Brown midrib corn silage and Tifton 85 bermudagrass in rations for early-lactation cows

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ABSTRACT

Forty Holstein cows were used in an 8-wk randomized trial to evaluate the effects of feeding combinations of forages with improved fiber digestibility on performance during early lactation. Treatments were arranged as a 2×2 factorial to include silage from normal (NCS) or brown midrib (BMR) corn silage with or without 10% Tifton 85 bermudagrass hay (T85). In a simultaneous digestion trial, degradation and passage kinetics and ruminal fermentation parameters were evaluated in a 4×4 Latin square design trial using late-lactation Holstein cows fitted with ruminal cannulas. Dry matter intake (DMI) and neutral detergent fiber (NDF) intake were greater with BMR than with NCS; however, milk yield and composition were similar among corn silage types. Inclusion of T85 reduced milk yield but supported higher milk fat percentage, resulting in similar yields of energy-corrected milk. Blood glucose concentrations were higher for BMR compared with NCS, and inclusion of T85 increased blood urea N concentrations. Treatments did not alter liquid or solid phase passage rates or rumen turnover. Corn silage type did not affect ruminal pH or volatile fatty acid concentrations, but inclusion of T85 increased pH and molar proportion of acetate but decreased butyrate. Molar proportions of propionate were greater for NCS and T85 compared with BMR and T85, resulting in an interaction. Results of this trial indicate that combinations of forages with improved fiber digestibility can be used to support intake and performance of cows during early lactation.

Key words: Tifton 85 bermudagrass, fiber digestibility, brown midrib, forage quality

INTRODUCTION

Forage is typically the primary ingredient in rations fed to lactating dairy cows. Forage quality and intake

influence energy intake and availability in support of maintenance, milk yield, reproduction, and health. The cell wall component of forage has been identified as the best chemical predictor of DMI for dairy cows (Waldo, 1986), and the maximum NDF intake potential of lactating cows on a DM basis was reported to be between 1.1 and 1.2% of BW (Mertens, 1987). Although the cell wall is largely heterogeneous chemically, Jung and Vogel (1986) observed a strong curvilinear relationship between lignin concentrations and NDF digestibility based on the evaluation of different types of forages with varying lignin concentrations. This suggests that a single predictor based on NDF concentration may be insufficient to predict DMI. A meta-analysis of published data, including a wide variation in forage NDF degradability across and within forage families, indicated that for each unit increase in forage NDF digestibility, DMI increased 0.17 kg/d and milk yield increased 0.25 kg/d (Oba and Allen, 1999a).

Corn with the brown midrib mutation (**BMR**) has a lower concentration of lignin, which allows greater digestibility of NDF. Improved NDF digestibility has been suggested to reduce ruminal fill by increasing ruminal turnover so that cows can consume more DM. Oba and Allen (1999b) evaluated diets with similar NDF concentrations that differed only in NDF digestibility, using silage produced from either a BMR or an isogenic variety and observed 2.1 and 2.6 kg/d higher DMI and FCM, respectively, for cows fed the BMR.

Tifton 85 bermudagrass (*Cynodon* sp., **T85**) is an improved cultivar of bermudagrass that has a lower lignin concentration and greater NDF digestibility compared with other cultivars of bermudagrass (Mandebvu et al., 1999). These researchers reported that even though T85 had higher concentrations of NDF than Coastal bermudagrass, in vitro digestibility of DM and NDF were 48 and 55% higher, respectively, for T85 compared with Coastal bermudagrass. No differences were observed in DMI or milk yield when T85 was substituted for alfalfa hay in rations fed to high-producing dairy cows at 12 to 15% of the dietary DM (West et al., 1997; Bernard et al., 2007), but when T85 provided greater proportions of the total ration, DMI and milk yield were reduced (West et al., 1997).

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In addition to corn for silage and warm-season perennials such as bermudagrass, forage systems common to the southeastern United States typically include winter annual forages. Cool-season forages are typically more digestible than warm-season forages. Previous research in our laboratory has demonstrated that annual ryegrass silage is highly digestible and supports high levels of milk yield when fed with corn silage or as the sole forage source (Bernard et al., 2002). Feeding forages with higher than average digestibility provides an opportunity to formulate diets with greater amounts of forage while reducing the amount of supplemental energy required to support milk synthesis. Incorporating these types of forages into the forage production system would also provide more flexibility in meeting nutrient management and conservation program needs. Inclusion of more grass into diets could potentially improve cow health through improved ruminal pH and digestible fiber that should help reduce the incidence of displaced abomasum and other metabolic disorders (Shaver, 1997). Because more homegrown forage could be used in the diet, the feed cost would be lower, thus improving net returns.

Research data are limited on feeding multiple forages, especially those that have high NDF digestibility that could be fed during the fall to cows in early lactation that have experienced chronic heat stress. The objective of this research trial was to determine the potential of incorporating forages that have above-average NDF digestibility and are suitable for production in the semitropical areas in rations containing a fixed amount of annual ryegrass silage.

MATERIALS AND METHODS

Experimental Forages

Annual ryegrass (Big Daddy, Southern States Cooperative, Richmond, VA) was planted using a no-till drill at the rate of 50.4 kg/ha in a Tifton sandy loam soil in late October after the second corn crop was harvested for silage. Fertilizer was applied to provide 80 kg/ha of N, 20 kg/ha of P, and 40 kg/ha of K. In late March, the annual ryegrass was mown while in a vegetative stage of maturity, wilted to approximately 45% DM, chopped to a theoretical length of chop of 1.9 cm, inoculated (Biotal 40788, Lallemand Animal Nutrition, Milwaukee, WI) and ensiled in 2.4-m silage bags. Corn silage was produced from a normal (NCS, Mycogen TMR2Q728, Mycogen Seeds, Indianapolis, IN) or BMR (Mycogen F2F721) hybrid strip-till planted at a seeding rate of 69,135 plants/ha in early April in a Tifton sandy loam soil after harvest of annual ryegrass. Fertilizer was applied to provide 251 kg/ha of N, 49 kg/ha of P, and 104

kg/ha of K. Corn was harvested at 50% milk line, and each corn variety was chopped to a theoretical length of chop of 1.9 cm, inoculated (Biotal 40788), and stored in 2.4-M silage bags. The T85 was harvested from a previously established stand after 4 wk of regrowth. Fertilizer was applied to provide 67 kg/ha of N, 17 kg/ha of P, and 34 kg/ha of K. The forage was cut and allowed to wilt to approximately 88% DM before baling with a small rectangular baler and stored in a barn until the trial began. During the trial, the T85 hay was chopped using a silage chopper to a length of 1.3 to 7.6 cm.

Production Trial

Forty Holstein cows in early lactation (82 ± 19 DIM, 22.6 ± 3.7 kg/d of DMI, 41.7 ± 9.0 kg/d of milk yield, $3.2 \pm 0.7\%$ milk fat, $2.9 \pm 0.4\%$ milk protein, and 678.8 ± 97.2 kg of BW) were used in an 8-wk randomized design with a 2×2 factorial arrangement of treatments. Protocols for this trial were approved by the University of Georgia Institute of Animal Care and Use Committee. Experimental diets were formulated using NCS or BMR with or without T85 plus a fixed amount of annual ryegrass silage (Table 1). Before beginning the trial, cows were trained to eat behind Calan doors (American Calan, Northwood, CT). Experimental diets were fed once daily as a TMR. Treatments were 1) NCS; 2) BMR; 3) NCS plus T85 (NCS + T85); and 4) BMR plus T85 (BMR + T85). Experimental diets 1 and 2 contained 40% of NCS or BMR plus 10% annual ryegrass, whereas diets 3 and 4 contained 34% of NCS or BMR, 10% of Tifton 85 bermudagrass (T85), and 6% of annual ryegrass (Table 1). Diets were formulated to be isocaloric and isonitrogenous. During a 2-wk pre-trial period, the cows were fed a ration based on corn silage and alfalfa hay. At the end of the preliminary period, cows were blocked by lactation number, milk yield, and DIM and randomly assigned to treatments for the following 6 wk.

Throughout the pretrial and sampling periods, cows were fed once daily at 110% of previous day's intake. The amount of TMR offered and refused was recorded daily for each cow. Samples of the experimental diets,orts, and ingredients were collected 3 times each week and dried at 60°C for 72 h in a forced air oven to determine DM. Cows were milked twice each day at 0400 and 1600 h. Milk yield was electronically recorded at each milking and the total amount recorded by cow each day (Alfa Laval Agri Inc., Kansas City, MO). Milk samples were collected once each week from consecutive p.m. and a.m. milkings for analysis of milk fat and protein concentrations (Dairy One, Ithaca, NY). Body weights were recorded at the end of the preliminary period and the sampling period on 3 consecutive days

Table 1. Ingredient composition (% of DM) of experimental diets containing normal (NCS) or brown midrib (BMR) corn silage with or without Tifton 85 bermudagrass hay (T85)

Ingredient	NCS	BMR	NCS + T85	BMR + T85
NCS	40.0	—	34.0	—
BMR	—	40.0	—	34.0
T85	—	—	10.0	10.0
Ryegrass silage	10.0	10.0	6.0	6.0
Whole cottonseed	5.0	5.0	5.0	5.0
Brewers grains, wet	13.4	13.4	13.4	13.4
Ground corn	18.5	18.5	18.5	18.5
Soybean meal, 48%	7.0	7.0	7.0	7.0
Megalac ¹	1.0	1.0	1.0	1.0
Prolak ²	3.0	3.0	3.0	3.0
Limestone	0.4	0.4	0.4	0.4
Magnesium oxide	0.2	0.2	0.2	0.2
Salt	0.2	0.2	0.2	0.2
Sodium bicarbonate	0.8	0.8	0.8	0.8
Premix ³	0.5	0.5	0.5	0.5

¹Calcium salts of free fatty acids; Arm and Hammer Animal Nutrition (Princeton, NJ).

²Animal-marine protein supplement; H. J. Baker & Bro. Inc. (Westport, CT).

³The premix contained (DM basis): 26.1% of Ca; 0.38% of Mg; 1.76% of S; 144 mg/kg of Co; 9,523 mg/kg of Cu; 1,465 mg/kg of Fe; 842 mg/kg of I; 28,617 mg/kg of Mn; 220 mg/kg of Se; 25,343 mg/kg of Zn; 867,140 IU/kg of vitamin A; 346,856 IU/kg of vitamin D; and 4.334 IU/kg of vitamin E.

after the p.m. milking. During wk 6, 10 mL of whole blood was collected from each cow 3 h after feeding and immediately placed on ice and delivered to the University of Georgia diagnostic laboratory for analysis of glucose and urea using a Boehringer Mannheim/Hitachi 912 automated chemistry analyzer (Roche Laboratory Systems, Indianapolis, IN).

Samples of forage and other ingredients were collected 3 times per week and dried at 60°C for 72 h in a forced air oven to determine DM content. Individual samples were ground to pass through a 1-mm screen and equal amounts combined by week to form a 300-g composite sample. The composite sample was subsampled and analyzed for ash, nitrogen (AOAC, 1990), NDF, ADF, and acid detergent lignin (Van Soest et al., 1991).

Data were subjected to analysis of covariance using PROC MIXED procedures of SAS (SAS Institute, 1999). Data collected during the pretrial period were used as a covariate in the statistical analysis. Sum of squares were partitioned to covariate, block, corn silage effect, T85 effect, week, week $\times$ corn silage, week $\times$ T85, and week $\times$ corn silage $\times$ T85. Cow within treatment was included as a random variable and week as a repeated measure. Blood metabolites were analyzed as described without the effect of week and its interactions.

Ruminant Digestion and In Situ Kinetics Trial

Four ruminally cannulated cows were used in an incomplete 4 $\times$ 4 Latin square design trial with three 14-d periods. Each experimental period consisted of 10 d for ration adjustment followed by a 4-d sample collection

period. Treatments were the same as those outlined previously. At the beginning of the trial, cows averaged 342 ± 7 DIM, 25.3 ± 5.7 kg of milk/d, and 724 ± 171.6 kg of BW. The cows were housed with the cows used in the production trial and fed behind Calan gates. Individual BW was recorded at the beginning and the end of the trial as described previously. The amount of feed offered and refused was recorded daily. Cows were milked twice a day at 0400 and 1600 h. Milk yield was electronically recorded at each milking and the total amount was recorded by cow each day (Alfa Laval Agri Inc.). No additional feed samples were required beyond those outlined above. Performance data of this group of cows were not analyzed statistically because of the short duration of each period.

Dry matter degradation kinetics of NCS and BMR corn silages and experimental rations was determined using the in situ technique beginning on d 11 and finishing on d 14 of each experimental period. Corn silage and TMR samples were incubated in the rumen of cows fed diets containing the respective corn silage and the same TMR during each period. All samples for incubation were dried (60°C for 72 h in a forced air oven) and ground to pass through a 5-mm sieve. Approximately 25 g of each experimental corn silage and TMR was weighed into a 10 cm $\times$ 20 cm polyester bag (Ankom, Fairport, NY) with a mean pore size of 50 μ m. Bags were inserted into the ventral sac of the rumen at 72, 48, 24, 16, 8, 4, 2, and 0 h relative to the withdrawal time. Four empty bags were included for each cow as blanks. Bags were placed in a nylon mesh bag (approximately 30 $\times$ 45 cm) with zipped open-

Table 2. Chemical composition (% of DM unless otherwise noted) of experimental forages¹

Ingredient	NCS	BMR	RGS	T85
DM, %	32.9	34.9	45.7	90.2
CP	8.4	7.5	13.1	13.4
NDF	43.8	42.3	45.1	75.6
ADF	24.0	23.0	27.8	36.2
Lignin	1.6	0.9	2.8	3.3
In situ DM digestibility	71.0	77.6	NA ²	62.5
In situ NDF digestibility	51.3	60.3	NA	57.2

¹NCS = normal corn silage; BMR = brown midrib corn silage; T85 = Tifton 85 bermudagrass hay; RGS = annual ryegrass silage.

²NA = not analyzed.

ings to ensure similar locations within the rumen and to facilitate location and removal. Upon removal, bags were rinsed with cold tap water until the water was clear. Zero-hour bags were washed without incubation in the rumen. Bags were placed into a forced air oven at 55°C and dried to a constant weight. Dried samples were weighed and DM digestibility calculated. Residual DM at each time point was expressed as a proportion of the initial amount in the bag. Sample residues were analyzed for NDF concentration, and NDF digestibility after 48 h was determined (Table 3). Fractional degradation rates of both corn silages and experimental TMR in the rumen were calculated using the nonlinear model of Ørskov and McDonald (1979). The PROC NLIN procedure (SAS Institute, 1999) was used to fit the equation to each of the disappearance curves. Because a lag phase was not apparent from visual appraisal of these plots, this parameter was not included in the equation. The equation was as follows:

$$P = A + B(1 - e^{-ct}),$$

where P represents the fraction of DM that has disappeared (%) at time t, A represents the wash fraction that immediately disappears at time 0 h, B represents

the potentially degradable fraction (%), and c equals the fractional degradation rate (%/h). A restriction was set for $A + B \leq 100$. The Marquardt derivative method was used for the iterative process. Initial parameter estimates were determined by visual appraisal of each curve, and a grid search of 5 to 10 points around the initial estimates was set for each of the parameters to reduce the probability that the iteration process would run into a local minimum (Motulsky and Ransnas, 1987). Degradation rates were then statistically analyzed to evaluate for treatment effects.

Cows were dosed with chromium-mordanted fiber (75 g of Cr) and cobalt EDTA (50 g of Co) just before feeding on d 12 of the experimental period. The markers were introduced into the rumen and thoroughly mixed with rumen digesta. The Co-EDTA was mixed with water to facilitate mixing. Ruminal content samples were collected at 1, 6, 12, 24, 30, and 36 h after administration of Cr-mordanted fiber. Samples were dried at 55°C and ground through a 1-mm screen before analysis of Cr (AOAC, 1990). Approximately 100 mL of rumen fluid was collected at 0, 1, 2, 4, 6, 12, 24, 36, 48, 60, and 72 h after administration of Co-EDTA. Ruminal fluid samples were immediately frozen and stored for analysis of Co (AOAC, 1990).

Table 3. Chemical composition (% of DM unless otherwise noted) of experimental diets containing normal (NCS) or brown midrib (BMR) corn silage with or without Tifton 85 bermudagrass hay (T85)¹

Item	NCS	BMR	NCS + T85	BMR + T85
DM, %	42.9 ± 0.6	43.3 ± 0.5	47.0 ± 0.1	45.4 ± 0.9
CP	18.8 ± 0.7	18.7 ± 0.6	19.1 ± 0.9	18.8 ± 0.8
NDF	36.1 ± 2.2	35.2 ± 1.9	38.8 ± 2.3	39.5 ± 1.5
ADF	17.8 ± 1.3	17.3 ± 1.1	18.6 ± 1.4	19.0 ± 1.2
Lignin	2.1 ± 0.3	2.0 ± 0.5	2.2 ± 0.3	2.2 ± 0.4
NFC ²	34.5	34.5	31.3	31.0
Ether extract	4.9 ± 0.4	5.3 ± 0.4	4.8 ± 0.4	5.0 ± 0.5
Ash	6.9 ± 0.7	6.9 ± 0.9	6.6 ± 0.8	6.1 ± 0.9
48-h in situ DM digestibility	78.6 ± 0.4	77.2 ± 1.4	75.3 ± 0.9	78.5 ± 0.6
48-h in situ NDF digestibility	56.3 ± 1.2	60.2 ± 1.0	50.5 ± 1.8	56.3 ± 1.2
NE _L , ² Mcal/kg	1.63	1.63	1.64	1.65

¹Values represent means ± SD.

²Calculated using NRC (2001) model and chemical values reported in Table 2.

Because fluid and ruminal samples were taken from the same compartment (i.e., the rumen) where markers had been delivered, disappearance of the labeled solid and liquid particles was described by a one-compartment simple exponential model:

$$C_t = C_0 e^{-kt},$$

where C_t is the concentration of marker (mg/L) in the compartment at time t (h), C_0 is the initial concentration of marker (mg), and k is the fractional disappearance rate (h^{-1}), equivalent to the fractional outflow rate of the liquid or solid digesta (Ramanzin et al., 1991). For ruminal liquid data, 0-h samples were not considered as steady state conditions. Liquid and solid passage rates and ruminal retention times were determined using nonlinear procedures of SAS and analyzed to evaluate whether they differed among treatments.

A second sample of ruminal fluid (approximately 500 mL) was collected at 0, 2, 4, and 6 h after feeding. These ruminal fluid samples were filtered through cheesecloth and subsampled into a 20-mL aliquot acidified with 4 mL of 25% metaphosphoric acid and frozen for analysis of VFA (Erwin et al., 1961). A second 50-mL aliquot was immediately frozen for analysis of pH and ammonia concentrations.

Data from the digestion trial were analyzed as an incomplete 3×4 Latin square (3 periods, 4 cows, 4 treatments). Liquid and solid particle passage rates and rumen turnover times were analyzed using the GLM procedure of SAS. The model included effects of cow, period, corn silage type, inclusion of T85, and interaction of corn silage type and T85. Ruminal ammonia, VFA, and pH data were analyzed using the MIXED procedure of SAS. The model for VFA, pH, and ammonia also included effects of hour and the interactions with treatment. Hour was included as a repeated effect. Significance was declared when $P < 0.05$ and the PDIFF option used for mean separation.

RESULTS

The chemical composition of the forages used in the trial is outlined in Table 2. The CP concentration of NCS was slightly higher than that of the BMR. Concentrations of NDF and ADF were similar for both NCS and BMR, but the lignin concentration of NCS was 1.8 times higher than that measured for BMR. Concentrations of NFC were slightly lower for diets containing T85. Although both corn silages had similar fiber concentrations, 48-h in situ DM and NDF digestibility was 6 and 4 percentage units higher, respectively, for BMR compared with NCS. Concentrations of NDF and

ADF in T85 were higher than those of NCS, BMR, or ryegrass silage, but in situ NDF digestibility of T85 was intermediate to that of BMR and NCS. Because of the high NDF concentration (76% of DM) in T85, in situ DM digestibility was 10 to 15% lower than either NCS or BMR, respectively.

The chemical composition of the experimental diets is outlined in Table 3. Concentrations of CP were similar for all diets. As expected, concentrations of both NDF and ADF were slightly higher for diets containing T85, which resulted in slightly lower NFC for these diets compared with those without T85. The DM and NDF in the BMR diets were 4 and 7% more digestible, respectively, than that observed for the NCS diets. The 48-h in situ DM and NDF digestibility were 5 and 3 percentage units higher, respectively, for rations without T85 than for those containing T85. Dietary NE_L concentrations were calculated using the NRC (2001) model and were similar for all diets based on actual analysis of ingredients.

Performance Trial

Cows fed diets containing BMR consumed more DM ($P = 0.01$) and NDF ($P = 0.01$) than those fed diets containing NCS (Table 4). No differences in DMI were observed for inclusion of T85, but NDF intake ($P = 0.01$) and NDF intake as a percentage of BW ($P = 0.01$) were higher for cows fed diets containing T85 compared with those without T85. Milk yield and composition were similar for cows fed BMR and NCS; however, milk yield was lower ($P = 0.02$) and milk fat percentage was higher ($P = 0.04$) for cows fed diets containing T85 compared with those without T85. There was a trend for an interaction of corn silage type and inclusion of T85 ($P = 0.06$) for milk fat percentage because milk fat percentage was similar for diets containing BMR with or without T85 but was lower for the NCS without T85 compared with the NCS with T85. Yield of ECM was the similar for all treatments. There was a tendency ($P = 0.10$) for dairy efficiency (kg of milk/kg of DMI) to be numerically lower for diets containing BMR because of higher DMI and similar milk yield. No differences were observed in BW or BW change during the trial.

Blood glucose concentrations were higher ($P = 0.03$) for cows consuming diets containing BMR compared with NCS (Table 4). An interaction ($P = 0.05$) of corn silage type and inclusion of T85 was observed for BUN concentrations as cows fed BMR had lower BUN concentrations without T85 compared with that observed for the BMR plus T85, whereas BUN concentrations were similar for diets containing NCS with or without T85.

Table 4. Effect of diets containing normal (NCS) or brown midrib (BMR) corn silage with or without Tifton 85 bermudagrass hay (T85) on intake, milk yield, milk composition, and select blood metabolites of lactating cows

Item	NCS		BMR		SE	Contrast, ¹ <i>P</i> =		
	0% T85	10% T85	0% T85	10% T85		CS	T85	INT
DMI, kg/d	24.7	24.7	26.4	25.6	0.5	0.01	0.34	0.35
NDF intake, kg/d	8.9	9.6	9.3	10.1	0.2	0.01	0.01	0.71
NDF, % of BW	1.34	1.44	1.37	1.47	0.03	0.46	0.01	0.98
Milk, kg/d	40.6	38.1	41.0	39.8	0.7	0.14	0.02	0.36
Fat, %	3.12 ^b	3.65 ^a	3.31 ^{ab}	3.35 ^{ab}	0.13	0.68	0.04	0.06
Fat, kg/d	1.27	1.39	1.36	1.33	0.15	0.86	0.77	0.71
Protein, %	2.94	2.87	2.86	2.85	0.08	0.49	0.63	0.68
Protein, kg/d	1.19	1.09	1.17	1.13	0.15	0.70	0.45	0.90
ECM, kg/d	38.3	38.4	39.5	38.5	1.0	0.62	0.45	0.65
Dairy efficiency ²	1.55	1.55	1.50	1.50	0.06	0.10	0.18	0.91
BW, kg	660	651	694	697	34	0.24	0.92	0.87
BW change, kg	28.5	30.3	38.2	39.0	6.4	0.17	0.84	0.93
Blood metabolites								
Glucose, mg/dL	64.2	67.2	69.7	68.7	1.5	0.03	0.53	0.19
Urea, mg/dL	15.7 ^{ab}	16.3 ^a	13.7 ^b	18.0 ^a	0.9	0.86	0.01	0.05

^{a,b}Means in the same row with unlike superscripts differ ($P < 0.05$).

¹CS = effect of corn silage type; T85 = effect of inclusion of T85; and INT = interaction of CS and T85.

²ECM/DMI.

Ruminant Digestion Trial

There were no differences in particle or liquid fractional passage rates and rumen retention times between treatments (Table 5). Dry matter degradation rates of corn silages and TMRs were similar for both silages and all experimental diets (Table 4). Ruminal pH was higher ($P = 0.01$) for diets with T85 compared with those without T85. Ruminal ammonia concentrations were similar for all treatments. Total VFA concentrations were similar among treatments. Corn silage type did not affect molar proportions of individual VFA. Molar proportions of acetate increased ($P = 0.03$) and butyrate decreased ($P = 0.001$) when T85 was included in the diet. There was an interaction of corn silage type and inclusion of T85 ($P = 0.04$) because of lower molar proportions of propionate for BMR plus T85 compared with BMR without T85, whereas NCS and NSC plus T85 had similar concentrations.

DISCUSSION

The higher feed intake observed for cows fed BMR corn silage compared with NCS is consistent with previous research (Rook et al., 1977; Oba and Allen, 1999a; Barrière et al., 2004). The suggested mechanism of action is enhanced fiber degradation and increased particle passage rates because of the lower lignin concentrations in BMR (Oba and Allen, 1999a; Tine et al., 2001). Although degradation rates, solid and liquid passage rates, and rumen retention time were similar for both NCS and BMR treatments in our trial, cows fed BMR had greater DMI and NDF intake.

Inclusion of T85 has been observed to maintain similar feed intake levels when fed at rates up to 15% of the DM in rations fed to Holstein cows in early lactation (West et al., 1997; Bernard et al., 2007). Because of lower lignin concentrations, the NDF fraction from T85 has higher rates of fiber degradation and passage kinetics compared with other cultivars of bermudagrass. In the current trial, inclusion of T85 at 10% of DM increased NDF intake without affecting DMI, which indicates that the potentially degradable NDF pool turned over from the rumen at a nonlimiting rate compared with rations without T85.

The milk yield response to BMR has not been consistent among trials. Increased milk yield with BMR was reported by Ballard et al. (2001), Ebling and Kung (2004), and Kung et al. (2008). However, in other experiments, milk yield was not different although energy intake improved. Other factors may prevent a positive milk yield response when energy intake increases. Dietary protein was approximately 2.5 percentage units less than that recommended by NRC (2001) in some studies (Frenchick et al., 1976; Block et al., 1981; Gehman et al., 2008), which may have limited the use of the additional energy intake for milk synthesis. Weiss and Wyatt (2006) reported increased milk yield when cows were fed BMR even though energy intake did not increase, suggesting utilization of body reserves, but the cows were in mid to late lactation. Kung et al. (2008) observed an increase in milk yield without an increase in energy intake, but energy mobilization from tissue may have occurred because the cows were in early lactation. Although no differences in BW change were

Table 5. Effect of normal (NCS) or brown midrib (BMR) corn silage type with or without Tifton 85 bermudagrass (T85) on degradation rates, passage rates, and fermentation parameters

Item	NCS		BMR		SE	Contrast, ¹ <i>P</i> =		
	0% T85	10% T85	0% T85	10% T85		CS	T85	INT
Ruminal passage rate, %/h								
Particulate phase	2.84	3.25	3.68	4.30	0.70	0.23	0.50	0.89
Liquid phase	12.89	20.57	12.86	13.42	3.10	0.29	0.23	0.30
Ruminal turnover time, h	36.08	30.88	29.02	27.09	4.81	0.30	0.49	0.74
DM degradation rate, %/h								
Corn silage								
A, % of DM	40.0	38.0	42.4	40.3	1.9	0.27	0.31	0.99
B, % of DM	38.3	38.6	38.4	44.7	3.3	0.39	0.35	0.40
c, %/h	3.87	4.90	4.64	4.37	1.05	0.90	0.73	0.56
TMR								
A, % of DM	36.9	32.6	34.1	35.5	2.2	0.98	0.52	0.24
B, % of DM	47.2	51.8	50.1	52.4	2.4	0.49	0.20	0.65
c, %/h	5.00	3.90	5.00	3.37	0.77	0.74	0.13	0.75
pH	6.61	6.97	6.69	6.97	0.07	0.72	0.01	0.74
Ammonia, mg/dL	7.20	7.67	6.25	8.87	0.99	0.90	0.18	0.32
Total VFA, mM	102.72	99.33	101.50	92.89	4.22	0.37	0.17	0.54
Acetate, % of total	59.44	60.58	59.14	61.70	0.78	0.61	0.03	0.38
Propionate, % of total	23.11 ^{ab}	23.92 ^a	23.31 ^a	22.18 ^b	0.30	0.09	0.72	0.04
Butyrate, % of total	12.37	10.62	12.58	10.64	0.50	0.82	0.001	0.85
Valerate, % of total	1.94	1.84	1.87	1.87	0.07	0.73	0.51	0.50
Isovalerate, % of total	1.83	1.89	1.90	2.13	0.16	0.37	0.37	0.59
Isobutyrate, % of total	1.31	1.14	1.20	1.48	0.13	0.36	0.68	0.09
Acetate:propionate	2.59 ^b	2.56 ^b	2.56 ^b	2.81 ^a	0.07	0.13	0.14	0.06

^{a,b}Means in the same row with unlike superscripts differ ($P < 0.05$).

¹CS = effect of corn silage type; T85 = effect of inclusion of T85; and INT = interaction of CS and T85.

detected during the trial, the authors suggested that a 3-wk trial period was probably too short to detect differences in energy intake or BW change. Although our trial lasted 6 wk, milk yield did not increase nor was there a significant change in BW although energy intake increased when BMR was fed. The NRC (2001) predicted BW gains of 0.7 and 0.9 kg/d for NCS and BMR, respectively, which is consistent with actual BW gains measured in our current trial.

Two mechanisms that could help explain the inconsistency of the effect of feeding BMR on increased DMI without a corresponding increase in milk yield are 1) the decreasing nature of ME partitioning toward milk synthesis as lactation progresses to replenish the body energy pool; and 2) the decreased energy demand and marginal milk response to increased energy intake in cows with lower productive potential (Agnew et al., 1999). Tine et al. (2001) observed that cows did not increase their production levels accordingly to the greater energy intake exhibited when cows received BMR diets. Those researchers determined calorimetrically that 45% of the extra ME intake was directed toward body tissues, 36% was lost as heat, and only 18% was used for milk synthesis. It is interesting to note that most of the trials (Block et al., 1981; Stallings et al., 1982; Tine et al., 2001) in which no increase in energy intake

or milk yield was observed in response to BMR were conducted with cows performing at a lower level than current high-genetic-merit fresh cows (21 to 34 kg/d of milk). Oba and Allen (1999a) suggested that high-yielding cows benefitted more from the enhanced NDF digestibility of corn silage because it allowed them to consume more DMI that supported higher milk yield. Cows fed BMR in the current trial used the additional energy consumed in support of numerical increases in ECM (38.3 vs. 39.0 kg/d, respectively) and BW gain (0.7 and 0.9 kg/d, respectively) compared with those fed NCS.

Cows fed T85 had lower milk yield but higher milk fat percentage, resulting in an equal ECM yield compared with those not fed T85. No differences were observed in milk yield or milk fat percentage when T85 was fed at 12.5% of dietary DM (Bernard et al., 2007) or until the feeding rate was greater than 15% of ration DM (West et al., 1997). Although DMI and milk yield were lower when T85 was fed at rates greater than 15% of dietary DM, yield of ECM was equal because of increased milk fat synthesis.

The absence of an effect of corn silage type on milk fat percentage in our trial is in agreement with previous reports (Keith et al., 1979; Sommerfeldt et al., 1979; Oba and Allen, 1999a, 2000a). Other researchers have

reported increased (Rook et al., 1977) or decreased (Frenchick et al., 1976; Block et al., 1981) milk fat percentage in response to BMR. The experimental diets fed in the current trial had higher NDF concentrations (35.7% for rations without T85 and 39.7% for rations with T85) than normally recommended (22–33% NDF and 19% forage NDF) by NRC (2001) for high-producing cows. The higher NDF content of the diets supplemented with T85 supported increased milk fat percentage, which is in agreement with previous research (West et al., 1997, 1998).

Most reports have not observed an effect of BMR on milk protein percentage or yield (Ballard et al., 2001; Ebling and Kung, 2004; Gehman et al., 2008) but others have observed increased milk protein percentage (Oba and Allen, 1999a; Qiu et al., 2003; Kung et al., 2008). Oba and Allen (1999b) suggested that increased DMI and diet fermentability of BMR should enhance microbial protein yield and flow to the small intestine, hence supplying more MP. We observed increased DMI when cows were fed diets containing BMR, which had higher *in situ* NDF digestibility, but the increased DMI did not affect milk protein percentage or yield.

Because glucose concentrations are typically low at the beginning of lactation and increase as DMI increases throughout early lactation, glucose can be an indicator of energy status in lactating cows (Dhiman et al., 1991). We observed higher blood glucose levels in cows fed BMR compared with NCS diets. Presumably, this would be because of the larger pool of fermentable NDF in BMR, which in turn would lead to increased absorption of VFA into the blood, and ultimately be reflected as elevated glucose concentrations (Sommerfeldt et al., 1979). However, VFA concentrations were similar for all treatments in our trial. Research has shown that increased glucose may be used for tissue retention (Reynolds et al., 2001) or may be oxidized to CO₂ (Knowlton et al., 1998) rather than directed toward milk synthesis. Most trials have not evaluated the effect of BMR on blood glucose.

Milk urea nitrogen has been proposed as an indicator of protein nutrition status and efficiency of N utilization for dairy cows and is directly affected by BUN concentrations because urea freely diffuses from blood to milk (Kauffman and St-Pierre, 2001). When carbohydrates with greater degradation rates were fed to lactating cows, BUN concentrations decreased (Lykos et al., 1997). In the current trial, inclusion of T85 increased BUN levels, probably because of a potentially slower degradation rate. This effect was differential between NCS and BMR because the magnitude of the increment was larger for BMR (13.7 to 18 mg/100 mL) than for NCS (15.7 to 16.3 mg/100 mL), suggesting that N ruminal utilization was more efficient with NCS.

Increased DMI encouraged by forages with higher NDF digestibility may occur because of faster degradation rates or faster passage rates. It is well established that BMR corn contains less lignin than its isotypes; as a result, it has a larger fraction of digestible DM and NDF than its isotypes (Oba and Allen, 2000b; Taylor and Allen, 2005b; Weiss and Wyatt, 2006). However, whether greater digestibility of BMR corn leads to increased DMI through faster particle degradation or faster transit through the rumen remains debatable because very few reports on rumen digestion kinetics are available in the literature and their results are inconsistent. Gehman et al. (2008) observed lower DM degradation rates, whereas Keith et al. (1979) observed higher NDF degradation rates in BMR corn silage compared with the isogenic variety, yet these differences were only numerical and not statistically evaluated in either trial. Oba and Allen (2000b) reported greater DM, NDF, and indigestible NDF passage rates for diets containing BMR. The same group (Taylor and Allen, 2005b) evaluated the degradation rate, passage rate, and turnover time of the NDF digestible pool and the passage rate and turnover time of the indigestible NDF pool in rations containing BMR or control corn silages and observed no differences related to corn variety. In our experiment, DM degradation rates, solid and liquid passage rates, and rumen retention times were not different between corn silage treatments. Moreover, even though addition of T85 was expected to increase retention times by slowing passage rates, that was not the case in our study, which is surprising for such high levels of NDF in the rations. Taylor and Allen (2005b) suggested that differences among experiments are probably because of treatment effects on DMI and are probably related to the extent that ruminal distension limits intake of cows at different physiological stages among research trials.

Feeding BMR silage has frequently lowered pH. Ruminal pH decreases when hydrogen ion production exceeds removal from the rumen and ruminal buffering capacity (Taylor and Allen, 2005a). In some studies, the pH decrease was seemingly related to a greater intake of fermentable OM with BMR diets (Rook et al., 1977; Oba and Allen, 2000a; Gehman et al., 2008), whereas in others enhanced fermentability of BMR and consequently higher VFA production may have led to the lower pH despite no increase in DMI. Taylor and Allen (2005b) observed that cows receiving BMR had reduced mean and minimum ruminal pH (5.96 and 5.42 respectively) compared with the isogenic control, and BMR tended to increase the fraction of time spent below pH 6.0. Zebeli et al. (2008) suggested that the following events should be avoided to minimize the risk of SARA: 1) a daily mean ruminal pH <6.16 and 2)

a period in which ruminal pH is <5.8 for >5.24 h/d. Ruminal pH measurements reported by Taylor and Allen (2005b) fall within these parameters, indicating that BMR may increase the risk of SARA. In our trial, pH was well above 6.16 for BMR despite the increased DMI. The higher pH was likely related to the higher NDF content in the rations. Inclusion of T85 seems to have provided further buffering capacity supporting pH values close to 7.0.

The effect of corn silage type on total VFA concentrations and molar proportions of individual VFA has not been consistent in the literature. Those trials in which an increase in total VFA was observed also reported increased molar proportions of propionate and decreased molar proportions of acetate (Taylor and Allen, 2005a) or no change in acetate (Rook et al., 1977). In contrast, those trials in which total VFA concentrations were not altered (Weiss and Wyatt, 2006) or decreased with BMR (Sommerfeldt et al., 1979; Greenfield et al., 2001) did not show any change in molar proportions of acetate or propionate or a decrease in molar proportions of acetate and increased butyrate (Gehman et al., 2008).

CONCLUSIONS

The results of this trial indicate that BMR supports greater DMI in early to mid lactation cows but this does not necessarily result in higher milk yield. The NRC (2001) model suggests that the improved energy intake is used to support small, numerical increases in milk yield and BW gain. Our results also indicate that inclusion of T85 at 10% of DM can maintain DMI and ECM yield and increase ruminal pH and molar proportions of acetate, which are used for improved milk fat percentage.

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