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

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## Story in Brief

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

## Introduction

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

## Experimental Procedures

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

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

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

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

## Results and Discussion

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

## Implications

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

## Literature cited

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

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

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

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

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## Story in Brief

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

## Introduction

Over one million acres of soft red winter wheat are planted each year for grain production in Arkansas. A large percentage of this wheat is planted on soil that is suitable for cattle production. The use of wheat forage for stocker cattle production in Arkansas is a unique and economical renewable resource (Daniels et al., 1999). Income is derived from both grain and the increased value as weight gain that is added to growing cattle that graze winter wheat forage (Daniels et al., 1999). Several cultivars of soft red winter wheat are planted in Arkansas each year for grain production. However, most of the predominant cultivars planted in the state have not been evaluated for the production of forage used in a stocker cattle operation. Horn et al. (1994) reported differences in ADG of steers that grazed various cultivars of hard red winter wheat. Similar cultivar differences of hard red winter wheat have been reported by Gribble and Krenzer (1994). Therefore, it was the objective of this study to evaluate growth performance of stocker cattle grazing forage of the common cultivars of soft red winter wheat planted in the state for grain production.

## Experimental Procedures

Eight cultivars of soft red winter wheat were seeded at a rate of 120 lb/acre on September 27 or 28, 1999 in prepared seedbeds. The wheat was seeded in 2-acre pastures, and each cultivar was replicated. Cultivars planted were Agri Pro Foster, Agri Pro Shiloh, Agri Pro Elkheart, Pioneer 2580, Coker 9543, Coker 9663, Delta King 9027, and Jaypee. All pastures were fertilized according to soil analyses. Thirty-two Angus steers averaging 503 lb BW were assigned randomly to pastures at a stocking density of one steer (503 lb) per acre on November 17, 1999, and they grazed until April 26, 2000. All steers were born and raised at the Livestock and Forestry Branch Research Station and were weaned and preconditioned 30 d prior to grazing. Steers were implanted with Ralgro and were fed 2 lb of corn containing 70 mg rumensin/lb for each animal per day. A commercial trace mineralized salt mixture was fed free choice. Steers were weighed, using a 12-h shrunk weight, initially and at 28-d intervals. The data were analyzed using GLM procedures of SAS (SAS Inst. Inc., Cary, NC).

## Results and Discussion

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

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

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

## Implications

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

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

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

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

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## Story in Brief

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

## Introduction

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

## Experimental Procedures

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

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

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

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

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

## Results and Discussion

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

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

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

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

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

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

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

## Implications

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[3] Potential extent of degradation in the rumen.

[4] Effective degradability expressed on a DM basis.

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

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

[7] Evaluated in three animals.

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

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## Story in Brief

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

## Introduction

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

## Experimental Procedures

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

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

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

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

## Results and Discussion

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

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

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

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

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

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

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

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

## Implications

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

## Literature Cited

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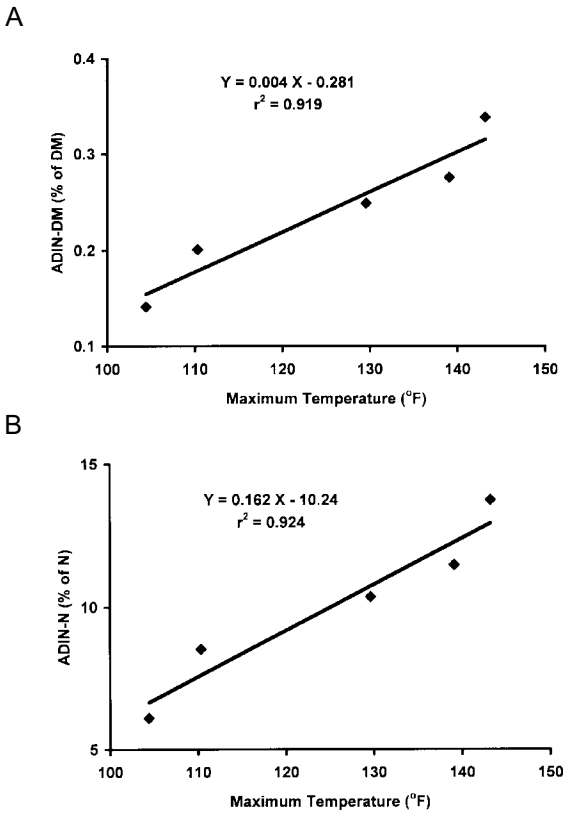


**Figure 1. Relationship between ADIN and maximum internal bale temperature for bermudagrass hay bales packaged at five concentrations of moisture. Concentrations of ADIN are expressed on the basis of (A) DM (ADIN-DM) and (B) total N (ADIN-N).**

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

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

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

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

[b] Standard error of the moisture mean.

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

[d] Nonsignificant effect (P > 0.05).

*, **, *** Significant at P ≤ 0.05, P ≤ 0.01, P ≤ 0.001, respectively.

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

*L.J. McBeth, K.P. Coffey, W.K. Coblentz, J.E. Turner, D.A. Scarbrough, C.R. Bailey, and M.R. Stivarius*[1]


## Story in Brief

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


## Introduction

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

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

## Experimental Procedures

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

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

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

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

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

## Results and Discussion

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

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

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

## Implications

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

## Literature Cited

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**Table 1. Composition of bermudagrass hays.**

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

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

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

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

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

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

HDD = heating degree-day.

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

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

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

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## Story in Brief

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

## Introduction

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

## Experimental Procedures

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

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

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

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

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

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

## Results and Discussion

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

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

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

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

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

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

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

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

## Implications

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

## Literature Cited

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

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

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

[1] SE = standard error of the mean.

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

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

[4] Fractional degradation rate in the rumen.

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

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

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

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

[1] SE = standard error of the mean.

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

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

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

[5] Fractional degradation rate in the rumen.

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

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

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

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

[1] SE = standard error of the mean.

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

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

[4] Fractional degradation rate in the rumen.

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

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

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

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

[1] SE = standard error of the mean.

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

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

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

[5] Fractional degradation rate in the rumen.

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

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

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## Story in Brief

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

## Introduction

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

## Experimental Procedures

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

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

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companion paper (Scarbrough et al., 2000).

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

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

## Results and Discussion

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

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

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

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

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

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

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

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

## Implications

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

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

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

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

[1] SE = standard error of the mean.

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

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

[4] Fractional degradation rate in the rumen.

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

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

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

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

[1] SE = standard error of the mean.

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

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

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

[5] Fractional degradation rate in the rumen.

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

# Effects of Rice Milling Procedures on Nutrient Composition of Rice Bran

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## Story in Brief

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


## Introduction

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

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

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

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

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

## Experimental Procedures

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

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nutrients by the University of Arkansas Department of Animal Science.

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

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

## Results and Discussion

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

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

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

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

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

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

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

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

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

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

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

## Implications

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

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

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

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

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

# Nutrient Composition of Forages in Arkansas, 1985–1999

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## Story in Brief

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

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

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


## Introduction

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

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

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

## Experimental Procedures

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

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

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

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

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

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

## Results and Discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Implications

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[2] Average value.

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

[4] Standard deviation.

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

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

[1] Includes all hay samples.

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

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

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