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FORAGES AND FEEDS: *Original Research*

Lactating dairy cows fed diets based on corn silage plus either brown midrib forage sorghum or brown midrib pearl millet silage have similar performance

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ABSTRACT

Objective: Our objective was to evaluate the feeding value of brown midrib (BMR) pearl millet (PMS) with that of BMR forage sorghum (FSS) in diets fed to lactating dairy cows on intake, milk yield, and milk composition.

Materials and Methods: Thirty-two mid-lactation Holstein cows (139 ± 21 DIM) were used in an 8-wk randomized complete design trial. Cows were fed individually a common diet based on 37.2% corn silage and 18.3% ryegrass silage for the first 2 wk, and data collected were used as a covariate in the statistical analysis. At the end of the preliminary period, cows were abruptly switched to diets containing 32.6% corn silage and 20.6% of the total DM from either PMS or FSS for the following 6 wk. Data were subjected to repeated measures analysis.

Results and Discussion: No differences were observed in DMI among treatments, but there was a treatment × week interaction because cows fed PMS consumed slightly less DM during wk 5 compared with those fed FSS. Yield of milk and components and component concentrations were not different among treatments. However, cows fed diets supplemented with FSS had greater MUN concentrations compared with those fed PMS, and the differences were greater for FSS during wk 4 and 6 compared with PMS, resulting in a treatment × week interaction. No differences were observed in BW and BCS among treatments.

Implications and Applications: Results of the current trial indicate that either BMR pearl millet or BMR forage sorghum will support similar performance of mid-lactation dairy cows when fed along with corn silage. These results provides additional options for planning forage production for producers.

Key words: pearl millet silage, forage sorghum silage, milk yield, milk components

INTRODUCTION

Corn silage is the primary forage used for feeding dairy cattle in the United States, with over 2.4 million ha harvested annually (USDA National Agricultural Statistics Service, 2019). Many produces also grow other alternative forages as part of their complete forage program to best use land, minimize drought risk, minimize harvest risk, improve efficiency, and meet total forage needs for their herds. Forage sorghum is a summer annual grown on more than 105 million ha each year. The nutritive value of traditional forage sorghum silage is comparable to tropical corn silage (Nichols et al., 1998) and is lower than corn silage (Contreras-Govea et al., 2010), resulting in lower milk yield when fed to lactating dairy cows (Grant et al., 1995; Aydin et al., 1999). Newer brown midrib (**BMR**) varieties of forage sorghum have greater fiber digestibility and support milk yield similar to that of corn silage (Grant et al., 1995; Aydin et al., 1999; Bernard and Tao, 2015). However, sugar cane aphids were identified as a new pest in forage sorghum in 2013 and have caused crop losses, reduced forage quality, and increased harvest difficulties due to the honeydew produced by the aphid (Knutson et al., 2015). Although control measures are available, some producers have sought alternative summer annual forages that are not susceptible to sugar cane aphids.

One potential option is pearl millet. Pearl millet is drought tolerant, tolerates poorer soil fertility, has good insect and disease resistance, and is not subject to prussic acid toxicity after a frost. The potential DM forage yield from pearl millet is greater than that of forage sorghum (Anonymous, 2019), but it requires multiple harvests compared with one harvest for forage sorghum. Previous research indicated that the digestibility of pearl millet silage is lower than that of forage sorghum (Ward et al., 2001). Improved pearl millet varieties with the BMR trait have improved fiber digestibility (Hassanat et al., 2006). However, limited data are available on the response of lactating cows to BMR pearl millet silage. Harper et al. (2018) reported no differences in performance of lactating cows when BMR pearl millet silage replaced 10% of the DM provided by corn silage. Brunette et al. (2014) reported

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that cows fed diets based on sweet millet had similar milk yield as those fed corn silage–based diets, suggesting that improved varieties may support more desirable production compared with older varieties. The objective of this trial was to compare diets based on corn silage and either BMR pearl millet silage or BMR forage sorghum silage to determine the DMI and production response of mid-lactation Holstein cows. Our hypothesis was that forage sorghum or pearl millet silage would support similar DMI and production when fed along with corn silage.

MATERIALS AND METHODS

The University of Georgia Institutional Animal Care and Use Committee approved all protocols before beginning the trial. Forage for the trial was produced at the Coastal Plain Experiment Station during the summer of 2016 on Tifton sandy loam soils. Brown midrib varieties of forage sorghum (Alta 7401, Alta Seeds, Irving, TX) and pearl millet (Exceed, Coffey Forage Seeds, Plainview, TX) were planted at recommended seeding rates of 17 and 42 kg/ha, respectively. Both varieties have BMR-6 and dwarf genes. The forage sorghum was direct chopped at soft dough stage of maturity at a theoretical chop length of 1.9 cm and ensiled in a 2.4-m plastic bag. The pearl millet was cut at heading using a disc mower fitted with flails, wilted to approximately 35% DM, chopped at a theoretical chop length of 1.9 cm, and ensiled in a 2.4-m plastic bag. A commercial inoculant (Biotal Buchneri 40788, Lallemand Animal Nutrition, Milwaukee, WI) was applied during bagging at the manufacturer's recommended rate to each forage. Both forages were allowed to ferment for a minimum of 5 mo before initiating the trial in the spring of 2017. Corn (AgraTech 1777VIP, AgriTech Seeds Inc., Atlanta, GA) was planted in Tifton sandy loam soil at a seeding rate of 70,000 plants/ha using strip-tillage methods and was irrigated using dairy waste effluent. Additional fertilizer was applied based on soil tests and recommendations of the University of Georgia. Corn was harvested at approximately three-fourths milk line and chopped to a theoretical chop length of 1.9 cm with a kernel processed roller setting of 2 mm. The forages were inoculated (Biotal 40788, Lallemand Animal Nutrition) and ensiled in a bunker for approximately 6 mo before the beginning of the trial.

Thirty-two mid-lactation Holstein cows (139 ± 21 DIM, 37.6 ± 4.7 kg/d milk, and 671 ± 62.8 kg of BW) were used in a randomized complete design trial. Cows were trained to eat behind Calan gates (American Calan, Northwood, NH) before beginning the trial. Cows were fed a common diet based on corn silage and ryegrass silage (Table 1) for 2 wk, and data collected from the preliminary period were used as a covariate. At the end of the preliminary period, cows were assigned to 1 of 2 treatments balanced for lactation number, DIM, and milk yield for the following 6 wk. Treatments consisted of diets based on a combination of 32.6% corn silage plus 20.6% of either BMR forage sorghum silage (**FSS**) or BMR pearl millet silage (**PMS**). Experimental diets were formulated to meet requirements for a cows at 100 DIM producing 45 kg/d milk with 3.5% fat and 3.0% protein. The ingredient composition of the experimental diets is presented in Table 1. Diets were formulated to contain 53% forage with 20.59% of the dietary DM provided by either PMS or FSS.

Cows were fed once daily beginning at 1300 h, and the amount of feed was adjusted as needed to maintain a 5% refusal. The amounts of feed offered and refused were recorded daily. Cows were milked 3 times daily at 0800, 1600, and 2400 h. Milk weights were electronically recorded at each milking (DelPro, DeLeval, Kansas City, MO) and summed daily. Milk samples were collected each week from 3 consecutive milkings during the preliminary period and during wk 4 to 6 of the trial. Samples were refrigerated and shipped next day air to Dairy One Cooperative (Ithaca, NY) for analysis of fat, protein, lactose, solids-not-fat, MUN, and SCC via mid-infrared spectroscopy (Foss 400, Foss North America, Eden Prairie, MN) as described by AOAC International (2000).

Samples of forages and experimental diets were collected 3 times each week. Dry matter was determined by drying for 48 h in a forced-air drying oven set at 55°C. Experimental diet mixes were adjusted as necessary for any changes in the DM content of forages. Samples were first ground to pass through a 6-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ) and then composited by week. The composite sample was ground to pass through a 2-mm screen using a Wiley mill. Experimental diets were analyzed for concentrations of DM (AOAC International, 2000, method 930.15), ash (AOAC International, 2000, method 942.05), ether extract (AOAC International, 2000, method 954.02), ADF (AOAC International, 2000, method 973.18), NDF using amylase and sodium sulfite and corrected for ash (Van Soest et al., 1991), and N (CN628 Carbon/Nitrogen Determinator; AOAC International 2000; method 990.03; LECO FP-5258 Nitrogen Analyzer, St. Joseph, MO). Samples of experimental silages were collected 3 times each week, frozen, composited by week, and shipped to Cumberland Valley Analytical Services (Waynesboro, PA) for analysis of DM, N, NDF, ADF, ether extract, and ash as described previously. Forage samples were also analyzed for 30-h NDF digestibility (Goering and Van Soest, 1970) and fermentation end-product concentrations using the filtrate of a 25-g wet sample blended with 200 mL of distilled water. Sample pH and concentrations of ammonia-N and lactic, acetic, propionic, butyric, and iso-butyric acids were determined as described by Barlow et al. (2012).

Initial BW was measured on 3 consecutive days at the end of the preliminary period after the 1600-h milking. Water was withheld after milking until weighing was complete. Initial BCS was assigned by a single observer according to Wildman et al. (1982). Final BW and BCS were measured at the end of the trial on 3 consecutive days as described for initial measurements.

Table 1. Ingredient and chemical composition (mean ± SD) of preliminary and experimental diets containing either brown midrib pearl millet silage (PMS) or forage sorghum silage (FSS)

Item, % of DM	Preliminary[1]	PMS	FSS
Ingredient			
Corn silage	37.22	32.60	32.60
Ryegrass silage	18.25		
PMS		20.59	
FSS			20.59
Brewers grains	8.74	9.87	8.58
Whole cottonseed	3.80		
Molasses[2]	4.18	3.86	3.43
Ground corn	12.17	13.73	19.56
Citrus pulp	2.66		
Soybean hulls		2.57	
Urea	0.23	0.17	
Concentrate[3,4]	29.75	16.61	16.61
Composition			
DM, %	44.5	47.3 ± 6.6	43.5 ± 7.6
CP	16.2	16.9 ± 1.1	17.8 ± 0.9
NDF	34.5	35.3 ± 2.2	36.7 ± 3.9
ADF	21.1	16.9 ± 1.1	16.5 ± 3.8
Starch[5]	22.7	26.3	25.8
Ether extract	4.5	3.4 ± 0.3	3.6 ± 0.7
Ash	7.6	11.8 ± 0.8	10.2 ± 0.5

[1]Chemical composition of the preliminary diet was calculated using forage analysis and reference values for all other ingredients (Nutritional Dynamics System, RUM&N SAS, Reggio Emilia, Italy).

[2]Molasses contained 68.1% DM and (% of DM) 24.0% CP, 14% soluble protein, 48.5% sugar, 0.2% ether extract, and 9.9% ash (Quality Liquid Feed Inc., Dodgeville, WI).

[3]Preliminary concentrate contained (% of DM) 44.73% soybean meal; 11.93% Amino Plus (AgProcessing Inc., Omaha, NE); 17.89% Prolak (H. J. Baker & Bros. LLC, Shelton, CT); 0.24% Smartamine M (Adisseo, Alpharetta, GA); 1.19% salt; 7.16% calcium carbonate; 5.96% sodium sesquinate; 2.85% magnesium oxide; 2.39% potassium carbonate; 1.42% OmniGen-AF (Phibro Animal Health, Teaneck, NJ); 1.79% Rumensin 3% (Elanco, Greenfield, IN); 0.48% vitamin E 24,409 IU/kg; 0.08% Procreatin7 (Phibro Animal Health); and 1.90% trace mineral and vitamin premix.

[4]Experimental concentrate contained (% of DM) 10.33% corn gluten feed; 25.82% soybean meal; 20.66% Amino Plus (AgProcessing Inc.); 20.66% Prolak (H. J. Baker & Bros. LLC); 0.03% Smartamine M (Adisseo); 0.52% salt; 6.20% calcium carbonate; 5.16% sodium sesquinate; 2.58% magnesium oxide; 3.10% potassium carbonate; 1.23% OmniGen-AF (Phibro Animal Health); 1.50% Rumensin 3% (Elanco); 0.41% vitamin E 24,409 IU/kg; 0.01% Procreatin7 (Phibro Animal Health); and 1.55% trace mineral and vitamin premix.

[5]Starch concentrations were calculated based on forage analysis and reference values for all other ingredients (Nutritional Dynamics System, RUM&N SAS).

Data were subjected to repeated analysis of co-variance using the PROC MIXED procedures of SAS (SAS Institute Inc., Cary, NC). The model included covariate, treatment, week, and the interactions of week and treatment. Data from the preliminary period were included as a covariate in the analysis of intake and production data. Cow within treatment was included as a random variable, and week was included as a repeated variable. The first-order autoregressive covariance structure was used according to Littell et al. (1998). Final BW and BCS and change in BW and BCS data were subjected to analysis of covariance. The model included the effect of treatment with cow within treatment as a random effect. Initial BW and BCS were included as a covariate in analysis for final BW and BCS. Significance was declared at $P \leq 0.05$ and a trend when $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

The chemical composition of the experimental diets is presented in Table 1. The DM content of the diet containing FSS was lower compared with PMS, reflecting the lower DM content of the FSS (Table 2). Concentrations of CP and ash were slightly greater for FSS compared with PMS, which may have been due to sampling errors as the SD for both variables was slightly more for PMS compared with FSS. No differences were observed in the concentrations of NDF, ADF, and ether extract among diets.

The chemical composition of forages fed in the trial is presented in Table 2. The FSS had lower DM content, consistent with direct harvest at soft dough stage of maturity. Concentrations of CP and fiber were within the expected range of these forages grown in a semi-tropical environment. Ash concentrations were greater for PMS and reflect contamination resulting from mowing with a disc mower and wilting before chopping. The 30-h NDF digestibility was lower than expected for PMS. The reason for the lower digestibility compared with that observed for FSS in part may be due to the greater ash content of the PMS. Greater ash content in the PMS resulted from a combination of sandy soils and use of a disc mower–conditioner. Crocker et al. (1998) reported lower ruminal NDF digestibility when samples were not corrected for ash. Both PMS and FSS had higher pH than corn silage, which was expected given the greater concentrations of fiber and ash, which would provide natural buffering. Total and individual VFA concentrations suggest that the silage was well fermented. Concentrations of 1,2 propanediol were greatest for FSS and least for PMS.

No differences ($P = 0.92$, SE = 0.6) in DMI were observed among treatments during the 6-wk trial, which averaged 28.6 and 28.7 kg/d for PMS and FSS, respectively. However, an interaction of treatment and week ($P < 0.0001$) was observed due to lower DMI during wk 1 for FSS compared with PMS (Figure 1), but no differences were observed during the remainder of the trial. This most likely reflects differences in palatability compared

Table 2. Chemical composition (mean ± SD) of corn, pearl millet, and forage sorghum silages

Item, % of DM unless noted otherwise	Corn	Pearl millet	Forage sorghum
DM, %	34.4 ± 3.9	37.2 ± 5.9	29.0 ± 7.1
CP	8.4 ± 0.3	14.2 ± 1.4	11.7 ± 0.4
Ammonia	1.1 ± 0.1	3.1 ± 0.8	1.4 ± 0.3
ADF	24.1 ± 1.0	35.4 ± 1.3	38.3 ± 2.7
NDF	39.3 ± 1.1	64.6 ± 1.9	60.5 ± 2.1
30-h NDFD,[1] % of NDF	60.5 ± 1.1	44.0 ± 5.7	63.6 ± 1.8
Ash	3.36 ± 0.60	15.93 ± 1.90	8.26 ± 0.81
Ca	0.25 ± 0.04	0.75 ± 0.09	0.59 ± 0.05
P	0.28 ± 0.02	0.41 ± 0.04	0.34 ± 0.03
Mg	0.17 ± 0.02	1.06 ± 0.04	0.51 ± 0.02
K	1.29 ± 0.06	3.06 ± 0.33	1.94 ± 0.14
Na	0.01 ± 0.00	0.03 ± 0.03	0.05 ± 0.02
pH	3.75 ± 0.06	4.88 ± 0.18	4.37 ± 0.15
Total VFA	8.34 ± 0.86	7.10 ± 0.69	8.39 ± 1.46
Lactic acid	4.93 ± 0.66	3.08 ± 0.98	2.60 ± 1.02
Acetic acid	3.41 ± 0.71	4.01 ± 1.55	5.79 ± 0.92
1,2-Propanediol	0.46 ± 0.23	0.12 ± 0.05	0.68 ± 0.29

[1]NDFD = NDF digestibility after 30 h of incubation, expressed as a percentage of NDF.

with the preliminary diet. The acetic acid concentration in the BMR forage sorghum was greater compared with that observed for the BMR pearl millet silage and potentially would reduce intake. The DMI increased in wk 2 for both diets, indicating that the cows adapted to any difference in palatability of forages. Milk yield during the 6-wk experimental period was not different among treatment ($P = 0.31$, SE = 0.6) and averaged 36.5 and 37.4 kg/d for PMS and FSS, respectively. An interaction of treatment and week ($P < 0.0001$) was observed for efficiency of milk production (milk/DMI), reflecting the differences observed in DMI during wk 1 (Figure 2).

Intake and production data during wk 4 to 6 are presented in Table 3. The DMI was not different ($P > 0.10$) for cows fed diets containing PMS or FSS, which averaged 26.4 kg/d or 3.9% of BW (Table 3). Previous researchers have not reported a difference in DMI when cows were fed diets based on corn silage or BMR forage sorghum (Grant et al., 1995; Aydin et al., 1999; Bernard and Tao, 2015, 2017). Brunette et al. (2014) reported lower DMI for cows fed diets based on either regular or sweet pearl millet silage compared with corn silage. These authors reported lower NDF intake for diets based on corn silage compared with regular and sweet pearl millet silages that averaged 1.21, 1.35, and 1.33% of BW, respectively. In contrast, Amer and Mustafa (2010) did not observe any differences in DMI, but NDF intake was greater for cows fed diets with pearl millet silages (1.35% of BW) compared with corn silage (1.18% of BW). In our current trial, NDF intake averaged 1.38 and 1.43% of BW for PMS and FSS, respectively. Although the NDF digestibility of PMS was lower than FSS, this did not negatively affect DMI. We

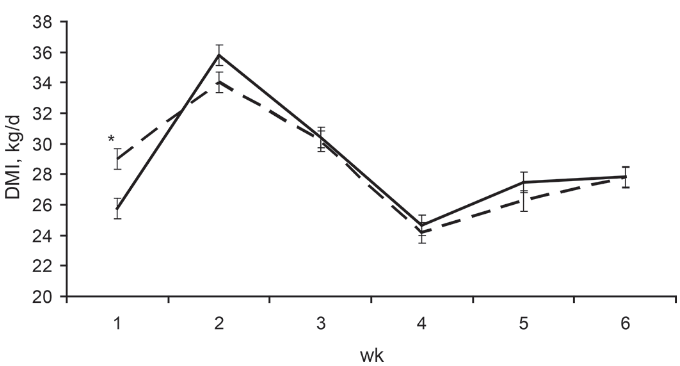

Figure 1. Interaction of treatment and week ($P < 0.0001$, SE = 0.7 kg/d) for DMI of cows fed diets based on corn silage plus brown midrib (BMR) pearl millet (dashed line) or BMR forage sorghum silage (solid line). Means with * differ ($P < 0.001$). The error bars show the SE.

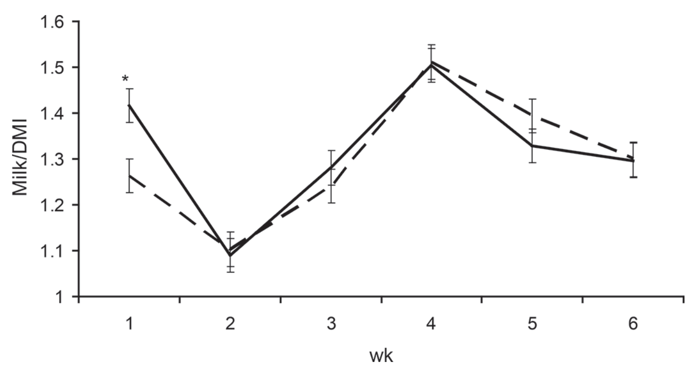

Figure 2. Interaction of treatment and week ($P < 0.0001$, SE = 0.04 kg/d) for efficiency (milk/DMI) of cows fed diets based on corn silage plus brown midrib (BMR) pearl millet (dashed line) or BMR forage sorghum silage (solid line). Means with * differ ($P < 0.001$). The error bars show the SE.

Table 3. Intake and production response of mid-lactation Holsteins fed diets supplemented with pearl millet silage (PMS) or forage sorghum silage (FSS) during wk 4 to 6

Item	PMS	FSS	SE	*P*-value
DMI, kg/d	26.3	26.5	0.6	0.892
Milk, kg/d	36.1	36.9	0.7	0.436
Fat, %	3.42	3.48	0.09	0.633
Fat, kg/d	1.23	1.28	0.05	0.732
Protein, %	2.78	2.78	0.03	0.949
Protein, kg/d	1.00	1.03	0.03	0.635
Lactose, %	4.79	4.72	0.03	0.097
Lactose, kg/d	1.73	1.74	0.04	0.789
Solids-not-fat, %	8.47	8.46	0.04	0.842
Solids-not-fat, kg/d	3.06	3.12	0.06	0.566
ECM, kg/d	35.5	36.5	1.0	0.698
Efficiency, ECM/DMI	1.35	1.38	0.04	0.769
MUN, mg/dL	14.27	16.72	0.32	<0.0001
Final BW, kg	672.6	681.7	5.0	0.212
BW change, kg	7.7	16.8	5.0	0.211
Final BCS	3.03	3.10	0.06	0.483
BCS change	0.35	0.41	0.06	0.483

are not aware of research comparing diets containing corn silage and either PMS or FSS produced from BMR varieties. These results indicate that these greater fiber forages did not affect DMI when mixed with corn silage.

No differences ($P > 0.10$) were observed in yield of milk or components, percentage of milk components, or yield of ECM among treatments during wk 4 to 6. An interaction of treatment and week ($P = 0.043$) was observed for milk protein percentage, which was greater for PMS during wk 5 compared with FSS (Figure 3). In our previous research comparing corn silage and forage sorghum silage from either the first or second crops, no differences were observed in milk yield or component yield but diets based on forage sorghum had greater milk fat percentage (Bernard and Tao, 2015, 2017). Aydin et al. (1999) reported lower and greater milk yield for cows fed BMR forage sorghum compared with corn silage in 2 trials. In their first trial, yield of milk fat, protein, and lactose was lower for cows fed BMR forage sorghum compared with corn silage. Milk component yield was not reported in their second trial, but no differences in milk component concentrations were observed. Amer and Mustafa (2010) reported greater milk fat yield and percentage for cows fed pearl millet compared with corn silage. Yield of protein, lactose, and solids-not-fat were lowest for regular pearl millet and intermediate or not different for sweet millet compared with corn silage (Brunette et al., 2014). Brunette et al. (2016) did not observe any difference in yield of milk, fat, lactose, or solids-not-fat; however, milk protein yield was slightly lower when pearl millet silage harvested at early boot stage of maturity was substituted for grass silage in diets also containing 20% of the dietary DM as corn silage.

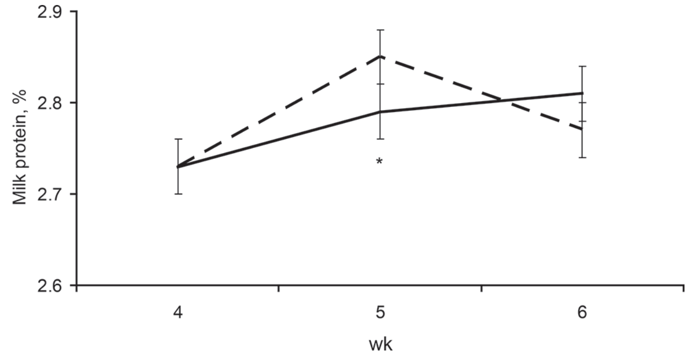

Figure 3. Interaction of treatment and week ($P < 0.0403$, SE = 0.03%) for milk protein percentage of cows fed diets based on corn silage plus brown midrib (BMR) pearl millet (dashed line) or BMR forage sorghum silage (solid line). Means with * differ ($P < 0.001$). The error bars show the SE.

Concentrations of MUN during wk 4 to 6 were greater ($P < 0.0001$) for cows fed FSS compared with PMS and averaged 16.72 and 14.27 mg/dL, respectively. An interaction of treatment and week ($P < 0.0001$) was observed as MUN was lower for PMS during wk 4 and 6 compared with FSS (Figure 4). The greater concentrations observed for FSS are partially due to the diet containing slightly more CP than the PMS diet (Table 1). Increased MUN concentrations have been reported for diets based on forage sorghum (Bernard and Tao, 2015, 2017) or pearl millet silage (Brunette et al., 2014) compared with diets containing corn silage. Similar increases were observed when pearl millet replaced grass silage (Brunette et al., 2016) or corn silage (Harper et al., 2018). It is possible that fed diets with greater starch concentrations would better use the protein from the BMR forage sorghum, but no research we are aware of has been conducted to evaluate the effect of starch on MUN in diets containing forage sorghum.

No differences ($P > 0.10$) were observed in efficiency of converging DMI to ECM, final BW or BCS, or change in BW or BCS during the trial. This is consistent with previ-

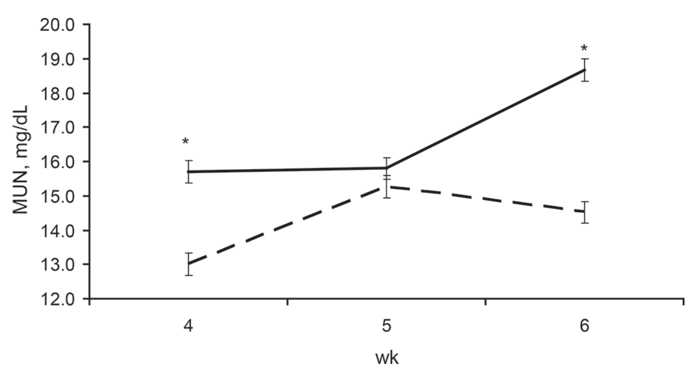

Figure 4. Interaction of treatment and week ($P < 0.0403$, SE = 0.03%) for MUN of cows fed diets based on corn silage plus brown midrib (BMR) pearl millet (dashed line) or BMR forage sorghum silage (solid line). Means with * differ ($P < 0.001$). The error bars show the SE.

ous research (Bernard and Tao, 2015, 2017; Harper et al., 2018) and suggests that the diets provided similar energy content to support production and BW gain.

APPLICATIONS

The results of this 6-wk trial indicate that either PMS or FSS can be fed along with corn silage to mid-lactation Holstein cows without altering intake or milk yield or composition. Concentrations of MUN were greater for FSS, which is consistent with previous research. The choice of PMS or FSS should be based on yield, agronomic characteristics, and cropping schedule.

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