Short communication: Effects of feeding pearl millet silage on milk production of lactating dairy cows

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ABSTRACT

Twenty Holstein cows were used in a randomized complete block experiment to determine the feeding value of pearl millet silage (MS) for dairy cows relative to corn silage (CS). Two isonitrogenous diets were formulated with a 53:47 forage:concentrate ratio. Pearl millet silage and CS comprised 67% of the forages in each diet. Relative to CS, MS contained higher crude protein (13.0 vs. 9.4%), neutral detergent fiber (66.9 vs. 40.7%), and acid detergent fiber (38.8 vs. 23.9%). Dietary treatments had no effect on dry matter (average = 23.9 kg/d) or crude protein (average = 4.2 kg/d) intake. However, cows fed MS consumed more neutral detergent fiber (9.7 vs. 8.3 kg/d) than did cows fed CS. Silage type had no effect on milk yield (average 38.0 kg/d), whereas energy-corrected milk (43.8 vs. 38.6) and 4% fat-corrected milk (41.8 vs. 35.5 kg/d) were greater for cows fed MS than for those fed CS. Milk protein, lactose, and total solids concentrations were not influenced by dietary treatments. However, cows fed MS produced milk with a greater milk fat concentration (4.17 vs. 3.78%) than did cows fed CS. We concluded that MS, when compared with CS, had a similar effect on feed intake, milk yield, and milk efficiency. Because of increased milk fat concentration, cows fed MS produced more energy-corrected milk than did cows fed CS.

Key words: milk composition, milk yield, pearl millet silage

Pearl millet [*Pennisetum glaucum* (L.) R.] is a tropical plant possessing the C4 photosynthetic pathway with tolerance to drought, heat, and low soil pH (Maiti and Wesche-Ebeling, 1997). Because of its adaptability to harsh conditions, millet can be grown in areas unfavorable to other cereals, such as corn (Hanna, 1995). Several studies have evaluated the potential of pearl millet as a silage for ruminants (Messman et al., 1992; Hill et al., 1999). Due to difficulties in wilting, pearl millet

is usually ensiled at a lower DM content than other forages (Messman et al., 1992; Hill et al., 1999; Ward et al., 2001). Limited data exist regarding the feeding value of pearl millet silage. Heifers fed millet silage consumed less DM and gained less BW than do those fed corn silage (Hill et al., 1999). In another study, Ward et al. (2001) showed that heifers fed pearl millet silage consumed more DM than did heifers fed sorghum silage or tropical corn silage. Pearl millet silage fed to dairy cows in place of alfalfa plus corn silage had no effect on milk yield or milk fat concentration. However, DMI and milk protein concentration declined as a result of feeding pearl millet silage. Adapted and new hybrids of forage pearl millet suitable for growing conditions in eastern Canada have recently been developed by Agriculture and Environmental Renewal Canada (Delhi, ON, Canada). The new hybrids produce 9.5 to 10.9 t of DM/ha under nonirrigated conditions and can be used as a biological control of root-lesion nematodes when used in crop rotation (AERC, 2007). The nutrient profile and in vitro degradability of some of these hybrids have already been determined (Hassanat et al., 2006, 2007). However, the feeding value of these hybrids for dairy cows has not been determined. The objectives of this study were to determine the effects of replacing corn silage with pearl millet silage in the diets of lactating dairy cows on subsequent milk yield and composition.

Forage millet (hybrid CSPM 7) was seeded in the last week of June 27, 2008, and harvested at the heading stage (plant height, 120 cm; harvest height, 10 cm) on September 22, 2008. Corn was planted on May 12, 2008, and harvested at half milkline stage (35% DM) on September 12, 2008. All forages were chopped to a theoretical cut length of 8 mm with a forage harvester and ensiled in tower silos.

Twenty lactating Holstein cows of mixed parities, in early to mid lactation (BW 721 ± 59.3 kg, 139 ± 63.5 DIM), were blocked by parity and DIM and divided into 2 equal groups. The cows were housed in tiestalls with free access to water. Two isonitrogenous diets were formulated with a 53:47 forage:concentrate ratio to meet the nutrient requirements of dairy cows in early lactation (NRC, 2001). The forage part of the diets

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Table 1. Fermentation characteristics and chemical composition (mean $\pm$ SD) of millet and corn silages (DM basis, $n = 2$)

Item	Silage type	
	Pearl millet	Corn
pH	3.86 $\pm$ 0.007	3.64 $\pm$ 0.011
Water-soluble carbohydrates, %	1.1 $\pm$ 0.12	0.9 $\pm$ 0.17
Lactic acid, %	8.5 $\pm$ 0.70	7.9 $\pm$ 0.25
Acetic acid, %	2.0 $\pm$ 0.13	1.2 $\pm$ 0.01
Propionic acid, %	0.1 $\pm$ 0.01	0.12 $\pm$ 0.02
Aerobic stability, h	18 $\pm$ 4.69	62.2 $\pm$ 11.28
DM, %	26.9 $\pm$ 0.08	37.3 $\pm$ 0.15
Ash, %	7.4 $\pm$ 0.41	2.9 $\pm$ 0.01
CP, %	13.0 $\pm$ 0.57	9.4 $\pm$ 0.71
Ether extract, %	2.1 $\pm$ 0.01	2.5 $\pm$ 0.08
NDF, %	66.9 $\pm$ 0.47	40.7 $\pm$ 1.3
ADF, %	38.8 $\pm$ 0.52	23.9 $\pm$ 0.86
Acid detergent lignin, %	2.3 $\pm$ 0.02	2.2 $\pm$ 0.40
Starch, %	2.2 $\pm$ 0.01	34.9 $\pm$ 0.40
Soluble protein, % of CP	68.9 $\pm$ 0.88	67.6 $\pm$ 2.21
Nonstructural carbohydrates, %	12.9 $\pm$ 1.07	45.7 $\pm$ 2.41
NPN, % of CP	66.2 $\pm$ 1.49	58.0 $\pm$ 0.85
Neutral detergent insoluble protein, % of CP	17.5 $\pm$ 2.29	12.9 $\pm$ 0.22
Acid detergent insoluble protein, % of CP	8.0 $\pm$ 0.42	6.4 $\pm$ 0.04
In vitro DM disappearance (48 h), %	66.6 $\pm$ 3.94	68.0 $\pm$ 1.69
In vitro NDF disappearance (48 h), % of NDF	58.3 $\pm$ 3.10	33.1 $\pm$ 1.16
In situ DM disappearance (48 h), %	62.3 $\pm$ 2.45	69.6 $\pm$ 2.10
In situ NDF disappearance (48 h), % of NDF	52.0 $\pm$ 1.41	39.1 $\pm$ 3.96
Indigestible NDF, ¹ % of NDF	37.6 $\pm$ 0.69	47.8 $\pm$ 2.24
NE _L , ² Mcal/kg	1.41 $\pm$ 0.013	1.72 $\pm$ 0.031

¹Estimated following 120 h of in vitro incubation.²Calculated according to Weiss et al. (1992).

consisted of 66% pearl millet (**MS**) or corn (**CS**) silage (Table 1). Diets were offered ad libitum as TMR twice daily at 0800 and 1600 h. The experimental period consisted of 14 d of diet adaptation and 14 d of data collection. Cows were milked twice daily at 0600 and 1600 h, and milk yield was recorded at each milking. Pooled milk samples from the a.m. and p.m. milkings were collected twice per week during the collection period for later analysis. Diets and silages were sampled 3 times per week during the collection period and composited by week. The composited feed samples were oven-dried at 60°C for 72 h, ground through a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and stored at room temperature for later analysis. Orts were measured daily to determine daily intake for each cow.

Extracts from MS and CS were analyzed for water-soluble carbohydrates (DuBois et al., 1956) and organic acids (Mullin and Emmons, 1997). Aerobic stability of both silages was measured as described by Hassanat et al. (2007). Ground feed and silage samples were analyzed for DM (at 105°C for overnight), ash (at 600°C for 2 h), acid detergent lignin, and ether extract using standard procedures (AOAC, 1990). Neutral detergent fiber (Van Soest et al., 1991) and ADF (AOAC,

1990) were determined with an Ankom Fiber Analyzer (Ankom Technology Corp., Macedon, NY). Analysis of NDF was conducted without the inclusion of sodium sulfite and with the addition of heat-stable α -amylase. Crude protein ($N \times 6.25$) was measured using a Leco nitrogen analyzer (FP-428 Nitrogen Determinator, Leco Corp., St. Joseph, MI). Starch content of diets and silages was determined according to McCleary et al. (1997). Soluble protein and NPN were determined according to Licitra et al. (1996), whereas acid and neutral detergent insoluble protein were determined by analyzing NDF and ADF residues for total N. Dried, ground (2-mm) samples of MS and CS were placed in duplicate into Dacron bags (10 $\times$ 20 cm; pore size, 50 μ m; Ankom Technology) and inserted into the rumen before morning feeding for 48 and 120 h. Following removal from the rumen, bags were washed in tap water until rinse water was clear and dried at 65°C for 48 h. Residues were analyzed for DM and NDF. In vitro DM and NDF disappearances of dried and ground (1-mm) forages were determined using the DAISYII fermenter (Ankom Technology). Rumen fluid for the in vitro incubation was obtained from a lactating cow fed a 50:50 forage:concentrate diet. Milk samples were analyzed for fat, protein, lactose, and MUN with an

Table 2. Ingredients and chemical composition of dietary treatments (DM basis)

Item	Dietary treatment	
	Millet silage	Corn silage
Ingredients, %		
Pearl millet silage	35.0	
Corn silage		35.4
Alfalfa silage	9.8	9.8
Grass hay	8.0	8.0
High moisture corn	29.5	28.2
Soybean meal	10.4	12.2
Amino plus ¹	3.5	3.4
Megalac	1.9	
Mineral mix ²	0.5	1.1
Blue salt ³	0.4	0.3
Sodium bicarbonate	1.0	1.0
Urea		0.4
Limestone		0.3
Chemical composition, %		
DM	46.7 ± 0.60	51.7 ± 0.26
Ash	7.1 ± 0.12	5.8 ± 0.40
CP	18.0 ± 0.20	17.5 ± 0.58
Ether extract	3.5 ± 0.28	3.1 ± 0.05
Starch	24.4 ± 0.75	30.1 ± 2.67
NDF	39.5 ± 2.25	36.0 ± 0.76
ADF	23.1 ± 2.23	21.0 ± 0.71
Acid detergent lignin	3.0 ± 0.16	3.2 ± 0.16
Soluble protein, % of CP	40.5 ± 0.85	52.4 ± 1.85
Neutral detergent insoluble protein, % of CP	17.0 ± 0.71	14.6 ± 1.39
Acid detergent insoluble protein, % of CP	8.0 ± 0.42	6.3 ± 0.08
NE _L , ⁴ Mcal/kg	1.65 ± 0.01	1.68 ± 0.01

¹Contained: 50.5% CP, 20% NDF, 8% ADF, 1.4% ether extract, 0.42% Ca, and 0.7% P.

²Contained 99% NaCl, 400 mg of Co/kg, and 70 mg of I/kg.

³Contained per kilogram: 4.5% Ca; 2.5% P; 6.6% Na; 1.5% Mg; 1.2% K; 0.11% S; 1,372 mg of Fe; 1,032 mg of Mn; 1,500 mg of Zn; 247 mg of Cu; 16 mg of I; 16 mg of Co; 10 mg of Se; 185,000 IU of vitamin A; 32,500 IU of vitamin D₃; and 900 IU of vitamin E.

⁴Calculated according to Weiss et al. (1992).

infrared analyzer (MilkoScan, model Foss 4000, Foss Food Technology, Hillerød, Denmark). Milk total solids were determined according to AOAC (1990).

Data from the production study were analyzed as repeated measures using PROC MIXED of SAS Institute (1989) for a randomized complete block design. The model included cow effect, treatment effect, parity effect, interaction of parity × treatment, time effect, interaction of time × treatment, and the residual error. Significant differences were declared at $P < 0.05$.

Fermentation data suggest that MS was well preserved, as indicated by low pH and high lactic acid concentration (Table 2). A pH of less than 4.2 is indicative of well-preserved silage (McCullough, 1978). These results suggest that the water-soluble carbohydrate concentration of the pre-ensiled millet (i.e., 8.4% of DM) was sufficient for ideal fermentation. The pH values for MS in the present study were lower, whereas the lactic acid values were greater than those reported by Hill et al. (1999) and Ward et al. (2001). Pearl millet silage had greater CP, NDF, and ADF concentrations but less starch and NE_L than did CS (Table 2). These differences

can be attributed primarily to the grain development in corn. Forage pearl millet was harvested at the heading stage, whereas corn was harvested when the grain was at one-half milkline. The NDF, ADF, and CP values for pearl millet silage were in good agreement with those previously reported by Messman et al. (1992), Hill et al. (1999), and Ward et al. (2001), whereas the values for the various protein fractions were similar to those reported by Hassanat et al. (2006). In vitro and in situ DM disappearances were greater for CS than MS, whereas in vitro and in situ NDF disappearances were greater for MS than CS (Table 2). Differences in DM disappearance between MS and CS can be attributed mainly to the higher starch and nonstructural carbohydrate concentrations of CS relative to MS (Table 1).

Intakes of DM and CP were not affected by silage type (Table 3). In contrast, Messman et al. (1992) found that cows fed MS consumed less DM than did cows fed CS. However, when expressed on BW basis, DMI was not different. In previous studies, heifers fed MS consumed more (Ward et al., 2001) or less (Hill et al., 1999) DM than did those fed CS. In those studies, silages were fed

Table 3. Effects of feeding millet silage on dairy cow performance

Item	Dietary treatment		SEM ¹	P-value ²
	Pearl millet silage	Corn silage		
Intake				
DM, kg/d	24.1	23.6	0.81	0.81
DM, % of BW	3.30	3.35	0.098	0.71
CP, kg/d	4.3	4.1	0.14	0.34
NDF, kg/d	9.7	8.3	0.33	<0.01
NDF, % of BW	1.35	1.18	0.035	<0.01
ADF, kg/d	5.9	5.0	0.22	<0.01
Yield, kg/d				
Milk	38.9	37.0	1.95	0.60
ECM	43.8	38.6	1.67	0.03
4% FCM	41.8	35.5	1.69	0.02
SCM	41.1	35.6	1.65	0.03
Fat	1.73	1.38	0.085	0.04
Protein	1.23	1.21	0.051	0.82
Lactose	1.87	1.68	0.105	0.44
TS	5.21	4.64	0.244	0.29
SNF	3.48	3.26	0.171	0.67
Milk efficiency ³	1.61	1.60	0.084	0.73
Composition, %				
Fat	4.35	3.78	0.147	0.04
Protein	3.12	3.29	0.073	0.15
Lactose	4.69	4.53	0.060	0.06
TS	13.11	12.60	0.210	0.24
SNF	8.77	8.82	0.106	0.59
MUN, mg/dL	12.4	11.2	0.64	0.23

¹Pooled standard error of the mean.²P-values for treatment effects.³Milk yield/DMI.

alone and not as a part of a TMR as in our study. Cows fed MS consumed more ($P < 0.05$) NDF than did cows fed CS (Table 3), likely due to the higher NDF content of MS relative to CS (Table 2). In agreement with our findings, Ward et al. (2001) found that heifers fed forage pearl millet silage consumed more NDF than did heifers fed sorghum or tropical corn silages. Mertens (1997) suggested that cows should be able to consume 1.1% of their BW/d as NDF, without limiting milk production, which is in agreement with the consumption of cows fed CS. However, some studies reported that dairy cows could consume higher NDF (e.g., 1.39% of BW) without negatively affecting milk production (Ivan et al., 2005). The NDF intake reported by Ivan et al. (2005) is similar to that reported for cows fed MS (Table 3). Higher NDF digestibility and lower indigestible NDF (Table 2) might have contributed to the high NDF intake by cows fed MS.

Milk yield was similar for both dietary treatments and averaged 38 kg/d (Table 3). However, ECM, SCM, and 4% FCM were all greater ($P < 0.05$) for cows fed MS than for those fed CS. Data regarding performance of dairy cows fed MS are limited. Replacing a combination of CS and alfalfa silage with a combination of PM and alfalfa silage resulted in similar milk yields and 4%

FCM (Messman et al., 1992). Milk fat concentration was greater ($P < 0.05$) in the milk of cows fed MS than in the milk of cows fed CS (Table 3). However, concentrations of other milk components were not affected by silage type. The ratio of NDF:starch was higher in the MS diet than in the CS diet (1.71 vs. 1.19, Table 1), which may explain the difference in milk fat concentrations between dietary treatments. Increasing ruminally degradable starch decreased milk fat concentration without affecting milk yield (Slater et al., 2000). Beckman and Weiss (2005) reported a linear decrease in milk fat concentration as the dietary NDF:starch ratio decreased. Our results regarding milk fat concentrations are different from those of Messman et al. (1992), which showed similar milk fat concentrations for cows fed MS or CS. This discrepancy could be caused by differences in forage:concentrate ratio. The level of CS (66.5 vs. 50% of total forages) was higher in our study than in the Messman et al. (1992) study.

Results from this study demonstrated considerable potential for pearl millet silage as a source of forage for lactating dairy cows. A complete replacement of corn silage with pearl millet silage showed no detrimental effects on dairy cow feed intake or milk yield. A major advantage of feeding pearl millet silage relative to corn

silage was the increased milk fat concentration, which resulted in greater ECM and 4% FCM. Further studies are required to investigate the effects of MS on milk fat concentration under various dietary regimens. Factors such as stage of maturity at harvest and different forage:concentrate ratios warrant further investigation.

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