Effects of Corn Silage Hybrid and Dietary Concentration of Forage NDF on Digestibility and Performance by Dairy Cows¹

X. Qiu, M. L. Eastridge, and Z. Wang

Department of Animal Sciences, The Ohio State University, Columbus 43210

ABSTRACT

Eight intact multiparous cows and four ruminally and duodenally cannulated primiparous cows were fed four diets in a replicated 4 × 4 Latin square design: 1) 17% forage neutral detergent fiber (NDF) with brown midrib corn silage (BMRCS), 2) 21% forage NDF with BMRCS, 3) 17% forage NDF with conventional corn silage (CCS), and 4) 21% forage NDF with CCS. Diets contained 17.4% crude protein and 38.5% NDF. Each period consisted of 4 wk for intact cows and 2 wk for cannulated cows. For intact cows, DM intake was higher for BMRCS than CCS, and milk urea N was higher for 21 than 17% forage NDF. Milk protein yield tended to be higher and milk urea N lower for cows fed BMRCS than those fed CCS. Milk yield and milk protein percentage were similar among treatments. For the cannulated cows, ruminal mat consistency was similar among treatments. Based on a 72 h *in situ* incubation, BMRCS was lower in indigestible NDF than CCS. The BMRCS resulted in a higher proportion of ruminal propionate than CCS. Cows fed 21% forage NDF had a higher proportion of acetate and a lower proportion of propionate than cows fed 17% forage NDF. The total tract digestibility of nutrients and efficiency of bacterial N synthesis were similar among treatments, except that BMRCS resulted in lower intestinal fatty acid digestibility than CCS, and 17% forage NDF tended to result in higher total tract fatty acid digestibility than 21% forage NDF. Ruminal NDF digestibility was similar among dietary treatments. The increased milk production observed from feeding BMRCS in some studies may be explained by higher DM intake rather than increased total tract digestibility of the diets.

(**Key words:** brown midrib, corn silage, forage NDF)

Abbreviation key: BMR = brown midrib, BMRCS = brown midrib corn silage, CCS = conventional corn si-

lage, CS = corn silage, FA = fatty acid, FNDF = forage NDF.

INTRODUCTION

Corn silage (CS) hybrids with the brown midrib (BMR) gene have been proposed to be good forage sources when DMI is a particular concern, such as with high-producing cows (Oba and Allen, 1999; Oba and Allen, 2000a). The BMR CS (BMRCS) consistently has a lower lignin concentration and an increased *in vitro* digestibility of NDF, with little difference in NDF and protein concentrations, compared to conventional CS (CCS) (Cherney et al., 1991). Cows in early lactation tend to be in negative energy balance, and gut fill is considered to be one of the factors limiting energy intake by dairy cows (Allen, 1996). An enhanced NDF digestibility has been speculated to increase DMI, and thus energy intake, when the maximum intake is limited by physical fill.

Eastridge (1999) summarized several studies and showed that inclusion of BMRCS in diets consistently increased DMI by cows, ranging from 0.4 to 3.3 kg/d. However, milk yield responses were more variable than DMI responses. Cows fed BMRCS produced 1.0 kg/d more milk than cows fed the control silage (Eastridge, 1999), but some studies have not resulted in a positive response in milk yield by feeding BMRCS (Rook et al., 1977; Sommerfelt et al., 1979; Block et al., 1981).

The use of BMRCS in diets with low forage NDF (FNDF) has been anecdotally questioned because BMRCS has higher *in vitro* NDF digestibility. However, there is no documented justification to support this potential concern. Oba and Allen (2000c) found that although *in vitro* NDF digestibility of BMRCS was higher than for CCS, enhanced *in vitro* NDF digestibility does not necessarily translate to increased NDF digestibility either in the rumen or in the total tract. However, BMRCS may possibly increase DMI and rate of passage, thus improving efficiency of microbial protein production. Oba and Allen (2000a) also observed that BMRCS depressed milk fat percentage when fed in a low NDF diet. However, the question remains whether milk fat percentage is more responsive to total dietary NDF or dietary FNDF, particularly when BMRCS is fed to lac-

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Corresponding author: M. L. Eastridge; e-mail: eastridge.1@osu.edu.

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tating cows. We hypothesized that BMRCs can be effectively used in low forage diets as long as sufficient dietary NDF and FNDF are provided. The objective of this study was to determine whether BMRCs interact with concentration of dietary FNDF to affect ruminal fermentation, nutrient digestibility, and animal performance.

MATERIALS AND METHODS

Corn Silage

During spring 1997, two CS hybrids, Cargill 6208FQ and Cargill 657 (Cargill Hybrid Seeds, Minneapolis, MN), were planted in adjacent fields on the Waterman Farm at The Ohio State University (Columbus). Except for the *bm3* mutation, Cargill 657 was isogenic to Cargill 6208FQ. Yields were measured by collecting the forage from one thousandth of an acre in four different rows within two locations of the field for each hybrid. The conventional and BMR hybrids were harvested and chopped on September 3 and September 10, respectively, when the corn grain reached 23% and 43% milk line, respectively, and the whole plant contained about 30% DM. Both hybrids were ensiled separately in 2.4 × 60 m plastic bags (Ag-Bag Corporation, Astoria, OR).

Animals, Diets, and Experimental Design

Four ruminally and duodenally cannulated primiparous cows (average DIM = 49) and eight intact multiparous cows (average DIM = 162) were used in two separate 4 × 4 Latin Squares. The treatments were: 1) 17% FNDF with BMRCs, 2) 21% FNDF with BMRCs, 3) 17% FNDF with CCS, and 4) 21% FNDF with CCS. The diets contained 17.3% CP and 38.5% NDF, with soybean hulls providing 23.4 and 17.8% of DM for 17 and 21% FNDF diets, respectively (Table 1). About 75% of the forage was from CS and 25% from alfalfa silage. Diets were prepared once a day as TMR, and all cows were fed individually twice a day at 0700 h and 1900 h for ad libitum intake. The CS and alfalfa silage samples were taken weekly, and concentrates were sampled biweekly to determine DM concentration at 55°C and to adjust the ration accordingly.

Sampling Methods

For the cannulated cows, each period consisted of 14 d with the last 7 d used for collection of milk yield and DMI data. The last 4 d of each period were used for collection of milk composition and digestibility data. Feed offered and refused were sampled daily during d 11 through 14 and were composited for determination of DM, OM, N, NDF, ADF, starch, and fatty acid (FA)

concentrations for the collection period. Feed offered was sampled immediately before the pm feeding, and feed refusals were collected, weighed, and sampled at about 1630 h each day. Digestibility of feed components was determined by the use of Cr₂O₃, which was dosed in the rumen twice daily from d 5 through d 14 at each feeding at 100 g per dose in the form of a pellet. The pellets contained 5% Cr₂O₃, with the carrier being soybean hulls. Milk samples were taken at both am and pm milkings on two alternating days for determination of milk fat and protein.

On d 10 of each period, ruminal mat consistency was measured (Vaage and Milligan, 1993; Welch, 1982). A weight of exactly 0.454 kg was put at the bottom of the rumen at each feeding, with one end of the attached string left outside the rumen. At 3 h postfeeding, the free end of the string was pulled through two pulleys mounted on both ends of a board. A weight of 2.27 kg was hooked onto the end of the string. After the counterweight was engaged, the distance the weight inside the rumen traveled through the ruminal mat was recorded every 20 s.

Nylon bags (10 × 20 cm and approximately 50 μm pore size; Ankom, Fairport, NY) were dried for at least 3 h at 55°C and air equilibrated for about 0.5 h. Approximately 2 g of CS of CCS or BMR type were measured into the nylon bags. The CS was dried at 55°C and ground through a 2-mm Wiley Mill screen (Arthur A. Thomas, Philadelphia, PA). Incubation started immediately prior to the 0700-h feeding on d 11 of each period. The bags were briefly soaked in cold tap water and then submerged about 30 cm into the ruminal contents. Bags (n = 2 per time point) were removed at 0, 3, 6, 12, 24, 48, and 72 h of incubation. After removal, bags were placed in cold water to slow the fermentation, and then the bags were rinsed thoroughly in running cool tap water to remove the external feed particles. Samples were frozen for later analyses.

Ruminal samples for determination of pH, NH₃-N, and VFA were taken on the last 2 d of each period at 3, 6, 9, and 12 h post feeding. Approximately 500 ml of ruminal contents were collected; after measuring pH of the ruminal fluid, 50 ml were filtered through four layers of cheese cloth, and 3 ml of 6 N HCl were added to the 50 ml of ruminal fluid to stop fermentation. Ruminal fluid samples were composited and frozen until later analyses for VFA and NH₃-N.

Ruminal samples for harvesting of bacteria were taken at 3, 6, 9, and 12 h on d 11, 12, 13, and 14, respectively, of each period. Approximately 600 ml of ruminal contents were placed in a blender. A 0.9% saline solution was added to create a slurry, and the mixture was blended at low speed for 1 min to detach some of the particle-associated bacteria from the feed parti-

Table 1. Ingredient and chemical composition of experimental diets.

Item	Treatment ¹			
	17BMRCS	21BMRCS	17CCS	21CCS
	(% of DM)			
Ingredient composition				
Alfalfa silage	10.40	12.59	10.40	12.59
BMRCS	31.50	39.12	—	—
CCS	—	—	31.50	39.12
Dry shelled corn, ground	12.95	7.41	12.95	7.41
Soybean hulls	23.39	17.80	23.39	17.80
Soybean meal, 44% CP	14.80	16.40	14.80	16.40
Blood meal	1.33	1.33	1.33	1.33
Tallow	2.04	2.04	2.04	2.04
Dicalcium phosphate	0.50	0.44	0.50	0.44
Feed grade limestone	1.08	1.06	1.08	1.06
Magnesium oxide	0.12	0.12	0.12	0.12
Trace mineralized salt	0.52	0.52	0.52	0.52
Potassium sulfate	0.15	0.12	0.15	0.12
Sodium bicarbonate	0.79	0.80	0.79	0.80
Feed grade urea	0.33	0.15	0.33	0.15
Vitamin supplements ²	0.10	0.10	0.10	0.10
Chemical composition				
NDF	40.0	37.2	38.1	38.5
FNDF	17.1	21.2	17.1	21.2
ADF	28.1	25.6	27.1	27.9
CP	17.2	17.4	17.3	17.4
NE _L , ³ Mcal/kg	1.74	1.72	1.74	1.72
Fatty acids	3.38	3.47	3.37	3.33
Starch	32.7	33.6	32.8	32.6
Ash	6.45	6.50	6.51	6.54
P	0.40	0.41	0.41	0.42
K	1.41	1.44	1.40	1.47
Ca	0.96	1.01	1.01	1.00
Mg	0.26	0.27	0.27	0.27

¹17BMRCS = 17% forage NDF (FNDF) with brown midrib corn silage (BMRCS); 21BMRCS = 21% FNDF with BMRCS; 17CCS = 17% FNDF with conventional corn silage (CCS); and 21CCS = 21% FNDF with CCS.

²0.02% vitamin A (30,000 IU/g), 0.02% vitamin D (3000 IU/g), and 0.06% vitamin E (44 IU/g).

³Calculated using NRC (1989) values for feeds.

cles. The mixture of ruminal contents and saline solution was then filtered with eight layers of cheese cloth. After filtration, 500 ml of fluid were collected, composited for each day of the collection period, and frozen for later analyses.

Duodenal samples were taken every 6 h during the 4-d collection period, with the starting time being altered by 1.5 h each day. About 280 ml of duodenal contents were collected, composited for each day of the collection period, and stored in a freezer at -20°C. Later, samples were thawed and subsampled while blending. Samples were frozen for later analyses of OM, NDF, N, NH₃-N, FA, Cr, and purines.

Fecal samples were taken every 12 h during the 4-d collection period, with the starting time being altered by 3 h each day. Samples of feces were frozen and later analyzed for OM, NDF, N, FA, and Cr. Representative samples of feed offered, feed refused, duodenal contents, and feces taken during the collection period were lyophilized, composited, and ground through a 2-mm screen in a Wiley mill prior to lab analysis.

The eight intact cows were fed each diet for 4 wk, with the last 2 wk used for sample collection. Milk yield and DMI were recorded daily, and milk was sampled twice weekly. Body weight was recorded weekly. Chewing activity by intact cows was observed for 24 h two consecutive times during period four of the study.

Laboratory Procedures

To standardize DMI for fluctuating DM concentration, 200- to 250-g representative samples of feed offered and refused were dried in an oven at 55°C for 72 h. Chromium concentrations of duodenal and fecal samples were determined as described by Williams et al. (1962) using a Varian SpectraAA Atomic Absorption Spectrometer 220 (Varian Australia Pty Ltd., Mulgrave, Australia). Purine concentrations of rumen bacteria and duodenal contents were used to determine microbial flow to the duodenum (Ushida et al., 1985; Zinn and Owens, 1986). Nitrogen concentrations of feed, digesta, and rumen bacteria were determined ac-

cording to Bremner and Mulvaney (1982) using a Tecator Digestion 20 System, 1015 Digestor and a Tecator Kjeltex System, 1026 Distilling Unit (Tecator AB, Hoganas, Sweden). Analysis of fiber components was according to Goering and Van Soest (1970) and more recent modifications to the NDF procedure (Van Soest et al., 1991). To minimize the interference by fat with the fiber analysis, all feed and digesta samples were filtered with 100 ml of boiling ethanol prior to treatment in 30 ml of 8 M urea and 0.2 ml α -amylase (Sigma A-5426; Sigma Chemical Co., St. Louis, MO). Starch was determined as described by Wang et al. (2001). Individual minerals were analyzed by inductively coupled plasma spectrometry at the Research Extension Analytical Laboratory (Wooster, OH).

In situ samples were thawed and dried at 55°C for at least 48 h. Residual matter was analyzed for NDF. Percentage of NDF of the original sample of CS was determined and used to calculate percentage of indigestible NDF. The NDF residues at 72 h were used to calculate potentially digestible NDF.

Ruminal fluid samples were thawed, mixed, and centrifuged at $15,000 \times g$, and the supernatant was filtered through Waterman #1 paper. The filtered supernatant was saved for later analysis of $\text{NH}_3\text{-N}$ and VFA. A Hewlett Packard 5890, Series II (Hewlett-Packard Company, Avondale, PA) GLC with an HP 3396A Integrator (Hewlett-Packard Company) was used for all VFA analyses. The GLC was equipped with a 1.8-m glass column packed with GP 10% SP-1200/1% H_3PO_4 on 80/100 Chromosorb WAW (Supelco, Inc. Bellefonte, PA). The internal standard used was 2-ethylbutyric acid, and N was the carrier gas. Injector port temperature was 185°C, and the detector port was set at 195°C. The column was held at 115°C for 8 min.

Feed offered, feed refused, duodenal contents, feces, and bacteria samples were analyzed for FA according to the procedure described by Sukhija and Palmquist (1988). Milk FA was analyzed according to some modifications of this procedure. Milk fat was collected by centrifugation of 12 to 15 ml of milk at $8000 \times g$ to form a solid milk fat layer on top of the milk, and 100 mg of milk fat were used for analyses. Two milliliters of hexane were used as a solvent instead of benzene. Methylation occurred by heating samples for 1.5 h at 50°C. After removal of the solvent layer, 1.0 ml of hexane was added to the original culture tube, samples were again mixed and centrifuged, and the solvent layer was removed and composited with the first solvent layer. Approximately 0.5 g anhydrous sodium sulfate was added to the composited sample, and the sample was vortexed again and let stand for 0.5 h prior to the final centrifugation.

The GLC was equipped with a 30-m, 0.25-mm ID, 10% SP-2380 fused silica capillary column (Supelco, Inc., Bellefonte, PA) for analysis of all feed, digesta, bacteria, and milk FA. For feed, digesta, and bacteria FA, the injector port temperature was 230°C and the detector port was set at 250°C. The column was held at 165°C for 13 min and then increased at 2.5°C/min to 200°C and held for an additional 2 min. For milk FA, the injector port temperature was 240°C and the detector port was 250°C. The column was held at 60°C for 4 min, then increased at 3°C/min to 165°C, then increased at 1°C/min up to 180°C, held for 7 min, then increased at 5°C/min up to 210°C and held for an additional 5 min. Milk fat and true protein were determined using infrared spectroscopy, and milk urea N was determined by using a Skalar SAN Plus segmented flow analyzer (Skalar, Inc., Norcross, GA) at the DHI Laboratory (DHI Cooperative, Inc., Columbus, OH).

Statistical Analysis

Treatments were arranged in a 2×2 factorial design for a replicated 4×4 Latin square. All statistical analyses of the data except those of ruminal pH and VFA were performed using the general linear model procedure of SAS (1997). Effects of square, cow, period, and dietary treatment were tested. Data for ruminal pH and VFA were analyzed with the MIXED model procedure of SAS (1997) with repeated measures for time of sampling. Cow was classified as a random effect. The first-order autoregressive [AR(1)] type was selected as the appropriate covariance structure for the repeated measures. Contrasts were made for: 1) BMRCs versus CCS, 2) 17 versus 21% FNDF, and 3) the interaction of CS hybrids and dietary level of FNDF. Significance was declared when $P < 0.05$, and tendency was stated when $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

Chemical Composition of Diets and Corn Hybrids

Diets contained 38.5% NDF, 17.3% CP, and 32.9% starch (Table 1). Chemical composition of the BMR and conventional corn hybrids and the silage made from them was similar except that the BMR corn and its silage had lower lignin concentrations (Table 2). The forage yield of BMR corn was about 13.5% lower than that for the conventional corn.

DMI, Milk Yield, and Milk Components

For the intact cows, consistent with previous studies (Eastridge, 1999), DMI was higher for BMRCs than CCS (Table 3). There was an interaction between FNDF

Table 2. Composition and yield of corn for silage.¹

	Nonensiled Corn		Corn Silage	
	BMRC	CC	BMRCS	CCS
DM, %	31.4	28.6	35.6	33.5
DM yield, t/ha	15.4	17.8	—	—
Ear, % of DM	42.6	51.7	—	—
Stover, % of DM	57.4	48.3	—	—
	% of DM			
CP	7.24	7.48	7.67	7.76
NDF	45.9	44.5	41.6	41.1
ADF	24.2	24.3	27.2	26.6
Lignin	1.14	2.12	1.13	2.34
Starch	34.8	33.9	33.1	31.6
Ash	4.12	4.04	4.18	4.04

¹BMRC = brown midrib corn, BMRCS = brown midrib corn silage, CC = conventional corn, and CCS = conventional corn silage.

and CS for DMI. This interaction revealed that the higher level of inclusion of CCS decreased DMI, but an increase in BMRCS in the diet did not decrease DMI, possibly because of higher digestibility of the silage NDF (Table 6) or higher passage rate. Oba and Allen (2000a) hypothesized that reducing physical fill in the rumen by feeding more degradable NDF increases DMI and productivity to a greater extent when animals are fed a high NDF compared to a low NDF diet. The data from our study would support the increase in DMI, but not milk production, with BMRCS compared with CCS in a high NDF diet.

Milk yield was similar among treatments. Previous studies showed that, although inclusion of BMRCS in diets consistently resulted in higher DMI, milk yield responses were more variable than DMI responses. In some studies, milk yield increased by feeding BMRCS (Keith et al., 1979; Oba and Allen, 1999), but other studies did not find a positive response (Rook et al.,

1977; Stallings et al., 1982). In a recent study, Tjardes et al. (2000) observed that BMRCS improved total tract digestibility of OM and NDF but not performance by growing beef steers.

An interaction occurred between silage and FNDF for milk fat percentage. Increasing concentration of FNDF with BMRCS increased milk fat percentage but decreased it with CCS. Milk fat yield and milk protein percentage were similar among treatments, but milk protein yield tended to be higher for BMRCS than CCS. The MUN was higher for 21 than 17% FNDF but tended to be lower for BMRCS than CCS. For the cannulated cows, milk yield and milk protein yield were higher for BMRCS than CCS (data not shown). Because the cannulated cows were fed each diet for only half as long as the intact cows (2 versus 4 wk), the DMI, milk yield, and milk composition yield from these cows were not included in Table 3. However, these results accentuated the observation that milk yield responses of feeding BMRCS are more variable than DMI responses.

Ruminal Fermentation Characteristics and Mat Consistency

Ruminal pH was similar among treatments, but cows fed BMRCS had a higher proportion of ruminal propionate than cows fed CCS (Table 4). Cows fed 21% FNDF had a higher proportion of acetate and lower proportion of propionate than cows fed 17% FNDF. The proportion of butyrate was higher for cows fed CCS than those fed BMRCS. The acetate:propionate ratio was lower for BMRCS than CCS and 17 than 21% FNDF.

Ruminal mat consistency was similar among main effects, but there tended ($P = 0.06$) to be an interaction between CS hybrids and FNDF in total ascension time (Table 5), with the shortest retention time occurring for

Table 3. Effect of corn silage hybrid and dietary level of forage NDF on DMI and performance by intact lactating cows.

	Treatment ¹				SE	Probability ²		
	17BMRCS	21BMRCS	17CCS	21CCS		Silage	FNDF	S × F
DMI, kg/d	26.2	26.8	25.0	23.5	0.6	<0.01	0.29	0.03
% of BW	3.85	3.87	3.70	3.52	0.02	0.01	0.22	0.04
Milk yield, kg/d	35.5	35.5	34.0	34.1	1.2	0.11	0.96	0.93
4% FCM, kg/d	34.1	35.0	33.5	32.9	1.2	0.14	0.88	0.38
Milk fat, %	3.76	3.89	3.93	3.79	0.09	0.58	0.95	0.05
Milk fat, g/d	1326	1387	1331	1285	53	0.21	0.84	0.17
Milk protein, %	3.31	3.29	3.28	3.35	0.04	0.62	0.44	0.11
Milk protein, g/d	1167	1158	1110	1116	40	0.09	0.96	0.79
MUN, mg/dl	15.9	17.3	16.6	18.1	0.5	0.06	<0.01	0.83

¹17BMRCS = 17% forage NDF (FNDF) with brown midrib corn silage (BMRCS); 21BMRCS = 21% FNDF with BMRCS; 17CCS = 17% FNDF with conventional corn silage (CCS); and 21CCS = 21% FNDF with CCS.

²Silage = main effect of corn silage hybrid; FNDF = main effect of forage NDF level; and S × F = interaction between corn silage hybrid and FNDF level.

Table 4. Effect of corn silage hybrid and dietary level of forage NDF on ruminal fermentation.

	Treatment ¹				SE	Probability ²		
	17BMRCS	21BMRCS	17CCS	21CCS		Silage	FNDF	S × F
pH	5.78	6.02	5.93	5.81	0.11	0.68	0.45	0.11
Ammonia N, mM	16.0	14.8	17.1	17.9	1.4	0.41	0.92	0.69
Total VFA, mM	121	120	112	118	3	0.30	0.57	0.51
Acetate, mol/100 mol	62.1	63.6	63.5	64.9	0.5	0.13	0.01	0.98
Propionate, mol/100 mol	24.3	22.8	21.7	20.8	0.7	0.03	0.05	0.78
Butyrate, mol/100 mol	9.9	10.1	10.7	10.7	0.2	0.03	0.59	0.74
Acetate:propionate	2.56	2.79	2.93	3.12	0.13	0.03	0.05	0.90

¹17BMRCS = 17% forage NDF (FNDF) with brown midrib corn silage (BMRCS); 21BMRCS = 21% FNDF with BMRCS; 17CCS = 17% FNDF with conventional corn silage (CCS); and 21CCS = 21% FNDF with CCS.

²Silage = main effect of corn silage hybrid; FNDF = main effect of forage NDF level; and S × F = interaction between corn silage hybrid and FNDF level.

17% FNDF and BMRCS. Considerable variation among cows was noticed in terms of ruminal mat consistency measurements, with some cows always resulting in shorter total ascension times and others consistently resulting in longer retention times in spite of the different dietary treatments.

Oba and Allen (2000b) observed that enhanced NDF digestibility of CS did not decrease physical effectiveness of NDF. In the present study, feeding BMRCS at 17% FNDF did not alter the ruminal mat consistency of the cannulated cows, and total time spent chewing was similar among treatments based on observations with the intact cows (582 min/d). Ruminal fermentation was apparently not severely affected by this treatment based on ruminal pH being similar among treatments and the acetate-to-propionate ratio being greater than 2.5.

In Situ NDF Disappearance and Dietary Nutrient Digestibility

Potentially digestible NDF, calculated by subtracting NDF washout and NDF residuals after 72 h of in situ incubation, and rate of disappearance of potential di-

gestible NDF were similar among treatments (Table 6). The NDF washout was higher for BMRCS than CCS. Indigestible NDF was lower for BMRCS than CCS because BMRCS was lower in lignin. It is not clear at this point why the NDF washout was higher for BMRCS than CCS. This may have occurred because some portion of the NDF in BMRCS was more fragile, thus easily broke into small particles and washed out of the in situ bags due to less extent of binding by lignin. If confirmed by further study, this feature may contribute to higher passage rate of BMRCS from the rumen and thus partially explain the higher DMI with feeding BMRCS.

The intake, duodenal and fecal flows, and digestibility of various dietary components are provided in Table 7. The intakes of OM and other dietary components were higher for 17 than 21% FNDF and higher for BMRCS than CCS. The total tract digestibility of these components, except FA, and efficiency of microbial protein synthesis were similar among treatments. Stomach NDF digestibility was similar among dietary treatments. Rook et al. (1977) found an improvement in NDF digestibility by feeding BMRCS when the diet consisted of 60% forage and 40% concentrate, but NDF digestibility was lower for the BMRCS treatment than the control

Table 5. Effects of corn silage hybrid and dietary level of forage NDF on ruminal mat consistency.

	Treatment ¹				SE	Probability ²		
	17BMRCS	21BMRCS	17CCS	21CCS		Silage	FNDF	S × F
Distance traveled in first min, cm	14.0	11.3	15.3	13.4	2.8	0.40	0.25	0.83
Rate after 1 min, cm/min	5.21	3.43	3.48	4.42	1.60	0.78	0.71	0.24
Total ascension time, min	6.43	7.59	7.32	6.88	0.62	0.72	0.43	0.06

¹17BMRCS = 17% forage NDF (FNDF) with brown midrib corn silage (BMRCS); 21BMRCS = 21% FNDF with BMRCS; 17CCS = 17% FNDF with conventional corn silage (CCS); and 21CCS = 21% FNDF with CCS.

²Silage = main effect of corn silage hybrid; FNDF = main effect of forage NDF level; and S × F = interaction between corn silage hybrid and FNDF level.

Table 6. Effects of corn silage hybrid and dietary level of forage NDF on *in situ* disappearance of NDF in silage.

	Treatment ¹					Probability ²		
	17BMRCS	21BMRCS	17CCS	21CCS	SE	Silage	FNDF	S × F
Potentially digestible NDF, %	51.1	57.8	54.0	51.8	3.1	0.63	0.49	0.20
Washout, %	15.6	10.6	7.5	5.6	1.6	0.01	0.08	0.37
Indigestible NDF, %	33.3	31.7	38.5	42.6	2.5	0.02	0.65	0.29
Disappearance rate of potentially digestible NDF, %/h	3.11	2.78	3.09	3.32	0.58	0.67	0.91	0.61

¹17BMRCS = 17% forage NDF (FNDF) with brown midrib corn silage (BMRCS); 21BMRCS = 21% FNDF with BMRCS; 17CCS = 17% FNDF with conventional corn silage (CCS); and 21CCS = 21% FNDF with CCS.

²Silage = main effect of corn silage hybrid; FNDF = main effect of forage NDF level; and S × F = interaction between corn silage hybrid and FNDF level.

when the diet consisted of 96% forage and 4% concentrate. Oba and Allen (2000c) observed that, although *in vitro* NDF digestibility of BMRCS was higher than

for CCS, enhanced *in vitro* NDF digestibility does not necessarily correlate with increased NDF digestibility either in the rumen or in the total tract. However, these

Table 7. Effects of corn silage hybrid and dietary level of forage NDF on nutrient digestibility by lactating cows.

	Treatment ¹					Probability ²		
	17BMRCS	21BMRCS	17CCS	21CCS	SE	Silage	FNDF	S × F
OM								
Intake, kg/d	17.1	15.7	16.0	14.1	0.6	0.06	0.03	0.70
Duodenal flow, kg/d	9.91	9.02	8.79	8.23	0.62	0.18	0.29	0.76
Fecal flow, kg/d	4.92	4.34	4.23	4.39	0.33	0.42	0.57	0.23
Apparent stomach digestibility, % of intake	42.2	43.0	44.1	41.6	2.4	0.93	0.77	0.55
True stomach digestibility, % of intake	60.2	63.8	65.8	63.1	2.3	0.36	0.87	0.25
Apparent intestinal digestibility, % of intake	29.5	29.4	29.0	26.8	3.8	0.72	0.80	0.81
Apparent total tract digestibility, % of intake	71.7	72.4	73.0	68.4	2.5	0.63	0.50	0.35
NDF								
Intake, kg/d	6.56	5.61	5.78	5.14	0.32	0.06	0.02	0.62
Stomach digestibility, % of intake	54.7	54.8	52.6	46.5	2.9	0.15	0.38	0.36
Intestinal digestibility, % of intake	13.3	8.5	12.4	9.8	2.8	0.94	0.26	0.73
Total tract digestibility, % of intake	68.0	63.3	65.0	56.3	3.2	0.21	0.11	0.58
Nitrogen								
Intake, kg/d	3.22	2.91	3.00	2.50	0.11	0.03	0.02	0.32
Duodenal flow, kg/d	2.58	2.42	2.51	2.21	0.09	0.23	0.10	0.73
Apparent stomach digestibility, % of intake	17.6	18.0	13.5	14.4	3.0	0.28	0.84	0.94
True stomach digestibility, % of intake	70.4	76.7	74.6	74.4	3.9	0.84	0.50	0.47
Efficiency of microbial protein synthesis, g of N/kg of OM truly digested	26.3	27.7	28.2	28.3	2.1	0.60	0.75	0.79
Apparent intestinal digestibility, % of intake	57.2	57.6	62.4	57.1	3.9	0.59	0.58	0.53
Apparent total tract digestibility, % of intake	74.8	75.6	75.9	71.5	2.0	0.53	0.45	0.29
Starch								
Intake, kg/d	4.30	3.91	4.01	3.33	0.23	0.02	0.01	0.32
Duodenal flow, kg/d	1.11	1.02	0.82	0.73	0.15	0.09	0.73	0.84
Apparent stomach digestibility, % of intake	75.7	74.7	80.2	78.7	3.4	0.30	0.75	0.95
Apparent intestinal digestibility, % of intake	20.3	20.9	16.4	13.4	3.9	0.23	0.79	0.68
Apparent total tract digestibility, % of intake	96.0	95.7	96.6	92.1	1.4	0.35	0.16	0.22
Fatty acids								
Intake, g/d	619	585	576	508	16	0.02	0.03	0.35
Duodenal flow, g/d	549	529	546	507	16	0.49	0.15	0.60
Apparent stomach digestibility, % of intake	11.1	8.6	2.6	0.8	3.6	0.09	0.60	0.94
True stomach digestibility, % of intake	41.1	40.0	35.2	39.1	0.3	0.34	0.68	0.47
Apparent intestinal digestibility, % of intake	66.7	67.0	78.8	76.6	3.1	0.02	0.78	0.71
Apparent total tract digestibility, % of intake	77.8	75.6	81.5	77.3	1.3	0.10	0.07	0.50

¹17BMRCS = 17% forage NDF (FNDF) with brown midrib corn silage (BMRCS); 21BMRCS = 21% FNDF with BMRCS; 17CCS = 17% FNDF with conventional corn silage (CCS); and 21CCS = 21% FNDF with CCS.

²Silage = main effect of corn silage hybrid; FNDF = main effect of forage NDF level; and S × F = interaction between corn silage hybrid and FNDF level.

authors concluded that NDF digestibility could possibly correlate with increased DMI and rate of passage and improved efficiency of microbial protein synthesis. When fed ad libitum, DMI was 2.4 kg/d higher for cows fed a BMRCs diet compared with cows fed an isogenic diet, and when DMI was kept similar by limit feeding cows on BMRCs, apparent digestibilities of OM, NDF, and ADF were greater for cows fed BMRCs than cows fed the isogenic diet (Tine et al., 2001). In the present study, digestibilities of OM and NDF were not higher for BMRCs than CCS, possibly because of an increased DMI with BMRCs. The BMRCs resulted in lower intestinal FA digestibility than CCS, and 17% FNDF tended to result in higher total tract digestibility of FA than 21% FNDF.

CONCLUSIONS

Compared to CCS, feeding BMRCs increased DMI and tended to increase milk protein yield. Responses on milk yield were more variable. The lower lignin concentration in BMRCs does not always result in a higher digestibility of dietary NDF either in rumen or total tract. Feeding BMRCs in low forage diets may not necessarily have adverse effects on ruminal fermentation and animal performance if dietary concentrations of total NDF, FNDF, and nonstructural carbohydrates are well balanced.

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