Response of Lactating Dairy Cows to Diets Based on Brachytic Forage Sorghum Silage or Corn Silage Harvested from Summer or Fall and Supplemented with Soybean Meal or Mechanically Pressed Cottonseed Meal

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ABSTRACT

A 6-wk randomized design trial with a 4 x 2 factorial arrangement of treatments was conducted to evaluate the intake and production response of 48 lactating Holstein cows to diets based on corn (CS) or forage sorghum silage (FS) harvested in the summer (S) or fall (F) and supplemented with either soybean meal (SBM) or mechanically pressed cottonseed meal (CSM). Corn was planted in April, harvested in July (CSS), a second crop planted in August and harvested in November (CSF). Forage sorghum was planted in April, harvested in July (FSS), allowed to regrow and harvested again in November (FSF). Ensiled forages provided 41.67% of the dietary DM in the experimental diets and CSM replaced a portion of the N provided by SBM. Cows were fed a corn silage based diet for 2 wk prior to beginning the 4 wk experimental period. No differences were observed in DMI or milk yield among treatments. An interaction of forage source and protein supplement was observed for milk fat which was lowest for CSF-CSM compared with the other treatments. No differences were observed in yield or concentration of milk protein, lactose, or SNF. An interaction was observed for efficiency of milk production which was lowest for CSS-SBM and CSF-CSM compared with CSF-SBM, FSS-SBM, FSF-SBM and FSF-CSM. Concentrations of MUN were lower for CSS and CSF compared with FSS and FSF and for CSM compared with SBM. The results of this trial indicate that diets based on CS or FS harvested in S or F can support similar performance. The results also indicate that CSM can support similar performance as SBM.

INTRODUCTION

Forage sorghum (**FS**) is grown in many areas of the Southeast where irrigation is not available or limited because of its lower water requirements compared with corn (Contreras-Govea et al., 2010; Miron et al., 2007). However, forage sorghum has lower starch concentrations resulting in lower energy concentrations compared with corn (Bean et al. 2005). When lactating dairy cows were fed diets based on normal forage sorghum, milk yield was not different compared with that of cows fed a diet based on tropical corn silage (**CS**) (Nichols et al., 1998). However, milk yield typically lower than that observed for cows fed diets based on temperate corn silage (Aydin et al. 1999; Grant et al., 1995; Miron, et al., 2007). Varieties of forage sorghum with the brown midrib gene (BMR) produce forage that has reduced lignin concentrations and higher NDF digestibility (Contreras-Govea et al., 2010). When BMR forage sorghum was fed to lactating dairy cows, FCM yield was similar to that of cows fed corn silage based diets (Grant et al., 1995; Aydin et al., 1999; and Oliver et al, 2004).

Another issue with forage sorghum is that it is very susceptible to lodging. Varieties with the brachytic dwarf gene are shorter (approximately 1.8 m height versus 3.6+ m) than normal forage sorghum and have shorter internodes without affecting the number of leaves, leaf size, maturity, or yield. Most brachytic dwarf varieties also contain the BMR gene. Yosef et al. (2009) did not observe any difference in the in vitro or in vivo DM digestibility of silage produced from dwarf compared with normal forage sorghum hybrids.

In the semi-tropical regions of the Southeast, forage sorghum can be ratooned to produce a second crop of forage without replanting when forage sorghum is planted in early spring. For producers with either limited capacity to irrigate or limited water resources, this system provides an option to increase forage production while using less water for irrigation. Since a second crop would not have to be planted, it also provides an opportunity to reduce total labor and production cost in light of continued increases in fuel and energy cost.

Cottonseed meal (**CSM**) is a byproduct of extracting oil from whole cottonseed that is included in rations fed to lactating dairy cows. Compared with soybean meal (**SBM**), the amino acid quality of CSM is lower because of lower lysine concentrations (4.13 versus 6.29% of CP, respectively; Bernard, 2011). However, DMI and performance of lactating cows fed supplemented with CSM or SBM is similar (Bernard, 2011; Brito and Broderick, 2007). With increasing demand for oil for biodiesel production, smaller plants which use mechanical press for oil extraction have been built. The resulting cottonseed meal has lower CP and higher NDF and fat concentrations than mechanical extruded cottonseed meal (NRC, 1989). Currently there are limited data on the feeding value of mechanically pressed cottonseed meal for lactating dairy cows.

The objective of this trial was to evaluate the feeding value of brachytic dwarf forage sorghum silage produced in a system where it is allowed to regrow after the first harvest and harvested a second time compared with two corn silage crops produced during the same period. A second objective was to evaluate the performance of lactating dairy cows fed diets in which CSM was substituted for a portion of the SBM in diets fed to lactating dairy cows

MATERIALS AND METHODS

Forage Production

Forages were grown on a Tifton sandy loam soil on the Animal and Dairy Science farm unit located on the University of Georgia Tifton Campus. Temperate corn (Pioneer P1690YHR, DuPont Pioneer, Johnston, IA Company, St. Louis, MO) was planted on April 10, 2014 at a seeding rate of approximately 79,070 seed/ ha. Forage was harvested on July 24, 2014 and ensiled in a 2.4 m plastic bag until beginning of a production trial. The second crop (DeKalb 67-87, Monsanto Company, St. Louis, MO) was planted on July 29, 2014 and managed the same as outlined for the first crop. Corn was harvested on October 30, 2014 and ensiled in a 2.4 m plastic bag.

A brachytic dwarf brown midrib forage sorghum variety (Alta 7401, Alta Seeds, Amarillo, TX) was planted at a seeding rate of approximately 7.85 kg/ha on April 18, 2014. Forage was harvested on August 8, 2014 when the grain has reached the dough stage of maturity and ensiled in a 2.4 m plastic bag until beginning of a production trial. The crop was fertilized and allowed to regrow and produce a second crop. The forage was harvested on November 6, 2014 at early dough stage of maturity and ensiled in a 2.4 m plastic bag.

Both first crops of CS and FS were fertilized with 44.7 kg/ha N, 44.7 kg/ha P_2O_5, and 93.4 kg/ha K_2O before planting and top dressed with 154 kg/ha N. The same fertilization program was used for the second crop of corn. The ratoon crop of forage sorghum received 73 kg/ha N, 18.3 kg/ha P_2O_5

and 36.6 kg/ha K_2O and was top dressed with 154 kg/ha N. Herbicides were applied according to University of Georgia recommendation and crops were irrigated as needed to maintain soil moisture.

Production Trial

Forty-eight multiparous lactating Holstein cows averaging 140.9 ± 55.9 DIM, 42.6 ± 6.3 kg/d milk, 3.5 ± 0.7% fat, 691.3 ± 73.2 kg BW, and 3.10 ± 0.19 BCS were used in a 6 wk randomized design trial with a 4 x 2 factorial arrangement of treatments. Cows were trained to eat behind Calan doors (American Calan, Northwood, NH) before beginning the trial. All cows were fed a basal diet based on corn silage for 2 wk and data collected for use as a covariate in the statistical analysis. At the end of the preliminary period, cows were assigned randomly to one of eight treatments by ECM for the following 4 wk. Treatments include four forage sources: 1) summer corn silage (CSS), 2) fall corn silage (CSF), 3) summer forage sorghum (FSS), or 3) regrowth fall forage sorghum (FSF) and two protein supplements: 1) soybean meal (SBM) or 2) cottonseed meal (CSM).

Diets (Table 1) were formulated to provide equal concentrations of CP, NDF, and energy based on preliminary forage analysis and fed as a TMR once daily in amounts to provide a minimum of 5% orts. The amount of feed offered and refused was recorded daily. Samples of dietary ingredients and experimental rations were collected for DM analysis three times each week. Rations were adjusted as necessary to account for changes in the DM content of individual ingredients. Individual samples were composited by week and ground to pass through a 1-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ). Forage samples were analyzed for concentrations of DM, ash (AOAC, 2000), CP (Leco FP-528 Nitrogen Analyzer, St. Joseph, MO), ADF (AOAC, 2000), NDF corrected for ash (Van Soest et al., 1991), and 30 h NDF digestibility (Goering and Van Soest, 1970). Fermentation end product concentrations of the silages were determined as described previously (Bernard and Tao, 2015). Samples of experimental diets were analyzed for DM, ash, CP, ADF, (AOAC, 2000) and NDF adjusted for ash (Van Soest et al., 1991) and ether extract (AOAC, 2000).

Cows were milked 3 times daily at 0700, 1500, and 2300h and milk yields recorded electronically (Alpro, DeLaval, Kansas City, MO) at each milking. Milk samples were collected from three consecutive milkings once each week for analysis of milk fat, protein, lactose, SNF, and MUN concentrations by infrared spectrophotometric analysis with a Foss 4000 instrument (Foss North America, Eden Prairie, MN; Dairy One Cooperative, Ithaca, NY).

Individual BW was recorded on three consecutive days following the 0700 milking at the end of the pretrial period and at the end of the experimental period. To minimize variation, BW was recorded immediately after milking before allowing access to feed or water. Body condition scores were assigned by two individuals during the last week of the preliminary period and wk 5 of the experimental period (Wildman et al., 1982).

Data from the production trial were analyzed using the PROC MIXED procedure of SAS (SAS Institute, 2008). The model included the effects of covariate, parity, forage source, protein supplement, wk, and the interactions of forage source, protein supplement, and wk. Cow within forage source and protein supplement was included as a random effect and wk was included as a repeated measure. Significance was declared when $P \leq 0.05$ and trends when $P > 0.05$ and ≤ 0.10. When significance was detected, the PDIFF option was used for mean separation.

RESULTS AND DISCUSSION

The chemical composition of CS harvested in S and F were similar (Table 2). The CP and ash content of the FSF was slightly higher and NDF slightly lower than FSS. All forages were well fermented as indicated by the pH. Total VFA and acetic acid concentrations were higher for S than F. The chemical composition of the experimental diets is presented in Table 3. Overall CP concentrations were higher than initially formulated, but the increase was greater for the FSF which had higher CP concentrations than FSS. The CSM averaged (% of DM): 35.5 % CP, 44.6% NDF, 30.3% ADF, 8.1% EE, and 5.8% ash.

No differences ($P > 0.10$) were observed in DMI among treatments (Table 4). Milk yield was not different among forage sources but tended to be higher ($P = 0.0871$) for CSM compared with SBM (35.9 versus 34.0 kg/d, respectively). Milk fat percentage ($P = 0.0156$) and yield ($P = 0.0063$) were lower for CSF (3.25 % and 1.09 kg/d, respectively) compared with the other forages (3.67, 3.72 and 3.62% and 1.32, 1.26 and 1.30 kg/d milk for CSS, FSS, and FSF, respectively). An interaction of forage source and protein supplement ($P = 0.0310$) was observed because milk fat percentage was lowest for CSF-CSM compared with other diets. No differences were observed in concentration or yield of milk protein, lactose or SNF. Yield of ECM tended to be lower ($P = 0.0846$) for CSF (32.2 kg/d) compared with CSS, FSS, and FSF (35.5, 34.0 and 35.5 kg/d, respectively). An interaction of forage source and protein supplement ($P < 0.0007$) was observed for efficiency of milk production (ECM/DMI) because lower efficiency of production for CSS-SBM and CSF-CSM compared with CSF-SBM, FSS-SBM, FSF-SBM and FSF-CSM. Concentrations of MUM were lower ($P = 0.0001$) for CSS and CSF compared with FSS and FSF (8.77, 8.23, 11.64, and 11.37 mg/dL, respectively) and for CSM compared with SBM ($P = 0.0024$, 9.31 and 10.70 mg/dL, respectively). No differences were observed in BW or BCS change during the trial.

In our previous trial (Bernard and Tao, 2015), no differences were observed in DMI, yield of milk, ECM or percentage of milk protein, lactose, or SNF of cows fed CS or FS harvested in S or F similar to that described in our current trial. However, milk fat percentage and MUN concentrations were lower for the diets based on CSS and CSF compared with FSS and FSF. No differences in milk yield or composition were reported in cows fed corn silage and BMR forage sorghum silage harvested from traditional single harvest systems (Grant et al., 1995; Aydin et al., 1999; Miron et al., 2007). Higher concentrations of MUN have been observed for diets based on forage sorghum (Colombini et al., 2012) or other summer annuals (Brunette et al., 2014; Dann et al., 2008).

In previous trials, no differences have been reported in performance of cows fed diets supplemented with either SBM or CSM (Bernard, 1997; Brito and Broderick, 2007; Meyer et al., 2001). The tendency for higher milk yield observed in the current trial may be related to the numerically higher fat content of the diets containing CSM which would have provided additional energy compared to those supplemented with SBM (Table 3). Brito and Broderick (2007) reported lower urinary and higher fecal N for cows fed CSM compared with SBM; however MUN concentrations were lower with CSM compared with SBM. The differences reported by these authors for CSM compared with SBM are explained by the observed lower total tract apparent digestibility of CP. While the digestibility of the CSM used in the current trial was not evaluated, the higher MUN of cow fed SBM suggest that the protein was readily digested used in support milk synthesis.

Results of the current trial along with the results of our previous trial suggest that silage produced from brachytic dwarf forage sorghum with the BMR trait can support similar milk yield and composition as cows fed diets based on corn silage. The results also suggest that FS ratoon growth supports similar milk yield as that produced from the first harvest. Substitution of SBM with mechanically pressed cottonseed meal did not alter milk fat or protein content, but tended to support higher milk yield. Additional research is needed to evaluate the digestibity of the protein from the mechanically pressed cottonseed meal.

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Table 1. Ingredient composition of experimental diets (% of DM) based on corn or forage sorghum silage harvested in the summer or fall and supplemented with either soybean meal (SBM) or mechanically pressed cottonseed meal (CSM).

	Corn silage		Forage sorghum	
Ingredient	SBM	CSM	SBM	CSM
Corn silage[1]	41.67	41.67		
Forage sorghum[2]			41.67	41.67
Ryegrass baleage	3.33	3.33	3.33	3.33
Ground corn	18.33	16.42	25.77	25.77
Soybean hulls	15.67	14.50	5.93	3.02
Megalac[3]	1.67	1.67	1.67	1.67
Soybean meal	6.67	1.42	9.17	3.75
Cottonseed meal		8.33		8.33
Amino Plus[4]	2.25	2.25	2.25	2.25
Prolak[5]	2.58	2.58	2.58	2.58
Urea	0.17	0.17	0	0
Mepron[6]	0.05	0.05	0.05	0.05
Metabolys[7]			0.17	0.17
Salt	0.25	0.25	0.25	0.25
Calcium carbonate	0.70	0.70	0.67	0.67
Calcium monophosphate	0.33	0.33	0.25	0.25
Potassium carbonate	0.17	0.17	0.33	0.33
Magnesium oxide	0.17	0.17		
Sodium bicarbonate	0.83	0.83	0.83	0.83
Dynamate[8]	0.25	0.25	0.17	0.17
Omigen-AF[9]	0.20	0.20	0.20	0.20
Monensin, 3g/454 g[10]	0.25	0.25	0.25	0.25
Trace-mineral-vitamin premix[11]	0.30	0.30	0.30	0.30

[1]Corn silage was provided from silage harvested during the summer or fall.

[2]Forage sorghum was provided from silage harvested during the summer or fall.

[3]Calcium salts of long chain fatty acids, Arm Hammer Animal Nutrition, Church & Dwight Co., Inc. Princeton, NY.

[4]Ruminally protected soybean meal, Ag Processing, Inc. Omaha, NE.

[5]Marine and animal rumen undegradable protein supplement, H. J. Baker & Bros., Inc., Westport, CT.

[6]Rumin protected methionine, Evonik Industries, Kennesaw, GA.

[7]Rumin protected lysine, H. J. Baker & Bros., Inc., Westport, CT.

[8]Potassium magnesium sulfate, Mosaic, Plymouth, MN.

[9]Immune stimulant, Prince Agri Products, Inc., Quincy, IL.

[10]Rumensin, Elanco Animal Health, Indianapolis, IN.

[11]Mineral-vitamin premix contained (DM basis): 30.2% Ca; 0.11% Mg; 0.31% S; 357 ppm Co; 3,472 ppm Cu; 230 ppm Fe; 388 ppm I; 23,882 ppm Mn; 102 ppm Se; 13,421 ppm Zn; 1,235,413 IU/kg Vitamin A; 123,536 IU/kg Vitamin D; 6,124 IU/kg Vitamin E.

Table 2. Chemical composition of experimental silages harvested.

	Corn silage		Forage sorghum	
	Summer	Fall	Summer	Fall
DM, %	33.2 ± 2.3	36.4 ± 2.6	24.6 ± 0.5	27.3 ± 1.5
	--------------------------------	% of DM	------------------------	
CP	8.1 ± 0.4	8.2 ± 0.5	9.5 ± 0.5	11.3 ± 0.3
Ammonia	0.96 ± 0.32	0.74 ± 0.04	1.18 ± 0.08	1.44 ± 0.06
NDF	39.0 ± 2.0	39.0 ± 1.7	56.1 ± 2.0	51.5 ± 0.8
ADF	25.2 ± 1.6	22.8 ± 1.1	37.0 ± 0.8	34.0 ± 0.9
NDFd, 30 h[1]	52.8 ± 1.9	52.1 ± 3.5	51.0 ± 1.2	52.7 ± 0.8
NFC[2]	47.6 ± 2.1	47.6 ± 1.8	27.6 ± 2.4	30.1 ± 0.7
Ash	3.20 ± 0.35	3.11 ± 0.18	5.02 ± 0.19	5.79 ± 0.40
Total VFA	5.82 ± 2.44	3.92 ± 0.23	10.63 ± 1.52	7.73 ± 0.91
Lactic acid	2.75 ± 1.39	2.95 ± 0.68	5.35 ± 0.77	5.12 ± 1.60
Acetic acid	2.77 ± 1.71	0.97 ± 0.63	5.27 ± 1.11	2.24 ± 0.24
Propionic acid	0.32 ± 0.27	ND[3]	0.06 ± 0.02	ND
Butyric acid	ND	ND	ND	ND
Isobutyric acid	ND	ND	ND	ND
1,2 Propanediol	0.22 ± 0.12	ND	2.78 ± 0.96	ND
pH	3.97 ± 0.16	4.02 ± 0.08	4.04 ± 0.10	3.98 ± 0.02

[1]NDFd, 30h = 30 h NDF digestibility

[2]NFC = non-fibrous carbohydrate

[3]ND = not detected

Table 3. Chemical analysis of experimental diets based on corn (CS) or forage sorghum silage (FS) harvested in the summer (S) or fall (F) and supplemented with either soybean meal (SBM) or mechanically pressed cottonseed meal (CSM).

Forage	CSS	CSS	CSF	CSF	FSS	FSS	FSF	FSF
Protein	SBM	CSM	SBM	CSM	SBM	CSM	SBM	CSM
DM, %	51.4 ± 5.6	52.4 ± 4.6	52.1 ± 3.5	53.9 ± 4.8	42.3 ± 2.8	42.5 ± 3.4	45.5 ± 3.9	44.7 ± 2.9
	---------- % of DM ----------							
CP	19.6 ± 1.1	18.7 ±1.0	19.3 ± 0.9	18.4 ± 1.7	19.5 ± 1.1	19.9 ± 1.0	21.5 ± 0.6	20.6 ± 0.4
NDF	32.5 ± 2.2	31.5 ± 1.4	32.2 ± 1.5	31.9 ± 1.4	31.6 ± 1.9	35.3 ± 1.7	32.3 ± 0.3	34.8 ± 0.5
ADF	18.8 ± 0.9	20.2 ± 1.1	19.4 ± 1.1	19.9 ± 0.9	20.5 ± 1.3	23.3 ± 0.9	19.8 ± 2.0	19.8 ± 0.8
EE	3.3 ± 0.3	3.2 ± 0.3	2.0 ± 0.5	2.6 ± 0.3	3.0 ± 0.3	3.7 ± 1.0	3.5 ± 0.2	3.7 ± 0.1
Ash	8.5 ± 0.8	8.6 ± 0.9	7.5 ± 0.3	7.6 ± 0.9	8.5 ± 0.3	8.4 ± 0.3	8.3 ± 0.6	7.7 ± 0.2

Table 4. Intake, milk yield and composition of cows fed diets based on corn (CS) or forage sorghum silage (FS) harvested in the summer (S) or fall (F) and supplemented with soybean meal (SBM) or mechanically pressed cottonseed meal (CSM).

Forage	CSS	CSS	CSF	CSF	FSS	FSS	FSF	FSF		*P*		
Protein	SBM	CSM	SBM	CSM	SBM	CSM	SBM	CSM	SE	Forage	Protein	Interaction
DMI, kg/d	24.4	25.8	20.6	24.4	22.7	24.2	23.1	23.5	1.6	0.4420	0.1029	0.7387
Milk, kg/d	34.9	36.3	32.6	36.5	33.0	34.8	35.5	36.1	1.7	0.6749	0.0871	0.7529
Fat, %	3.49[ab]	3.85[a]	3.42[ab]	3.09[b]	3.77[a]	3.67[a]	3.35[ab]	3.90[a]	0.16	0.0156	0.2956	0.0310
Fat, kg/d	1.22	1.40	1.11	1.13	1.25	1.28	1.19	1.41	0.07	0.0063	0.1608	0.3040
Protein, %	2.55	2.54	2.63	2.62	2.55	2.59	2.70	2.58	0.04	0.1097	0.3708	0.2748
Protein, kg/d	0.89	0.92	0.86	0.96	0.84	0.90	0.96	0.93	0.04	0.4730	0.2905	0.6228
Lactose, %	4.67	4.69	4.61	4.73	4.70	4.78	4.73	4.71	0.03	0.1840	0.0359	0.1855
Lactose, kg/d	1.63	1.70	1.50	1.73	1.55	1.66	1.68	1.70	0.09	0.8383	0.521	0.6423
SNF, %	8.04	8.10	8.03	8.15	8.08	8.18	8.20	8.10	0.06	0.4703	0.2549	0.2471
SNF, kg/d	2.80	2.94	2.62	2.98	2.67	2.85	2.91	2.92	0.14	0.6851	0.0860	0.7576
ECM, kg/d	34.0	37.0	31.6	33.9	33.4	34.8	34.3	37.1	1.4	0.0846	0.1557	0.9007
Efficiency	1.39[a]	1.44[ab]	1.54[c]	1.39[a]	1.47[bc]	1.44[ab]	1.48[bc]	1.58[c]	0.05	0.1620	0.5646	0.0007
MUN, mg/dL	9.89	7.66	8.95	7.51	11.82	10.92	12.13	11.14	0.73	0.0001	0.0024	0.7202
BW change, kg	5.0	25.3	15.6	23.6	15.8	10.1	20.4	21.1	7.3	0.6716	0.2744	0.3321
BCS change	0.14	0.01	0.11	0.17	-0.03	0.04	0.05	0.06	0.06	0.1360	0.9430	0.2430

[a,b,c] Means in the same row with unlike superscripts differ ($P < 0.05$).