Digestibility and feeding value of pearl millet as influenced by the brown-midrib, low-lignin trait.
D J Cherney, J A Patterson and K D Johnson


The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://www.journalofanimalscience.org/content/68/12/4345
DIGESTIBILITY AND FEEDING VALUE OF PEARL MILLET AS INFLUENCED BY THE BROWN-MIDRIB, LOW-LIGNIN TRAIT

D.J.R. Chemey, J. A. Patterson and K. D. Johnson

Purdue University, West Lafayette, IN 47907

ABSTRACT

Our objectives were to determine the intake and digestibility of pearl millet as influenced by the brown-midrib (BMR), low-lignin trait and to determine the relative acceptability of BMR pearl millet in relation to its normal counterpart. Two field replicates of brown-midrib pearl millet and its normal counterpart were harvested as hay at the boot to heading stage twice during the growing season (2 genotypes x 2 cuttings x 2 field replicates). Twenty-four wethers had ad libitum access to a total forage diet (pearl millet forage), water and trace mineralized salt. The experimental period was 21 d (14 d for adjustment and 7 d for sample collection). Lignin was 23% lower \( (P < 0.01) \) and in vitro DM digestibility (IVDMD) was 4% higher \( (P < 0.01) \) in BMR vs normal genotype forages. Wethers preferred first-cutting millet to second-cutting millet, as evidenced by 62% higher \( (P < 0.01) \) DMI for first-cutting forages. Dry matter intake of second-cutting forages was higher \( (P < 0.10) \) for BMR pearl millet forage than for normal pearl millet (2.0 vs 1.5% of BW), but first-cutting forages were similar in DMI (2.9% of BW). In an acceptability trial of pearl millet regrowth (4 wk), grazing lambs with access to both genotypes displayed a marked preference \( (P < 0.01) \) for the BMR genotype, spending an average of 2.6 min on plots containing the brown-midrib pearl millet for every minute spent on the normal genotype. Lignin and IVDMD digestibility analyses, in vivo digestibility and DMI values indicate that the BMR trait can improve the forage quality of pearl millet.

(Key Words: Brown-Midrib, Pearl Millet, Intake, Digestibility, Acceptability, Lambs.)


Introduction

One of the most efficient ways of increasing digestibility is by reducing lignin content, a primary deterrent to fiber digestion by the ruminant. Modification of the lignification process has occurred in brown-midrib (BMR) maize (Zea mays L.; Grand et al., 1985) and sorghum (Sorghum bicolor (L.) Moench; Porter et al., 1978). Brown-midrib mutants have lower lignin and higher in vitro DM digestibility (IVDMD) than their normal counterparts (Lechtenberg et al., 1974; Porter et al., 1978; Chemey et al., 1988). Colenbrander et al. (1973, 1975) determined that BMR3 mutant, low-lignin corn silage was superior to normal silage in DMI, in vivo digestibility and ADG, and Keith et al. (1979) reported that milk production was higher by cows fed BMR3 corn silage. Lusk et al. (1984) reported that in vivo DM digestibilities were higher in BMR12 sorghum vs normal counterparts (61.4 vs 53.3%).

Recently, Chemey et al. (1988) characterized a chemically induced BMR genotype in pearl millet. No animal trials have been conducted with BMR pearl millet, however, to evaluate its feeding value or the effect of lignin on intake and digestibility of BMR pearl millet vs its normal counterpart. Objectives of
this experiment were to determine the influence of the BMR traits on intake, digestibility, acceptability and ADG by lambs fed pearl millet vs its corresponding BMR mutant.

Materials and Methods

A BMR-mutant pearl millet (Cherney et al., 1988) and its normal counterpart (both from KS81-1089, an inbred pearl millet line derived from Tift23D2B1/2 X PI-185642) were planted near West Lafayette, IN at the Purdue University Agronomy Farm. Fields were drilled at a rate of 11.2 kg pure live seed/ha, and received 112 kg/ha of N fertilizer prior to planting on June 16, 1989. Two field replicates of normal and BMR genotypes were planted. The two field replicates of each genotype were harvested as hay on August 1, 1989 (cutting 1) and again on September 22, 1989 (cutting 2) when forages were at the boot to early head stage of maturity, for a total of eight forages (two replicates, two cutting dates and two genotypes).

An intake and digestibility trial was conducted at the Sheep Unit of the Purdue Univ. Animal Sciences Research Center. Twenty-four Suffolk x Hampshire wethers (44.4 ± 3.1 kg), aged 6 to 8 mo, were fed one of the eight test forages (3 wethers/forage or 6 wethers/ [genotype x cutting]). Wethers were assigned randomly to forages and metabolism crates. Forages were chopped with a forage harvester set so that the largest particles were less than 5-cm long; most particles were larger than 2.5 cm.

Wethers were in metabolism crates for 21 d. The first 14 d allowed wethers to adjust to crates and forages (d 1 through 14). Intake and digestibility were measured simultaneously on d 14 to 21, allowing a 7-d collection period. Wethers had ad libitum access to test forages, allowing an 8 to 12% refusal. Wethers were fed once daily at 0700. Nipple waterers located at the front of each crate supplied drinking water. Trace mineralized salt5 (no vitamins) was available to each wether. High/low average temperatures during the collection period were 13.8/6.4°C. Wethers were weighed on two consecutive days at the beginning of the trial and two consecutive days at the end of the trial in order to determine ADG. Animals all had ad libitum access to alfalfa-orchardgrass hay prior to initiation of the trial and to normal pearl millet at the end of the trial to minimize differences in gut fill.

Orts (forage not eaten and left in the feed bin) were weighted daily, composited and frozen until they could be dried in a forced-draft oven at 60°C. Waste forage (forage not eaten and not in the feed bin) was collected on screens under each wether, recovered at the end of the collection phase, weighed and frozen until it was dried at 60°C. Feces were subsampled (20%) and frozen. Daily fecal subsample collections were pooled and dried at 60°C. Forage, orts, waste and feces samples were ground through a Wiley mill fitted with a 3-mm screen. Approximately 200 g of each sample were reground with a cyclone mill5 fitted with a 1-mm screen.

Sequential analysis of NDF, ADF and permanganate lignin (KLIG) was conducted for all samples (Robertson and Van Soest, 1981 as modified by Cherney et al., 1989). Dry matter intake, DM digestibility (DMD), NDF digestibility (NDFD), NDF intake (NDFI), ADF digestibility (ADFD) and ADF intake (ADF1) were calculated for all animals. Intake data were expressed on a percentage of BW basis. In vitro DM digestibility was determined according to the procedures of Marten and Barnes (1980). Crude protein of test forages was calculated using a micro-Kjeldahl procedure (Nelson and Sommers, 1973). Total nonstructural carbohydrates (TNC) of test forages were determined using the method of Smith (1981). Total alkaloids (Simons and Marten, 1971) and oxalic acid (Supelco, Inc., 1975) concentrations were measured for test forages.

The study was statistically analyzed as a nested factorial design with the following form: Y = μ + Genotype + Rep (Genotype) + Cutting + Genotype × Cutting + Rep (Genotype × Cutting) + Error, where Y = ADG, DMD, NDFD, ADFD, DMI, NDFI or ADFI; μ = mean; Genotype = normal or BMR; Rep = field replicate; Cutting = cutting 1 or cutting 2 and Error = residual error. The differences between genotypes was tested by the Rep (Genotype) term. Differences among the eight test forages in NDF, ADF, KLIG, IVDMD, CP and TNC were tested with the following

---

5Farm & Ranch Morton (Chicago, IL) isofix T-M salt brick; NaCl (95 to 98%), Zn (>3.5%), Mn (>28%), Fe (>175), Cu (>0.35%), I (>0.007%), Co (>0.007%).
6Udy Corporation, Fort Collins, CO.
Acceptability of pearl millet genotypes was measured when grazed the 1st wk of September 1989, following 1 mo of regrowth. Forage was at the boot stage of growth, and both genotypes were approximately 18 to 24 inches in height. In a replicated study, four Suffolk lambs (60 kg; 7 to 8 mo of age) were placed in a paddock measuring 6 × 15 m. Paddocks consisted of 6-m × 6-m areas each of BMR and normal pearl millet, separated by a 3-m × 6-m alley. A water trough placed at one end of the alley provided water to the animals. Animals were left in paddocks for 8 h.

Acceptability was determined using both visual and gravimetric methods. Location of the animals within the paddock was recorded every 5 min for the 8 h. Activity of the animals was not specifically recorded, but we noted that animals were grazing the majority of time that they were on BMR or normal plots. Ratio of time spent on BMR plots vs time spent on normal plots was calculated as [(number of lambs on BMR plots/5 min time interval × 5 min) × number of 5 min time intervals]/[(number of lambs on normal plots/5 min time interval × 5 min) × number of 5-min time intervals]. Time spent on plots and gravimetric measurements were tested for differences in genotypes using TTEST of SAS (1982). For gravimetric measurements, four pre- and four post-graze samples (45-cm × 60-cm areas, clipped to ground level) per plot were collected to determine DM consumption of BMR and normal genotypes. Pre-graze samples were collected from outside the paddock. Sequential fiber analyses (Cherney et al., 1989) of pre-grazed samples also were determined. The chemical composition portion of this study was analyzed statistically as a randomized replicated complete block. Sources of variation included genetic type (BMR or normal), pre- or post-graze, and sample replicates (4).

Results and Discussion

There were differences in chemical characteristics of forages used in this study (Table 1). Cutting × genotype interactions were observed for NDF (P ≤ .03) and ADF (P ≤ .02) among forages. Interactions were caused primarily by lower NDF and ADF in cutting 2 of the BMR genotype. Cutting × genotype interactions were not observed for KLIG, IVDMOD, CP or TNC. Brown-midrib pearl millet was 22.5% lower (P < .01) in KLIG and 3.9% higher (P < .01) in IVDMOD than the normal genotype. This is consistent with reported results from other studies involving the BMR trait. Cherney et al. (1988) observed 20% lower KLIG and 10% higher IVDMOD in BMR pearl millet, and Cherney et al. (1986), Gerhardt et al. (1987) and Fritz et al. (1988) reported an average 23% lower lignin and 7% higher IVDMOD in BMR sudangrass than their normal counterparts.

Crude protein tended to be slightly lower in cutting 2 than in cutting 1 (P ≤ .07), and a trend was observed for lower (P ≤ .12) CP in the normal genotype vs the BMR genotype, but variations in field replicates resulted in non-significant differences. Genotype and cutting did not influence (P > .10) TNC.

Digestibilities of DM, NDF and ADF were consistently higher (P ≤ .05) for the BMR genotype than for the normal genotype (Table 2). Lusk et al. (1984) reported similar in vivo digestibilities between BMR12 and normal sorghum genotypes with Holstein cows. Wedig et al. (1986) using sheep and Fritz et al. (1988) using Holstein cows, however, observed higher in vivo DMD in BMR12 vs normal sorghum × sudangrass genotypes; Wedig et al. (1988) also noted higher in vivo NDFD and ADFD. In vivo results for pearl millet in this study follow the same patterns as those observed by Fritz et al. (1988) and Wedig et al. (1988), and are consistent with IVDMOD results in this study.

Cutting had no apparent effect (P > .10) on DMD, NDFD or ADFD. Genotype × cutting interactions were not observed (P > .10) for these criteria. Differences in KLIG may account partially for differences observed in digestibility, because lignin limits the extent of forage digestion by ruminants (Van Soest, 1982). In this study, lignin and DMD were correlated negatively (r = -.71; n = 24; P = .05).

Genotype × cutting did not influence NDFI or ADFI (P > .10; Table 2). Cutting 2 was lower in DMI, NDFI and ADFI for both genotypes (P ≤ .01). Dry matter intake was 38% lower in cutting 2 for the normal genotype than for the BMR genotype; there was no difference in DMI between genotypes in cutting 1, resulting in a genotype × cutting interaction (P ≤ .10). The large difference in
TABLE 1. COMPOSITION AND DIGESTIBILITY OF HAYS USED IN STUDY

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Cuttinga</th>
<th>Repb</th>
<th>NDF</th>
<th>ADF</th>
<th>KLIGc</th>
<th>IVDMDc</th>
<th>CP</th>
<th>TNCc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1</td>
<td>1</td>
<td>67.2</td>
<td>34.6</td>
<td>4.6</td>
<td>67.3</td>
<td>11.3</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>67.5</td>
<td>33.9</td>
<td>4.7</td>
<td>67.0</td>
<td>14.3</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>67.5</td>
<td>34.9</td>
<td>4.4</td>
<td>65.3</td>
<td>9.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Brown-midrib</td>
<td>1</td>
<td>1</td>
<td>64.6</td>
<td>34.6</td>
<td>3.7</td>
<td>65.6</td>
<td>11.2</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>62.3</td>
<td>31.3</td>
<td>3.3</td>
<td>66.9</td>
<td>14.7</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>62.3</td>
<td>31.4</td>
<td>3.6</td>
<td>TNC</td>
<td>11.9</td>
<td>6.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Probability level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
</tr>
<tr>
<td>Cutting</td>
</tr>
<tr>
<td>Cutting x genotype</td>
</tr>
</tbody>
</table>

aCutting 1 = harvested August 1, 1989; cutting 2 = harvested September 22, 1989.
bRep = field replicate.
cKLIG = permanganate lignin; IVDMD = in vitro DM digestibility; TNC = total nonstructural carbohydrates.

DMI in cutting 2 between genotypes contributed to the difference (P ≤ .10) between genotypes observed for the main effect.

Average daily gains paralleled DMI (Table 2); animals fed cutting 1 forages gained weight; those fed cutting 2 forages lost weight. Animals fed normal cutting 2 forages, however, lost considerably more weight (P ≤ .01) than those fed BMR cutting 2 forages. Average daily gains of animals (six animals/genotype x cutting) in metabolism crates for 21 d may not reflect true potential for ADG of animals in feeding pens or on pasture; however, this information still is of use in evaluating feeding potential of pearl millet. Lambs fed normal cutting 2 forage took longer to adjust to consuming the forage compared with the others; this contributed to the large difference in ADG among forages, and reflected possible acceptability problems with normal cutting 2 forages.

Reported performance and intake of animals fed BMR forages vs normal forages is variable. Lusk et al. (1984) did not note any differences in DMI between BMR and normal sorghum silage; Keith et al. (1979) also did not observe any difference in DMI between normal vs BMR corn silage. Keith et al. (1979),

TABLE 2. APPARENT DIGESTIBILITY, INTAKE AND GAIN PERFORMANCE OF WETHERS FED TWO PEARL MILLET GENOTYPESa AND PROBABILITY LEVELS FOR DM DIGESTIBILITY, NDF DIGESTIBILITY (NDFD), ADF DIGESTIBILITY (ADFD), DMI, NDF INTAKE (NDFI), ADF INTAKE (ADFI) AND ADG

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Cuttingb</th>
<th>DMD</th>
<th>NDFD</th>
<th>ADFD</th>
<th>DMI</th>
<th>NDFI</th>
<th>ADFI</th>
<th>ADG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1</td>
<td>63.5</td>
<td>67.5</td>
<td>64.8</td>
<td>64.8</td>
<td>67.5</td>
<td>64.8</td>
<td>67.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>65.2</td>
<td>67.8</td>
<td>66.3</td>
<td>66.3</td>
<td>66.3</td>
<td>66.3</td>
<td>66.3</td>
</tr>
<tr>
<td>Brown-midrib</td>
<td>1</td>
<td>66.3</td>
<td>72.1</td>
<td>70.7</td>
<td>70.7</td>
<td>70.7</td>
<td>70.7</td>
<td>70.7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>67.1</td>
<td>69.9</td>
<td>68.0</td>
<td>68.0</td>
<td>68.0</td>
<td>68.0</td>
<td>68.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Probability level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
</tr>
<tr>
<td>Cutting</td>
</tr>
<tr>
<td>Genotype x cutting</td>
</tr>
</tbody>
</table>

aGenotypes.
bCutting 1 = harvested August 1, 1989; cutting 2 = harvested September 22, 1989.

SEM.
TABLE 3. FIBER AND CP COMPOSITION OF PRE-GRAZED NORMAL AND BROWN-MIDRIB PEARL MILLET GENOTYPE SAMPLES (%), N = 4

<table>
<thead>
<tr>
<th></th>
<th>NDF</th>
<th>ADF</th>
<th>KLIG*</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>58.0 (1.2)</td>
<td>29.1 (0.7)</td>
<td>2.9 (0.5)</td>
<td>17.6 (0.3)</td>
</tr>
<tr>
<td>Brown-midrib</td>
<td>57.9 (1.9)</td>
<td>29.2 (1.1)</td>
<td>2.7 (1.0)</td>
<td>17.2 (1.6)</td>
</tr>
<tr>
<td>Probability</td>
<td>.90</td>
<td>.88</td>
<td>.15</td>
<td>.44</td>
</tr>
</tbody>
</table>

*KLIG = lignin.

however, reported that milk yield was greater for cows fed BMR corn silage than for those fed normal corn silage. Rate of gain and DMI were greater for Holstein heifers fed BMR corn silage than for those fed normal corn silage (Colenbrander et al., 1973, 1975).

Reported differences in this study and those of others may have several explanations. Differences in genotypes (corn, sorghum, sorghum-sudangrass, pearl millet) and varieties may explain part of the reported differences in DMI and ADG. Feeding method, whether forage alone or as a forage:concentrate diet, may account for reported differences in DMI, ADG and milk yield. Storage of forage as hay vs silage may have caused differences in intake and digestibility among studies. For the pearl millet in this study, differences between cuttings in digestibility, intake and ADG may have been due to environmental effects such as season progression and temperature (which was lower for cutting 2). Forages were harvested at roughly equivalent stages of physiological maturity, boot to early head; however, cutting 1 forages had a higher leaf to stem ratio (11.5) than did cutting 2 forages (5.5). This possibly was caused by season progression and temperature differences. Cherry and Mertens (1989) indicated that differences in morphological ratio or composition might account for differences in DMI when forages had similar chemical composition; this may account partially for differences observed between cuttings.

Differences in DMI between the normal and BMR genotypes in cutting 2 are difficult to explain. There were differences in chemical composition (Table 1) and digestibility (Table 2), but it is unclear whether these differences were large enough to account for the differences in DMI or ADG.

Alkaloids (Roquette et al., 1980) and oxalic acid (Rachie and Majmudar, 1980) depress forage quality in pearl millet. Following prolonged drought conditions, cattle abruptly refused to graze many fields of commercial pearl millet. Total alkaloid concentration in non-drought-stressed forage ranged from 10 to 20 mg/kg vs 180 to 460 mg/kg in drought-stressed forage; alkaloid concentration in drought-stressed plants 4 d after a 1.8-cm rain was 20 mg/kg (Roquette et al. 1980). Alkaloids apparently were not the cause of acceptability problems in the present study, however, because alkaloids were at less than detectable levels in the test forages. Oxalic acid acts as an antimetabolite, interfering with protein metabolism (Rachie and Majmudar, 1980) and thereby reducing forage quality of pearl millet. Oxalic acid was not a problem in this study, however, because it also was below the detectable level in the test forages.

Results of the acceptability trial showed that the BMR genotype was preferred over the normal genotype by grazing lambs. The BMR plots were 10% lower in lignin concentration than normal pearl millet genotype plots at time

![Figure 1. Number of lambs grazing brown-midrib (bmr)/normal pearl millet during each 5-min time segment.](image-url)
of grazing (Table 3), but this did not result in lodging. Other fiber constituents did not differ. This is consistent with other studies using the BMR/normal genotypes in pearl millet (Cherney et al., 1988), corn (Grand et al., 1985) and sorghum (Porter et al., 1978), but it is not clear whether this relates to differences in acceptability.

Lambs displayed a marked preference (P ≤ .01) for the BMR genotype in both periods (Figure 1). While in grazing paddocks, lambs rested in alleys and most of their time in forage areas was spent eating. Lambs spent an average of 2.6 min on plots containing the BMR genotype for every min spent on plots containing the normal plants in both periods, even though much less total time was spent on either plot in period 2.

Visually, BMR areas were more heavily grazed than normal areas. Dry matter consumption, calculated from pre- and post-graze samples, substantiated these visual observations. The BMR pearl millet had 27.2 and 5.2% of the initial DM consumed by grazing in periods 1 and 2, respectively, whereas the plots containing the normal genotype were not measurably consumed (0%) during either period (P ≤ .01). Normal pearl millet paddocks were noticeably, though lightly, grazed, but plant growth during the 8-h period was not measured and probably resulted in the lack of measurably DM consumption.

Reasons for these differences in acceptability are not clear. It is not likely that high alkaloid or oxalic acid concentrations were responsible for differences in DMI or ADG, because they were undetectable in the test hays. Protein has been suggested as having a positive relationship with acceptability of forages (Marten, 1970). This is not likely to be the reason for acceptability differences in this study, because CP levels were high enough to meet maintenance requirements (NRC, 1985) and would not likely cause the intake adjustment problems observed with cutting 2 forages. Organoleptic factors may be involved. Reasons for this difference need to be further investigated.

Implications

Efficiency of forage utilization by livestock is dependent to a large extent on the quality of forage consumed. The brown-midrib trait can improve the forage quality of pearl millet; existing pearl millet genotypes should be improved by incorporating the brown-midrib trait. Improved acceptability and intake of late season harvests of brown-midrib millet vs normal millet could lengthen the grazing season, improving animal production.

Literature Cited


Res. Ctr., Ottawa, Canada.