was maintained at approximately 78°F. In addition, a radiant heater provided supplemental heat to a 6' diameter area covering two pens/heater.

*Experimental Management:* On the day of weaning, the pigs were moved from the farrowing rooms and distributed to their assigned pen. The test diets were then randomly allocated to pens within block. The pigs were offered ad libitum access to the Phase 1 treatment diets for the 0- to 14-d period, the Phase 2 treatment diets for the 14- to 28-d period, and the Phase 3 diet for the 28- to 42-d period. Water was available freely throughout the study.

*Animal care*: Except for weighing the pigs and the feed added and leftover at the end of each test period, the pigs in this study were cared for following typical commercial management procedures. This experiment was carried out in accordance with the Animal Care Protocol # 01015 for swine experiments issued by the University of Arkansas Animal Care Committee.

*Data Collection:* Pig body weight and feed intake was determined weekly to evaluate ADG, ADFI, and gain:feed.

*Statistical Analysis:* Data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was performed using the GLM procedures of SAS (SAS Inst., Inc., Cary, NC). The effects of source of protein, level of fish meal replacement, and the source x level of replacement interaction were evaluated.

## Results and Discussion

Overall performance was very good in this study. From d 0 to 7 (Week 1), d 7 to 14 (Week 2), and d 0 to 14 (Phase 1), pigs fed the positive control diet and those fed fish analog replacing 100% of fish meal had similar (Table 4, $P > 0.10$) ADG. During Phase 2 (Weeks 3 and 4), ADG was not significantly affected by dietary treatment. From d 0 to 28 (Phase 1-2), pigs fed the negative control diet had the highest ($P < 0.05$) ADG, while there were no differences ($P > 0.10$) in ADG between pigs fed the positive control fish meal diet and those fed fish analog at either replacement level. During phase 3 when all pigs were fed a common diet, gain in all pigs regardless of previous treatment was similar. Similarly, ADG for the overall experiment (Phase 1-3) was not affected by dietary treatment ($P > 0.10$).

Average daily feed intake was similar among the dietary treatments during Phase 1, Phase 2, and Phase 3 ($P > 0.10$); however, during Phase 2 and Phase 3, pigs fed the negative control diet tended to have increased ADFI ($P < 0.10$) when compared to those fed the positive control diet; daily feed intake in pigs fed fish analog at any replacement level was intermediary. For the overall nursery study (Phase I-III) pigs fed the negative control diet had increased ADFI ($P < 0.05$) when compared to those fed the positive control diet while there were no differences ($P > 0.10$) in ADFI between pigs fed the positive control fish meal diet and those fed fish analog at either replacement level.

Gain:feed ratio from d 0 to 7 was highest ($P < 0.05$) when pigs were fed the positive and negative control diets compared to pigs fed fish analog at either replacement level. However, during week 2 of Phase 1, for the overall Phase 1 period and during Phase 3, gain:feed was similar among the dietary treatments ($P > 0.10$). During Phase 2, gain:feed tended to be reduced in pigs fed the negative control diet compared to those fed the positive control diet ($P < 0.10$), and gain:feed in pigs fed fish analog at either replacement level was intermediary. For the overall experiment (Phase 1-3), gain:feed was improved in pigs fed the positive control diet when compared to all other treatments.

Although body weight of pigs fed fish analog at the 100% replacement level was lower ($P < 0.05$) than weight of pigs fed the negative control diet at the end of Phase 1 and Phase 2, there were no differences between body weight of pigs fed fish analog at the 100% replacement level and the positive control ($P > 0.10$). For the overall experiment (Phase 1-3), final body weight was similar among the dietary treatments ($P > 0.10$). This study indicates that fish analog protein resulted in gain comparable to fish meal when added to Phase 1 and Phase 2 diets for early-weaned pigs.

## Implications

Results of this study indicate that fish meal analog, a product based on animal proteins that has a composition very similar to fish meal, is an effective replacement for select menhaden fish meal in Phase 1 and Phase 2 nursery diets at either the 50% or 100% replacement level.

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**Table 1. Composition of experimental phase 1 diets.**

| | Phase 1 diets | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Item,% | Positive fish meal control | Negative control | 50% Fish meal rep. 50% fish analog | 100% Fish meal rep. fish analog |
| Yellow corn | 38.90 | 32.25 | 38.54 | 38.12 |
| Steam rolled oats | 5.00 | 5.00 | 5.00 | 5.00 |
| Lactose | 15.00 | 15.00 | 15.00 | 15.00 |
| AP –920 (plasma protein) | 2.50 | 2.50 | 2.50 | 2.50 |
| **Soybean meal, 48% CP** | **15.00** | **27.00** | **15.00** | **15.00** |
| **Select menhaden fish meal** | **8.00** | **0.00** | **4.00** | **0.00** |
| **Fish meal analog** | **0.00** | **0.00** | **4.00** | **8.00** |
| Pro. soy prot. (Optipro) | 7.45 | 7.45 | 7.45 | 7.45 |
| Fat | 4.00 | 5.20 | 4.35 | 4.70 |
| Ethoxyquin | 0.03 | 0.03 | 0.03 | 0.03 |
| Neo-terramycin 10/5 | 1.00 | 1.00 | 1.00 | 1.00 |
| Zinc oxide | 0.25 | 0.25 | 0.25 | 0.25 |
| CuSO4 | 0.07 | 0.07 | 0.07 | 0.07 |
| Mineral premix (NB-8534) | 0.15 | 0.15 | 0.15 | 0.15 |
| Vitamin premix (NB-6157C) | 0.25 | 0.25 | 0.25 | 0.25 |
| Dicalcium phosphate | 1.20 | 2.15 | 1.20 | 1.23 |
| Calcium carbonate | 0.34 | 0.76 | 0.35 | 0.37 |
| Lysine | 0.15 | 0.20 | 0.15 | 0.15 |
| Methionine | 0.11 | 0.14 | 0.11 | 0.11 |
| Threonine | 0.10 | 0.10 | 0.10 | 0.12 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 |
| ***Calculated composition*** | | | | |
| Lysine | 1.50 | 1.50 | 1.50 | 1.50 |
| Threonine | 0.98 | 0.98 | 0.98 | 0.98 |
| Tryptophan | 0.27 | 0.29 | 0.26 | 0.26 |
| Met + cys | 0.86 | 0.86 | 0.86 | 0.86 |
| Isoleucine | 0.89 | 0.93 | 0.87 | 0.85 |
| Ca | 0.90 | 0.90 | 0.90 | 0.90 |
| P | 0.80 | 0.80 | 0.80 | 0.80 |
| Metabolizable energy | 1574.89 | 1574.82 | 1574.93 | 1574.87 |
| Lactose | 14.85 | 14.85 | 14.85 | 14.85 |

**Table 2. Composition of experimental phase 2 diets.**

| | Phase 2 diets | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Item,% | Positive fish meal control | Negative control | 50% fish meal rep. 50% fish analog | 100% fish meal rep. fish analog |
| Yellow corn | 53.15 | 48.51 | 52.87 | 52.59 |
| Lactose | 10.00 | 10.00 | 10.00 | 10.00 |
| AP-301 | 2.00 | 2.00 | 2.00 | 2.00 |
| **Soybean meal, 48% CP** | **21.00** | **29.60** | **21.00** | **21.00** |
| **Select menhaden fish meal** | **6.00** | **0.00** | **3.00** | **0.00** |
| **Fish meal analog** | **0.00** | **0.00** | **3.00** | **6.00** |
| Fat | 3.70 | 4.60 | 3.95 | 4.22 |
| Ethoxyquin | 0.03 | 0.03 | 0.03 | 0.03 |
| Neo-terramycin 10/5 | 1.00 | 1.00 | 1.00 | 1.00 |
| Zinc oxide | 0.25 | 0.25 | 0.25 | 0.25 |
| CuSO4 | 0.07 | 0.07 | 0.07 | 0.07 |
| Mineral premix (NB-8534) | 0.15 | 0.15 | 0.15 | 0.15 |
| Vitamin premix (NB-6157C) | 0.25 | 0.25 | 0.25 | 0.25 |
| Dicalcium phosphate | 1.16 | 1.87 | 1.18 | 1.15 |
| Calcium carbonate | 0.37 | 0.72 | 0.38 | 0.42 |
| Lysine | 0.15 | 0.20 | 0.15 | 0.15 |
| Methionine | 0.11 | 0.13 | 0.10 | 0.10 |
| Threonine | 0.11 | 0.12 | 0.12 | 0.12 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 |
| ***Calculated composition*** | | | | |
| Lysine | 1.35 | 1.35 | 1.35 | 1.35 |
| Threonine | 0.88 | 0.88 | 0.88 | 0.88 |
| Tryptophan | 0.24 | 0.25 | 0.23 | 0.23 |
| Met + cys | 0.76 | 0.76 | 0.76 | 0.76 |
| Isoleucine | 0.77 | 0.79 | 0.75 | 0.74 |
| Ca | 0.80 | 0.80 | 0.80 | 0.80 |
| P | 0.70 | 0.70 | 0.70 | 0.70 |
| Metabolizable energy | 1569.59 | 1569.10 | 1569.10 | 1569.22 |
| Lactose | 9.90 | 9.90 | 9.90 | 9.90 |

**Table. 3. Treatment means for fish meal analog nursery study.**

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | |
| Item,% | Positive fish meal control | Negative control | 50% fish meal rep. 50% fish analog | 100% fish meal rep. fish analog | SEM | P-value |
| ADG, lb | | | | | | |
| Phase 1, wk 1 | 0.489$^{ab}$ | 0.525$^{a}$ | 0.412$^{c}$ | 0.437$^{bc}$ | .02 | < 0.01 |
| Phase 1, wk 2 | 0.844$^{b}$ | 0.955$^{a}$ | 0.785$^{b}$ | 0.822$^{b}$ | .03 | < 0.01 |
| Phase 1, wk 1-2 | 0.642$^{b}$ | 0.708$^{a}$ | 0.571$^{c}$ | 0.602$^{bc}$ | .02 | < 0.01 |
| Phase 2, wk 3-4 | 1.265 | 1.303 | 1.283 | 1.281 | .03 | 0.81 |
| Phase 1-2, wk 1-4 | 0.928$^{b}$ | 0.983$^{a}$ | 0.899$^{b}$ | 0.915$^{b}$ | .02 | <0.03 |
| Phase 3, wk 5-6 | 1.590 | 1.629 | 1.642 | 1.578 | .03 | 0.37 |
| Phase 1-3, wk 1-6 | 1.171 | 1.219 | 1.171 | 1.157 | .02 | 0.12 |
| ADFI, lb | | | | | | |
| Phase 1, wk 1 | 0.492 | 0.527 | 0.454 | 0.485 | .02 | 0.11 |
| Phase 1, wk 2 | 0.800 | 0.935 | 0.825 | 0.917 | .06 | 0.26 |
| Phase 1, wk 1-2 | 0.624 | 0.701 | 0.613 | 0.668 | .03 | 0.18 |
| Phase 2, wk 3-4 | 1.563$^{d}$ | 1.772$^{e}$ | 1.618$^{d}$ | 1.662$^{d}$ | .06 | 0.09 |
| Phase 1-2, wk 1-4 | 1.058$^{d}$ | 1.193$^{e}$ | 1.075$^{d}$ | 1.124$^{de}$ | .04 | 0.10 |
| Phase 3, wk 5-6 | 2.346$^{d}$ | 2.542$^{e}$ | 2.480$^{d}$ | 2.427$^{d}$ | .05 | 0.06 |
| Phase 1-3, wk 1-6 | 1.526$^{b}$ | 1.684$^{a}$ | 1.590$^{ab}$ | 1.601$^{ab}$ | .04 | 0.04 |
| Gain:feed | | | | | | |
| Phase 1, wk 1 | .992$^{a}$ | .982$^{a}$ | .902$^{b}$ | .895$^{b}$ | .022 | < 0.01 |
| Phase 1, wk 2 | 1.109 | 1.022 | 1.021 | .920 | .076 | 0.40 |
| Phase 1, wk. 1-2 | 1.043 | 1.001 | .962 | .905 | .039 | 0.11 |
| Phase 2, wk 3-4 | .823$^{d}$ | .738$^{e}$ | .803$^{d}$ | .778$^{d}$ | .024 | 0.09 |
| Phase 1-2, wk 1-4 | .888$^{d}$ | .820$^{e}$ | .849$^{de}$ | .818$^{e}$ | .020 | 0.08 |
| Phase 3, wk 5-6 | .683 | .646 | .665 | .653 | .014 | 0.29 |
| Phase 1-3, wk 1-6 | .772$^{a}$ | .724$^{b}$ | .742$^{b}$ | .726$^{b}$ | .010 | < 0.01 |
| Weight, lb | | | | | | |
| Initial | 13.75 | 13.78 | 13.73 | 13.76 | .01 | 0.29 |
| Phase 1, wk 1 | 17.66$^{ab}$ | 17.90$^{a}$ | 17.02$^{c}$ | 17.26$^{bc}$ | .18 | < 0.01 |
| Phase 1, wk 2 | 22.73$^{ab}$ | 23.63$^{a}$ | 21.74$^{c}$ | 22.18$^{bc}$ | .26 | < 0.01 |
| Phase 2, wk 2 | 37.90$^{ab}$ | 39.29$^{a}$ | 37.10$^{b}$ | 37.54$^{b}$ | .48 | 0.03 |
| Phase 3, wk 2 | 61.75 | 63.71 | 61.77 | 61.24 | .77 | 0.14 |

$^{a,b,c}$ Means in a row with no letter in common differ (P < 0.05).

$^{d,e}$ Means in a row with no letter in common differ (P < 0.10).

# The Effect of Phosphorylated Mannans on Growth and Immune Responses of Weanling Pigs

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## Story in Brief

Phosphorylated mannans (MAN) derived from the yeast cell wall of *Saccharomyces cerevisiae* may have the potential to beneficially modulate immune function in the weanling pig, possibly providing an alternative to the use of dietary growth-promoting antibiotics. In this study, 32 pigs (19 d of age and 12.6 lb initial BW) were randomly assigned to 16 pens in an environmentally-controlled nursery to determine the effects of dietary supplementation with mannans on growth and immune function. Average daily gain and F/G were improved ($P < 0.05$) when pigs were fed diets supplemented with mannans from day 0 to 14 and in the overall experiment after weaning. Percentage of neutrophils was lower ($P = 0.08$) and percentage of lymphocytes was higher ($P < 0.05$) in blood from pigs fed mannans compared to those fed the basal diet. Lamina propria macrophages isolated from pigs fed diets containing mannans phagocytosed a greater ($P = 0.05$) number of sheep red blood cells than those isolated from pigs fed the basal diet. On d 19 after weaning, pigs fed diets supplemented with MAN had a greater ($P < 0.10$) proportion of $CD14^+$ lamina propria leukocytes than control pigs. On d 21 after weaning, the proportion of $CD14^+MHCII^+$ lamina propria leukocytes was lower ($P < 0.10$) when pigs were fed MAN compared to control pigs. Supplementation of mannans in the diets of weanling pigs improves gain and efficiency, and modulates the immune capabilities of the weanling pig, both systemically and enterically.


## Introduction

The addition of antibiotic growth promoters to swine diets is a common practice, particularly to the diets of newly-weaned pigs. However, there has been increasing pressure on the industry to decrease or discontinue these additions because of the potential development of antibiotic resistance within bacterial populations. The need for alternative methods to improve growth and efficiency of swine production and to modulate the pig's natural ability to fight disease has prompted the scientific investigation of several feed additives and their ability to positively alter immune function. In a similar manner to the action of antibiotics added to the diet, phosphorylated mannans (MAN) have the ability to alter the microbial population in the intestinal tract, and have also been reported to alter immune function in swine. However, the mechanism by which MAN functions to modulate health is not well defined. Before the benefits of MAN can be successfully utilized in swine production systems, a better understanding of its mode of action is needed. Thus, the specific objectives of this study were to: 1) evaluate the effects of MAN on gain, feed intake, and feed efficiency of pigs weaned to a conventional, on-site nursery facility, and 2) measure the immunomodulatory effects of MAN.

## Experimental Procedures

A total of 32 pigs averaging 19 d of age and 12.6 lb of initial BW were weaned and randomly distributed within 16 pens, so that two pigs were contained in each pen. Dietary treatments consisted of a typical starter pig diet (10% SBM, 17.5% whey, 8.5% fish meal, 3.7% spray-dried animal plasma, 2% spray-dried blood cells, and antibiotics) with or without the addition of 0.3% MAN. Diets were assigned to pens in a completely randomized design. Dietary treatments were administered throughout the entire experimentation period.

Pig BW and feed intake were determined on d 14 and 21 of the experiment to calculate ADG, ADFI, and F/G. On d 14, pigs were bled via vena cava puncture to obtain a whole blood sample in tubes containing EDTA for the isolation of peripheral blood mononuclear cells to determine lymphocyte proliferation response and the phagocytic ability of blood monocytes/macrophages.

Pigs were euthanized by lethal injection of sodium pentobarbital on d 19, 21, 24, and 26 after weaning, so that four randomly selected pens (two pens representing each dietary treatment) were sampled on each day. Prior to euthanization, pigs were bled via vena cava puncture to determine differential blood leukocyte concentrations and flow cytometric analysis. After euthanization, 40 cm of jejunal tissue was obtained from each pig, and lamina propria leukocytes were isolated to determine macrophage phagocytic ability and for flow cytometric analysis.

Data were analyzed as a completely randomized design with pen as the experimental unit. The model included the effects of dietary treatment when analyzing ADG, ADFI, F/G, and monocyte/macrophage phagocytosis. Initial BW was used as a covariate when analyzing ADG, ADFI, and F/G. The model included dietary treatment, sampling day, and the treatment x day interaction when analyzing differential blood leukocytes and flow cytometric data. Data were analyzed using the General Linear Model procedure of SAS (SAS Inst., Inc., Cary, NC).

## Results and Discussion

Pigs fed diets supplemented with MAN had greater ($P < 0.05$) ADG and lower ($P < 0.05$) F/G, and tended to have greater ($P = 0.11$) ADFI than pigs fed the control diet from d 0 to 14 after weaning (Table 1). Although neither ADG, ADFI, nor F/G were altered ($P > 0.40$) as a result of dietary treatment from d 14 to 21 after weaning, the improvement in ADG and F/G was maintained in the overall experiment ($P < 0.05$). This was reflected by the greater ($P < 0.05$)

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BW of pigs fed MAN on d 14 and d 21 of the experiment compared to pigs fed the control diet. This observation is consistent with previous research, in which the addition of MAN to weanling pig diets was reported to increase gain and efficiency (Davis et al., 2002; Kim et al., 2000).

The percentage of lymphocytes increased ($P < 0.05$) and the percentage of neutrophils decreased ($P = 0.08$) in blood obtained from pigs fed MAN compared to control pigs (Table 2). Although not significantly different, the increase in the concentration of lymphocytes and the decrease in the concentration of neutrophils resulted in a numerically lower ($P = 0.14$) neutrophil-to-lymphocyte ratio when pigs were fed diets containing MAN compared to control pigs. An increase in the neutrophil:lymphocyte ratio is associated with stress in poultry (Gross and Siegel, 1983), and pigs exposed to stress have been reported to have an elevated proportion of neutrophils in the blood (Morrow-Tesch et al., 1994). The alterations in blood leukocyte proportions observed in this study indicate that MAN supplementation may alleviate some of the effects of weaning stress in young pigs.

Dietary treatments provided to pigs following weaning did not alter ($P > 0.50$) the percentage of phagocytic monocytes/macrophages, or the number of sheep red blood cells (SRBC) consumed by phagocytic monocytes/macrophages isolated from peripheral blood (Table 3). Although the percentage of phagocytic macrophages isolated from the jejunal lamina propria was not altered by dietary treatment, phagocytic macrophages isolated from pigs fed MAN consumed a greater ($P = 0.05$) number of SRBC per phagocytic macrophage than pigs fed diets without MAN (Table 3). On d 19 after weaning, pigs fed diets supplemented with MAN had a greater ($P < 0.10$) proportion of $CD14^+$ [3] lamina propria leukocytes than control pigs (Table 4). On d 21 after weaning, the proportion of $CD14^+$ leukocytes isolated from the peripheral blood ($P < 0.05$) and $CD14^+MHCII^+$ [4] lamina propria leukocytes ($P < 0.10$) was lower when pigs were fed MAN compared to control pigs. Gelderman et al. (1998) reported that macrophage function can be enhanced by the binding of mannose to receptors on the macrophage cell surface. The increase in the ability of jejunal lamina propria macrophages isolated from pigs fed MAN to phagocytose SRBC in this experiment may be a result of the exposure of macrophages to MAN in the enteric environment. Basta et al. (1999) reported that CD14 expression on monocytes was down-regulated as they differentiated into macrophages, and their phagocytic and bacteriocidal activities increased. Therefore, low CD14 and MHC-II expression on the cell surface of monocytes/macrophages may be indicative of their predominately phagocytic activities. The decrease in the proportions $CD14^+MHCII^+$ lamina propria leukocytes observed in this study when pigs were fed MAN compared to control pigs suggests an association with increased macrophage activation in the form of phagocytosis. Moreover, this association is corroborated by the greater number of SRBC phagocytosed by phagocytic macrophages isolated from the jejunum of pigs fed MAN.

## Implications

Phosphorylated mannans have the potential to serve as a growth-enhancing additive in the diets of newly-weaned pigs. Although the addition of MAN to weaned pig diets altered the immune characteristics measured in this study, further investigation is warranted to discern the mechanism by which mannans alter systemic and enteric immune function.

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**Table 1. Growth response of weanling pigs fed phosphorylated mannans or a control diet.[a]**

| Item | CONTROL | MAN | SEM | P= |
|---|---|---|---|---|
| d 0 to 14 | | | | |
| ADG, lb | 0.34 | 0.56 | 0.07 | 0.049 |
| ADFI, lb | 0.58 | 0.69 | 0.04 | 0.106 |
| Feed/gain | 1.76 | 1.21 | 0.11 | 0.005 |
| D 0 to final | | | | |
| ADG, lb | 0.52 | 0.69 | 0.05 | 0.033 |
| ADFI, lb | 0.79 | 0.86 | 0.04 | 0.243 |
| Feed/gain | 1.56 | 1.26 | 0.06 | 0.008 |
| Pig weight, lb | | | | |
| Initial | 11.90 | 13.11 | 0.50 | 0.108 |
| d 14 | 17.26 | 20.32 | 0.95 | 0.050 |
| d 21 | 22.43 | 26.11 | 1.05 | 0.034 |

[a] Values are means of eight pens representing each dietary treatment. Initial BW was used as a covariate when analyzing ADG, ADFI, feed/gain, and pig BW.

[3] $CD14^+$ indicates leukocytes positive for the cluster of differentiation-14 cell surface marker, indicative of monocytes/macrophages.

[4] $MHCII^+$ indicates leukocytes positive for major histocompatibility complex-II, an antigen-presenting molecule on the surface of many types of leukocytes.

**Table 2. Differential leukocyte proportions of weanling pigs fed phosphorylated mannans or a control diet.[a]**

| Item | Control | Mannan | SEM | P= |
|---|---|---|---|---|
| Leukocytes (%)[b] | | | | |
| Neutrophils | 52.8 | 45.3 | 2.7 | 0.080 |
| Lymphocytes | 42.8 | 50.7 | 2.0 | 0.026 |
| Monocytes | 0.68 | 0.4 | 0.23 | 0.401 |
| Eosinophils | 3.7 | 3.6 | 0.8 | 0.956 |
| Neutrophil-to-lymphocyte ratio | 1.39 | 1.05 | 0.15 | 0.142 |

[a] Values are means of eight pens representing each dietary treatment.

[b] Leukocyte proportions are presented as a percentage of total white blood cell counts within the peripheral blood.

**Table 3. Macrophage phagocytosis response of weanling pigs fed phosphorylated mannans or a control diet.[a]**

| Item | CONTROL | MAN | SEM | P= |
|---|---|---|---|---|
| Macrophage phagocytosis[b] | | | | |
| Blood | | | | |
| % Phagocytic | 15.7 | 16.5 | 1.73 | 0.769 |
| Avg. SRBC [c] | 1.62 | 1.70 | 0.07 | 0.432 |
| Lamina propria | | | | |
| % Phagocytic | 24.2 | 26.7 | 1.94 | 0.366 |
| Avg. SRBC [c] | 2.31 | 2.63 | 0.11 | 0.051 |

[a] Values are means of eight pens representing each dietary treatment.

[b] Percentage of phagocytic macrophages and average number of sheep red blood cells phagocytosed from macrophages isolated from the blood at d 14 after weaning.

[c] Values represent the average number of sheep red blood cells (SRBC) consumed by phagocytic macrophages.

**Table 4. The effect of phosphorylated mannan (MAN) supplementation on the proportions of blood and jejunal lamina propria CD14+ and CD14+MHCII+ leukocytes in weanling pigs at 19, 21, 24, and 26 d after weaning.[a]**

| MAN (%) | Day | Blood | | Lamina propria | |
|---|---|---|---|---|---|
| | | CD14+ | CD14+MHCII+ | CD14+ | CD14+MHCII+ |
| 0 | 19 | 2.6 ± 0.6 | 7.9 ± 1.7 | 6.9 ± 1.6 [z] | 2.9 ± 1.5 |
| 0.3 | | 4.3 ± 0.6 | 6.4 ± 1.7 | 13.5 ± 1.6 [y] | 7.4 ± 1.5 |
| 0 | 21 | 27.1 ± 1.0 [w] | 23.0 ± 1.0 | 32.3 ± 4.2 | 18.6 ± 3.2 [y] |
| 0.3 | | 20.3 ± 1.0 [x] | 21.1 ± 1.0 | 17.9 ± 4.2 | 3.3 ± 3.2 [z] |
| 0 | 24 | 9.8 ± 3.8 | 4.3 ± 1.2 | 9.4 ± 1.4 | 5.9 ± 1.7 |
| 0.3 | | 14.3 ± 3.8 | 6.0 ± 1.2 | 5.6 ± 1.4 | 2.2 ± 1.7 |
| 0 | 26 | 28.2 ± 2.4 | 15.6 ± 2.6 | 6.4 ± 3.1 | 3.3 ± 2.3 |
| 0.3 | | 28.5 ± 2.4 | 24.2 ± 2.6 | 8.5 ± 3.1 | 4.6 ± 2.3 |

[a] Blood and jejunal tissue were obtained on d 19, 21, 24 and 26 after weaning from eight pigs (four from each dietary treatment). Leukocytes from both tissues were immunofluorescently stained with mouse anti-pig monoclonal antibodies specific for CD14 and MHCII. Values represent the mean proportions ± SEM.

[w,x] For each day, means within a column without a common superscript differ ($P < 0.05$).

[y,z] For each day, means within a column without a common superscript differ ($P < 0.10$).

# Influence of *Lactobacillus brevis* 1E-1 on the Gastrointestinal Microflora, Gut Morphology, and Growth Performance of Weanling Pigs Pre- and Post-Weaning

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


## Story in Brief

Two experiments were conducted to determine the effect of milk supplementation with *Lactobacillus brevis* (1E-1) on pre- and post-weaning pig performance, intestinal microflora, and gut morphology. In both experiments, litters were allotted to two treatments at farrowing: 1) control milk supplement, and 2) as 1, with 1E-1. During the first 5 days post-weaning ($P < 0.06$) and from d 0 to 14 post-weaning ($P < 0.05$) of Exp. 1, pigs fed 1E-1 prior to weaning had greater ADG compared to pigs provided only milk supplement. Coliforms and *E. coli* were enumerated from esophageal, duodenal, jejunal, and ileal regions of the enteric tracts, and gut morphology was assessed in both experiments. In Exp. 1, pigs receiving 1E-1 had lower ($P < 0.05$) jejunal *E. coli* populations pre-weaning, and lower jejunal ($P < 0.10$) and ileal ($P < 0.02$) *E. coli* populations at weaning compared to pigs provided milk supplement. In Exp. 2, 1E-1 reduced coliform populations in the jejunum ($P < 0.10$) and ileum ($P < 0.05$) at weaning. Pigs provided 1E-1 had greater ($P < 0.05$) ileal villus:crypt ratio at 10 d of age compared to control pigs, although there was no difference at 21 and 28 d of age (interaction, $P < 0.05$). These data indicate that milk supplementation with 1E-1 during lactation improves subsequent nursery performance and may provide a healthier intestinal environment.


## Introduction

Recently there has been concern about the use of antibiotics in animal production in part due to the emergence of antimicrobial resistant bacteria. Over the past two decades, probiotics (direct-fed microbials), which include Lactobacillus cultures, have been used as an alternative to antibiotics in animal production (Jin et al., 1998). Lactobacilli are normal inhabitants of the gastrointestinal tract of pigs. Their beneficial role in the intestinal tract has been attributed to their ability to survive the digestive process, attach to the epithelial lining of the intestinal tract, produce lactic acid and other microbial compounds and prevent the colonization of pathogens via competitive exclusion (Savage, 1987). Maintaining a healthy intestinal microflora despite the changes that occur at weaning is crucial for subsequently optimizing pig growth. To investigate weaning-induced changes within the enteric system, two experiments were conducted to determine the effect of milk supplementation with *Lactobacillus brevis* (1E-1) on pre- and post-weaning pig performance, intestinal microflora, and gut morphology.

## Experimental Procedures

In each experiment, litters were randomly allotted to two treatments at farrowing: either a control milk supplement, or the control containing 1E-1. Milk supplement was supplied to the pigs ad libitum via an in-line system in a small bowl supplied by a central 30-gallon tank. The tank was equipped with a hydro pump with a pressure regulator that pumped the milk supplement to the pens as needed. A baby pig nipple inside each bowl allowing milk to flow into the bowl only when touched by a pig's nose was used to minimize spillage and waste of the milk supplement. On a daily basis, the entire system was flushed with hot water to remove spoiled milk or sediment, and fresh milk was prepared using a commercial milk replacer (Merrick's Litter-Gro, Merrick's, Inc., Union Center, WI).

Coliforms and *E. coli* were enumerated from esophageal, duodenal, jejunal, and ileal regions of the enteric tracts, and gut morphology (villus:crypt ratio and goblet cell enumeration) was assessed from one pig/litter at approximately 10 (pre-weaning) and 22 (weaning) days of age in Exp. 1 and 2, and after weaning at 28 days of age in Exp. 2. Pigs were euthanized and duodenal, jejunal, and ileal intestinal sections were evaluated for the enumeration of bacterial populations using polymerase chain reaction (PCR) techniques. Additionally, duodenal and ileal samples from the small intestine were obtained for histology in the evaluation of villus height, crypt depth, villus:crypt ratio, and neutral, acidic, and sulfuric mucin-producing goblet cells.

Data in both experiments were analyzed as a completely randomized design. Analysis of variance was performed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

## Results and Discussion

*Growth performance.* During the first 5 days after weaning ($P < 0.06$) and from d 0 to 14 post-weaning ($P \leq 0.05$) of Exp. 1, pigs fed 1E-1 prior to weaning had greater ADG compared to pigs provided only milk replacer (Figure 1). In Exp. 2, 1E-1 supplementation did not affect pig growth performance during the pre- or post-weaning periods. This discrepancy in performance response between the two experiments is likely due to the lower level of coliforms present in the control pigs in Exp. 2 compared to Exp. 1 (data not reported).

*Intestinal Microflora.* In Exp. 1, pigs receiving 1E-1 had lower ($P < 0.05$) jejunal *E. coli* populations pre-weaning and at weaning compared to pigs provided only milk supplement (Table 1). Ileal *E. coli* populations were lower ($P < 0.05$) at weaning for pigs receiving 1E-1 compared to pigs provided milk supplement without 1E-1. In Exp. 2, 1E-1 reduced coliform populations in the jejunum ($P < 0.10$) and ileum ($P < 0.01$) at weaning; however, populations in control pigs were 99% to 99.9% lower than in Exp. 1 (Table 1). In a previous study (Parrott et al., 1994), the intestinal tracts from 10 healthy pigs and five pigs with scours were sampled, and it was reported that healthy pigs had higher levels of lactobacilli, with the majority of isolates identified as *Lactobacillus brevis*. The administration of 1E-1 prior to weaning may deter the detrimental alterations in the micro-

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bial population that occur at weaning (Katouli et al., 1999).

*Intestinal Morphology.* In Exp. 2, pigs provided 1E-1 had greater ($P < 0.05$) ileal villus:crypt ratio at 10 days of age compared to control pigs, although there was no difference at 21 and 28 days of age (interaction, $P < 0.05$; Figure 2). The number of duodenal sulfuric goblet cells was somewhat less ($P < 0.06$) when pigs were provided 1E-1 compared to control pigs at 10 days of age, although there was no difference at 21 and 28 days of age (interaction, $P = 0.06$; Figure 3). Sulphomucins are normally absent from the small intestine, but can be produced by crypt goblet cells when the small intestinal mucosa is altered (Specian and Oliver, 1991). The lower number of sulfuric goblet cells, combined with the increase in villus:crypt ratio in 1E-1-supplemented pigs suggests that 1E-1 affords some protection from the intestinal disruption that occurs at weaning.

## Implications

Supplementation with *Lactobacillus brevis* bacteria has the potential to enhance post-weaning growth, and decrease *E. coli* and coliform populations in the small intestine. The observed decrease in potentially pathogenic bacterial populations and improvements in intestinal morphology after weaning indicate that *Lactobacillus brevis* may protect the newly-weaned pig from detrimental changes in the intestinal microflora at weaning and improve intestinal morphological structure.

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**Table 1. Pre- and post-weaning mean *E. coli* and coliform populations in the jejunum and ileum of pigs.**

| | Pre-weaning | | Post-weaning | |
|---|---|---|---|---|
| | Control | 1E-1 | Control | 1E-1 |
| Experiment 1 | | | | |
| Mean *E. coli* (cfu/g(log$^{10}$)) | | | | |
| Jejunum | 5.53$^{a}$ | 3.42$^{b}$ | 7.10$^{a}$ | 4.80$^{b}$ |
| Ileum | 5.91 | 4.71 | 6.63$^{a}$ | 4.96$^{b}$ |
| Experiment 2 | | | | |
| Mean coliforms (cfu/g(log$^{10}$)) | | | | |
| Jejunum | 2.98 | 1.30 | 2.36$^{c}$ | 1.00$^{d}$ |
| Ileum | 4.54 | 3.82 | 5.77$^{a}$ | 3.02$^{b}$ |

$^{a,b}$ Pre- and post-weaning means within a row with no letter in common differ ($P < 0.05$).

$^{c,d}$ Pre- and post-weaning means within a row with no letter in common differ ($P < 0.10$).

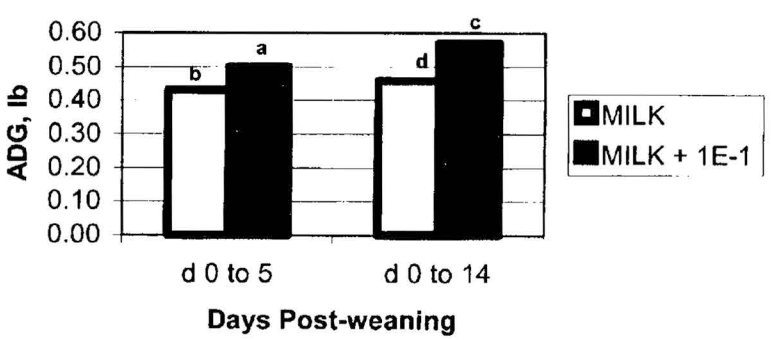


**Figure 1. Average daily gain of pigs provided milk supplementation or milk with 1E-1 supplementation during d 0 to 5 (SEM = 0.06) and d 0 to 14 (SEM = 0.04) after weaning in Experiment 1. Means within each post-weaning period with no letter in common differ (a,b $P < 0.06$; c,d $P < 0.05$).**

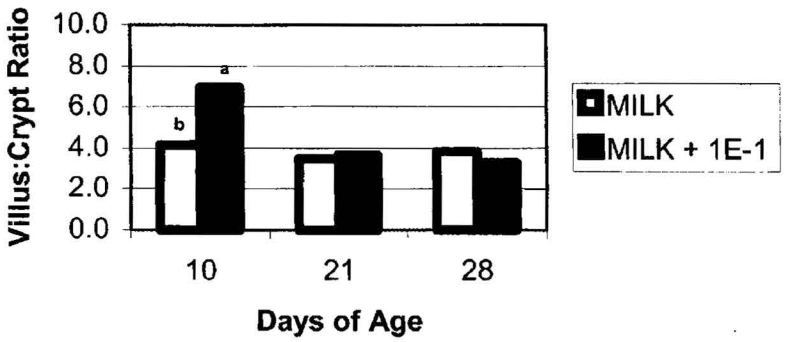


**Figure 2. Villus:crypt ratio measured from small intestinal ileal samples obtained from pigs at 10, 22, and 28 d of age in Experiment 2 (interaction, P < 0.05). a,b Means within each age group with no letter in common differ (P < 0.05).**

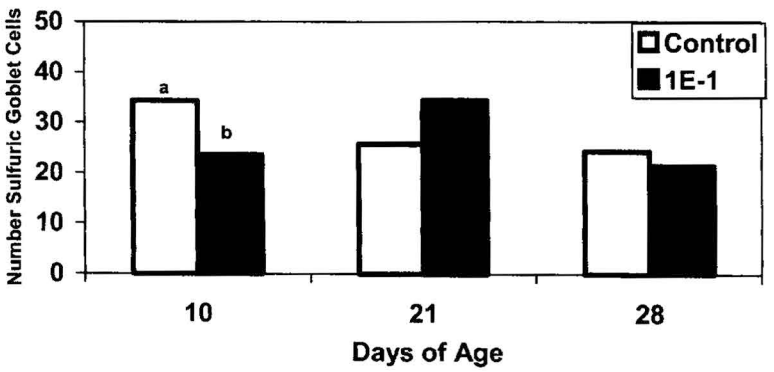


**Figure 3. Number of sulfuric goblet cells in the duodenum of pigs on d 10, 21, and 28 of age in Experiment 2 (interaction, P = 0.06). a,b Means within each age group with no letter in common differ (P < 0.06).**

# Effects of Immunization of Gilts Against 17α-hydroxyprogesterone on Follicular Size Distributions and Follicular Steroid Synthesis

*N.M. Post, D.L. Kreider, K. Cole, M.E. Nihsen, and C.V. Maxwell*


## Story in Brief

The objective of this experiment was to evaluate the effects of immunization of gilts against 17α-hydroxyprogesterone on follicular size distributions, follicular steroid synthesis, and ovulation rate. Thirty-six crossbred gilts at 147 d of age were immunized against adjuvant (Control; n = 18) or 17α-hydroxyprogesterone (17OHP; n = 18). Gilts were given an initial 0.6 mL injection divided between two subcutaneous sites at the base of each ear, followed 4 weeks later by a single booster injection. Estrus was checked twice daily with a boar. At 16 to 17 d following first estrus gilts were sacrificed, reproductive tracts were recovered and uterine weight, uterine length, number of corpora lutea, and number of small (0 to 3 mm), medium (4 to 6 mm), and large (> 7 mm) follicles was determined. Serum binding of 17α-hydroxyprogesterone in 17OHP was greater ($P < 0.01$) than Control, and increased ($P < 0.01$) with time. Age at puberty was not ($P = 0.28$) affected by treatment and averaged 187.1 ± 0.4 and 183.9 ± 1.7 d for Control and 17OHP, respectively. Serum progesterone during the first 17 d of the estrous cycle was higher ($P = 0.09$) for 17OHP gilts than for Control gilts. Serum estradiol-17β was not ($P = 0.84$) affected by treatment; however serum progesterone and estradiol-17β ($P < 0.01$) were affected by time. Uterine weight tended to be increased ($P = 0.12$) in 17OHP vs. Control, whereas mean uterine length was not ($P = 0.82$) different in 17OHP vs. Control (716.8 ± 47.8 vs. 625.3 ± 30.1 g and 214.8 ± 10.7 vs. 211.1 ± 11.2 cm., respectively). Ovulation rate at first estrus was higher ($P = 0.0038$) in 17OHP gilts than Control gilts (15.8 ± 0.6 vs. 13.4 ± 0.4, respectively). Follicular fluid estradiol-17β did not ($P = 0.62$) differ between treatments for any follicular size class; however, testosterone tended to be higher ($P = 0.16$) in medium follicles of 17OHP gilts than Control gilts (133.1 ± 22.5 vs. 94.5 ± 13.6 ng/ml, respectively). These data suggest that immunization against 17OHP altered follicular growth and steroid synthesis.


## Introduction

The most important factor contributing to the economic efficiency of swine production and the prime measure of reproductive performance is litter size. Ovulation rate and litter size in swine are influenced by a number of factors including breed, age and weight at breeding, and nutritional status at or near the time of breeding. Direct genetic selection for litter size has been of limited success due to low heritability (van der Lende and Schoenmaker, 1990) and decreased number of pigs weaned in the selected line (Johnson et al., 1999).

Cattle and sheep immunized against androgenic steroids had increased ovulation rate (van Look et al., 1978; Streenan et al., 1987). Gilts immunized against androstenedione have increased ovulation rate, but litter size at term was not affected (McKinnie et al., 1988; McKinnie, 1987). Kreider et al. (2001) reported increased ovulation rate and number of live pigs born at term in gilts immunized against 17α-hydroxyprogesterone; therefore, the objectives of this study were to determine the effects of immunization of 17α-hydroxyprogesterone on follicular dynamics and ovulation rate.

## Experimental Procedures

In this experiment, 36 prepubertal crossbred (Dekalb line 348) gilts at 147 d of age were blocked by litter number and weight, and then randomly assigned to one of two treatment groups: adjuvant only (Control; n = 18) or 1.0 mg of 17α-hydroxyprogesterone-3-CMO:Bovine Serum Albumin (BSA) (17OHP; n = 18). Gilts were housed at four animals/pen in 1.5 x 4.0 m slotted floor pens in a naturally ventilated curtain-sided finishing building, and were fed 1.8 kg/d of a ration formulated to meet, or exceed NRC (1998) recommendations. Immunization procedures used were similar to those previously described by Kreider et al. (2001) with the exception that Freund's incomplete adjuvant was used instead of light mineral oil. One milligram of 17α-hydroxyprogesterone-3-CMO:BSA was dissolved in 0.3 mL of 5% DEAE dextran (5% w/v in 0.45% saline) and emulsified with an equal volume of Freund's incomplete adjuvant. Gilts received an initial 0.6 mL injection divided equally between two subcutaneous sites in the loose skin at the base of each ear, and then four weeks later a single 0.3 mL booster injection.

After the booster immunization, gilts were monitored twice daily with a boar to determine estrus. At 16 to 17 d after the first detected estrus, gilts were sacrificed, and reproductive tracts were recovered. Uterine size (length and weight of trimmed uterus), number of corpora lutea, and number of follicles (0 to 3 mm, 4 to 6 mm, and > 7 mm) were determined, and follicular fluid for each size class was aspirated from follicles into a 1 mL syringe using a 22-gauge needle (pooled within size class within gilt). Follicular fluid was stored frozen at -20°C until assayed for estradiol 17-β and testosterone. Blood samples were collected via anterior vena cava puncture immediately prior to first immunization, at the booster immunization, and at d 0, 4, 8, 12, and 16 of the estrous cycle. Blood was allowed to clot, centrifuged for 20 min, serum was harvested, and serum samples were stored at -20°C until assay. Serum was analyzed for progesterone, testosterone, and estradiol-17β by RIA. Serum binding of 17α-hydroxyprogesterone was determined by measuring the percent of counts bound by a 1:100 dilution of serum when approximately 20,000 dpm of the appropriate tritium labeled antigen was added (Scaramuzzi et al., 1975).

Differences between the control and treatment (17OHP) groups were determined by analysis of variance. Data for reproductive variables were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Hormone and antibody binding were analyzed as split plot analyses using the repeated measures option of GLM. Four gilts in the control group and three gilts in the 17OHP group did not show estrus and were eliminated from the study.

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## Results and Discussion

Results for reproductive variables are summarized in Table 1. Immunization of gilts against the androgenic steroid precursor, 17α-hydroxyprogesterone, did not (P = 0.28) influence age at puberty. For the control group, age at puberty averaged 187.1 ± 2.4 d (n = 14), whereas the 17OHP group averaged 183.9 ± 1.7 d (n = 15). Uterine length was not (P = 0.82) affected by immunization against 17α-hydroxyprogesterone, but uterine weight tended to increase (P = 0.12) with the immunization against 17α-hydroxyprogesterone.

Immunization against 17α-hydroxyprogesterone increased (P = 0.0038) ovulation rate at first estrus, as determined by the number of corpora lutea present on the ovaries at slaughter. Mean ovulation rate for the control group was 13.4 ± 0.4 vs. 15.8 ± 0.6 for the 17OHP treatment group. Total number of follicles was not (P = 0.44) different overall, or in the three sizes of follicles, small (0 to 3 mm), medium (4 to 6 mm) and large (> 7 mm). Number of small (0 to 3 mm) follicles averaged 47.6 ± 8.0 for the control group and 58.5 ± 12.2 for the 17OHP treatment group (P = 0.47). The number of medium follicles (4 to 6 mm) averaged 9.0 ± 1.9 for the control group and was numerically greater than the 6.0 ± 1.5 for the 17OHP group, but groups were not statistically different (P = 0.22). In contrast the number of large follicles (> 7 mm) was numerically greater in 17OHP gilts than in controls, but not statistically higher (P = 0.32).

Concentrations of steroids in follicular fluid are presented in Table 2. Follicular fluid concentrations of testosterone in small follicles and large follicles did not differ (P = 0.31, P = 0.37, respectively) between the 17OHP and control gilts. Testosterone concentrations in medium follicles were numerically different (P = 0.16) between the 17OHP and the control gilts. Follicular fluid concentrations of estradiol-17β were not (P > 0.6) different for any size class between 17OHP and control gilts.

Serum binding of 17α-hydroxyprogesterone is illustrated in Figure 1. The serum binding response in the 17OHP treatment group was higher (P = 0.004), than the control group and increased with time (P = 0.001), indicating that a significant immune response was elicited by the antigen-adjuvant preparation used in this study.

Serum progesterone and estradiol responses during the estrous cycle are shown in Figures 2a and 2b. Serum progesterone during d 0 to 16 of the estrous cycle tended to be greater for gilts immunized against 17α-hydroxyprogesterone (P = 0.09) and was affected (P < 0.0001) by time. In contrast, concentration of serum estradiol-17β during d 0 to 16 of the estrous cycle was not affected (P = 0.84) by treatment, but was affected by time (P = 0.0002).

Results of this experiment indicated that immunization of gilts against 17α-hydroxyprogesterone increased ovulation rate at first estrus. This increase in ovulation rate is similar to that observed at the second estrus by Kreider et al. (2001) in gilts immunized against 17α-hydroxyprogesterone.

The increase in serum binding of 17α-hydroxyprogesterone over time indicates that the antigen-adjuvant preparation and immunization procedure were effective in eliciting an immune response against 17α-hydroxyprogesterone. In contrast to our previous study (Kreider et al., 2001), serum progesterone was greater in gilts immunized against 17α-hydroxyprogesterone throughout the estrous cycle vs. controls. The increase in progesterone was likely due to an increase in the number of corpora lutea and/or leutinized follicles. Follicular size class distributions were numerically different between treatments, but were not statistically altered. Follicular testosterone concentrations in 17OHP gilts tended to be higher in medium sized follicles versus controls.

## Implications

The results of this study indicate that immunization of gilts against 17α-hydroxyprogesterone can effectively increase ovulation rate, and suggest effects on follicular size distributions and follicular steroid concentrations. Further research is needed to substantiate these results.

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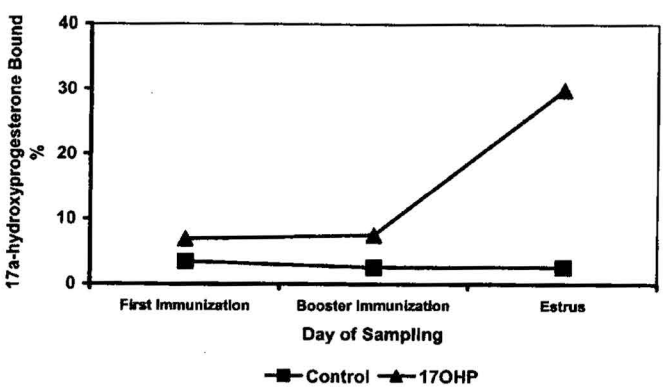


**Fig. 1. Serum binding of 17α-hydroxyprogesterone.**

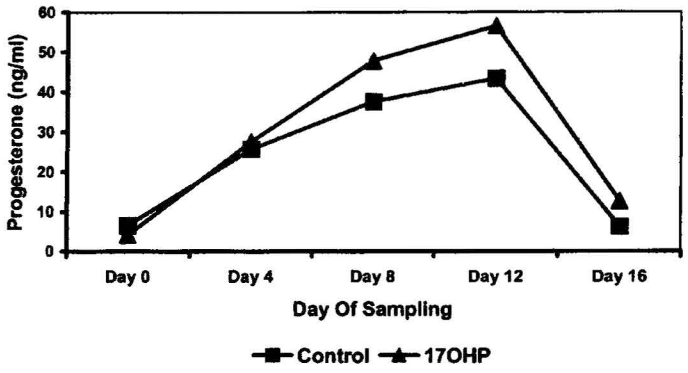


Fig. 2a. Serum progesterone concentration.

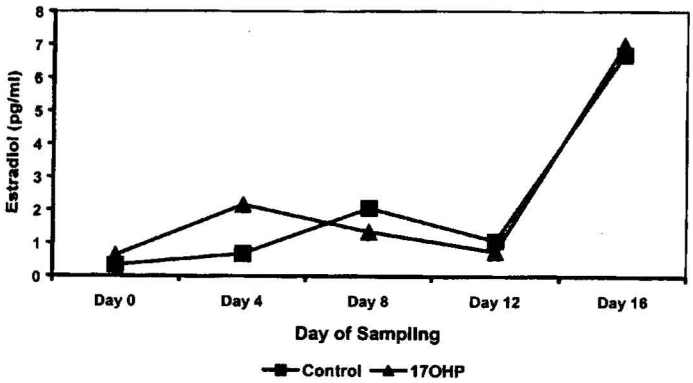


Fig. 2b. Serum Estradiol Concentration.

**Table 1. Effects of immunization of gilts against 17α-hydroxyprogesterone (17OHP) on reproductive variables and ovarian structures at day 16 or 17 of the estrous cycle.**

| | Treatment | | |
|---|---|---|---|
| Item | Control | 17OHP | Probability |
| Number | 14 | 15 | |
| Age at puberty, d | 187.1 ± 2.4 | 183.9 ± 1.7 | 0.28 |
| Uterine length, cm | 211.1 ± 11.2 | 214.8 ± 10.7 | 0.82 |
| Uterine weight, g | 625.3 ± 30.1 | 716.8 ± 47.8 | 0.12 |
| Corpora lutea, n | 13.4 ± 0.4 | 15.8 ± 0.6 | 0.0038 |
| Small follicles, n | 47.6 ± 8.0 | 58.5 ± 12.2 | 0.47 |
| Medium follicles, n | 9.0 ± 1.9 | 6.0 ± 1.5 | 0.22 |
| Large follicles, n | 3.1 ± 1.2 | 5.1 ± 1.6 | 0.32 |
| Total follicles, n | 59.6 ± 7.0 | 69.5 ± 10.2 | 0.44 |

**Table 2. Effects of immunization of gilts against 17α-hydroxyprogesterone on concentrations of testosterone and estradiol-17β in follicular fluid.**

| | | Treatment | | |
|---|---|---|---|---|
| Item | Follicle size | Control | 17OHP | Probability |
| Testosterone ng/ml | 1 to 3 mm | 33.4 ± 7.3 | 44.8 ± 8.2 | 0.31 |
| | 4 to 6 mm | 94.5 ± 13.6 | 133.1 ± 22.5 | 0.16 |
| | > 7 mm | 138.9 ± 26.7 | 111.5 ± 16.0 | 0.37 |
| Estradiol ng/ml | 1 to 3 mm | 25.3 ± 8.4 | 29.6 ± 6.3 | > 0.6 |
| | 4 to 6 mm | 244.2 ± 39.5 | 275.5 ± 56.3 | > 0.6 |
| | > 7 mm | 396.2 ± 55.6 | 346.6 ± 78.2 | > 0.6 |

# Relationship Between Body Length and Number of Nipples in Swine

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## Story in Brief

The objective of this study was to estimate the relationship between number of nipples (NT) counted at 100 days of age and body length at the end of performance test in Yorkshire swine. Data consisted of performance test records collected in a commercial swine operation from 1992 to 1995. At 100 days of age pigs were weighed (WT100) and selected for performance testing based on a combination of maternal and performance indexes which differed by breed. Body length (LEN) was measured at the end of the 77-day performance test. Genetic parameters were estimated using an animal model with litter effects and multiple-trait DFREML procedures. The model included WT100, LEN, and NT. Contemporary group was included as a fixed effect. Age at 100 days was included as a covariate for WT100, and age at 177 days was included as a covariate for LEN. Heritability estimates were 0.25 for WT100, 0.26 for LEN, and 0.29 for NT. Genetic correlations were 0.72 between WT100 and LEN, 0.21 between WT100 and NT, and 0.04 between LEN and NT. Correlations indicated very little or no relationship between LEN and NT for this population of Yorkshire swine.


## Introduction

Much effort has been devoted to the improvement of litter size in swine due to its impact on productive and economic efficiency. Mesa et al. (2003) reported that 14 generations of selection had resulted in a difference between lines of three fully formed piglets at birth. As litter size increases, having an adequate number of nipples to accommodate all pigs in the litter if the sow is to rear them herself may become a limiting factor. It seems logical that a sow that has a longer body would have room for more nipples than a sow with a shorter body, and that there might be a relationship between these two traits. The objective of this study was to estimate heritability of number of nipples and to examine the relationship between this trait and body length measured at the end of postweaning performance tests for a population of Yorkshire swine.

## Experimental Procedures

Data for this study consisted of performance test records of Yorkshire pigs collected in a commercial swine operation (The Pork Group, A Division of Tyson Foods, Inc., Rogers, AR) from 1992 to 1995. Two indexes (breeding values) for each animal were calculated at birth. One was a maternal index based on number born alive, farrowing interval, and litter weaning weight. The other was based on growth rate, leanness, and feed efficiency (Grow-Fin). The maternal index was computed using a three-trait model that included terms for the additive genetic effect, litter effects, and maternal genetic effects along with appropriate fixed effects. The Grow-Fin index was computed using a model that included only additive genetic effects and appropriate fixed effects. These two indexes were combined into an overall ranking with more emphasis given to the maternal index in Yorkshire. Boars from approximately 60% of the litters were culled at weaning based on the breed specific index. Culled boars (barrows) were grown out and slaughtered. For economic reasons, these animals were not performance tested. Remaining boars and all females were grown to 100 days of age. At this time number of nipples were counted (NT) and all pigs were weighed (WT100). A second culling event occurred with recalculated indexes using any new information collected on animals in the breed. Fifty to sixty percent of the females and 20 to 25% of the remaining boars were performance tested for approximately 77 days.

Boars were individually penned in 2.79 $m^2$ pens with slotted gating on slatted concrete floors. Barns were curtain-sided buildings that were tunnel ventilated in the winter. Boars 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. Exact composition of the diet varied due to ingredient cost. Gilts were fed this same diet in groups of 8 to 10 pigs in a pen with each pig having an area of 1.2 $m^2$. Different size pens were available in different facilities, so pens in some barns held eight pigs and in other barns 10 pigs. All pigs had ad libitum access to water. All pigs were weighed at the end of the 77 day performance test, and body length (LEN) was measured from the top of the tail to the point of the shoulder when the head is down.

Contemporary group was defined as all pigs of the same sex reared in the same house and started on test within a 3-mo period (quarter of a year). Data sets were edited to remove records of animals with missing sire or dam. Some description of the data sets is given in Table 1. There were 58 contemporary groups with 191 sires, 1,417 dams and 3,475 litters.

For each breed, genetic parameters were estimated using an animal model with litter effects and multiple-trait DFREML procedures (MTDFREML; Boldman et al., 1993; Boldman and Van Vleck, 1991). A three-trait model including WT100, LEN, and NT was used. Contemporary group was a fixed effect. Initial test age (AGE100) was a covariate for WT100, and final test age (AGE177) was a covariate for LEN. The WT100 was included in each analysis in an attempt to remove bias due to selection at 100 days of age; not all pigs weighed at 100 days of age were performance tested.

## Results and Discussion

Means and standard deviations are given in Table 2. Mean weight was 101.80 lb at the beginning of the performance test and

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256.96 lb at the end of the performance test. Mean LEN was 37.49 in, and average NT was 14.08.

Estimates of heritability were 0.25 for WT100, 0.29 for NT, and 0.26 for LEN (Table 3). These estimates are in the low to moderate range indicating that additive genetic variance does exist for these traits and progress in changing them could be made through selection. No literature estimates of heritability of body length were found. Cassady et al. (2002) reported estimates of heritability of number of nipples of 0.37 ± 0.03 in one experiment using Landrace, Yorkshire, Large White and Chester White pigs and 0.43 ± 0.03 in a second experiment using Duroc, Hampshire, Pietran, and Spot pigs. Pumfrey et al. (1980) reported a paternal half-sib estimate of heritability for number of teats of 0.32 using the University of Nebraska Gene Pool population. The genetic correlation between WT100 and body length was high (0.72). Estimates of genetic correlation for WT100 with NT and for LEN with NT were 0.21 and 0.04, respectively, indicating that neither of these traits would be good candidates for selection to increase NT in swine.

Common environmental litter effects explained 19% of the phenotypic variance for WT100, 16% of the phenotypic variance for LEN, but only 5% of the phenotypic variance for NT, indicating that this trait is not influenced by common litter effects.

**Table 1. Some description of the data.**

| Item | Number |
|---|---|
| Contemporary groups | 58 |
| Sires | 191 |
| Dams | 1,417 |
| Litters | 3,475 |
| Individuals in pedigree matrix ($A^{-1}$) | 20,634 |

**Table 2. Means and standard deviations for traits in analysis.**

| Trait[a] | N | Mean | SD |
|---|---|---|---|
| Age100, d | 19,442 | 99.94 | 3.30 |
| WT100, lb | 19,442 | 101.80 | 16.32 |
| Age177, d | 9,299 | 176.64 | 3.92 |
| WT177, lb | 9,299 | 256.96 | 29.03 |
| Body length, in | 9,292 | 37.49 | 2.18 |
| Number of nipples | 18,986 | 14.08 | 0.58 |

[a] WT100 is weight at 100 days of age; WT177 is weight at 177 days of age and body length is measured at the end of performance test.

## Implications

Heritability estimates are high enough to indicate that additive genetic variance does exist for weight at 100 days of age, number of nipples, and body length at the end of performance test. Each of these traits could be improved by selection; however low genetic correlations with number of nipples implies that selection for weight at 100 days of age or body length at the end of performance test will have little effect on number of nipples.

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**Table 3.Genetic parameters for weight and number of nipples at 100 days of age, and body length at the end of performance test.**

| Item[a] | Parameter estimate |
|---|---|
| $h^2$ WT100 | 0.25 |
| $h^2$ Number of nipples | 0.29 |
| $h^2$ Body length | 0.26 |
| | |
| rg WT100 with LEN | 0.72 |
| rg WT100 with number of nipples | 0.21 |
| rg LEN with number of nipples | 0.04 |
| | |
| $c^2$ WT100 | 0.19 |
| $c^2$ Number of nipples | 0.05 |
| $c^2$ Body length | 0.16 |

[a] WT100 is weight at 100 days of age; and body length (LEN) is body length measured at the end of performance test. $h^2$ is estimate of heritability; rg is estimate of genetic correlation; and $c^2$ is estimate of common environmental litter effect.

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