Corn Silage Hybrid Effects on Intake, Digestion, and Milk Production by Dairy Cows

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ABSTRACT

Three corn hybrids harvested as whole-plant silage were evaluated in three separate feeding trials with lactating dairy cows. In trial 1, 24 multiparous Holstein cows were used in a replicated 4 × 4 Latin square with 28-d periods. Treatments were conventional (Pioneer 3563) and leafy (Mycogen TMF 106) corn silage hybrids, each planted at low (59,000 plants/ha) and high (79,000 plants/ha) plant populations. There were no milk production differences between treatments. Total-tract digestibility of dietary starch was higher for leafy compared with conventional corn hybrids. In trial 2, 26 multiparous Holstein cows were assigned randomly to diets containing either conventional (48% forage diet) or brown-midrib (60% forage diet) corn silage in a crossover design with 8-wk periods. Milk yield was lower, but milk fat percentage and yield were higher, for the high-forage diet containing brown-midrib corn silage. In trial 3, 24 multiparous Holstein cows were used in a replicated 4 × 4 Latin square with 28-d periods. Treatments were corn silage at two concentrations of neutral detergent fiber (Garst 8751, 39.2% NDF; Cargill 3677, 32.8% NDF) each fed in normal- (53% of dry matter) and high- (61 to 67% of dry matter) forage diets. Milk production was not different between corn hybrids. Increased concentrate supplementation increased DMI and milk production. There were minimal benefits to the feeding of leafy or low-fiber corn silage hybrids. Feeding brown-midrib corn silage in a high-forage diet increased milk fat percentage and yield compared with conventional corn silage fed in a normal-forage diet.

(**Key words:** corn silage, intake, digestion, milk production)

Abbreviation key: bm3 = brown-midrib hybrid or corn silage, **CH** = conventional hybrid or corn silage, **LFY** = leafy hybrid or corn silage, **ML** = milkline, **TLC** = theoretical length of cut, **WPCS** = whole-plant corn silage, **39NDF** = 39% NDF corn silage, **33NDF** = 33% NDF corn silage.

INTRODUCTION

Corn hybrids traditionally have been selected on grain yield for production of both corn grain and whole-plant corn silage (**WPCS**). However, hybrids selected for high grain yield may not be the highest yielding hybrids for WPCS (Coors et al., 1994). Also, this selection strategy ignores differences in the nutritive value of WPCS related to corn genetics.

Although differences in fiber concentrations and in vitro digestibilities of WPCS produced from hybrids selected using conventional grain breeding strategies have been reported (Hunt et al., 1992), feeding trials to evaluate animal performance differences are limited. Hunt et al. (1993) and Barriere et al. (1995) reported improved gain and feed efficiency in beef steers and DMI and milk yield in dairy cattle, respectively, due to hybrid-related improvements in WPCS nutritive value.

Corn silage produced from brown-midrib (**bm3**) hybrids is noted for its reduced lignin content and increased in vitro NDF digestibility (Oba and Allen, 1999). Agronomic evaluations of bm3 hybrids have been discouraging because of poor grain and forage yields (Coors et al., 1994). Increased DMI and milk production have been reported for bm3 corn silage compared with its isogenic normal counterpart (Oba and Allen, 1999). Leafy (**LFY**) corn hybrids are characterized by more leaves above the ear and, in some cases, higher grain moisture content or softer kernel texture (Dwyer et al., 1998; Shaver, 1983). Several LFY hybrids are widely marketed, and approximately 16% of North American silage production is from LFY hybrids (Dwyer et al., 1998). Feeding trials with leafy WPCS are limited (Kuehn et al., 1999).

Our objectives were to evaluate WPCS hybrid effects on intake, lactation performance, and digestion by dairy cows.

MATERIALS AND METHODS

Trial 1

Conventional (**CH**; Pioneer 3563) and LFY (Mycogen TMF 106) corn hybrids were planted at both low (59,000

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plants/ha) and high (79,000 plants/ha) plant populations in four separate 1.2-ha plots within one 4.8-ha field at the University of Wisconsin West Madison Agricultural Research Station in early May 1996. Plant population was included as a main effect in a factorial design, because seed companies often recommend lower plant populations for LFY than CH presumably because of increased proportion of grain (Dwyer et al., 1998) and reduced NDF concentration (Cox et al., 1998) in WPCS produced from low plant populations. Harvest was as WPCS at 1/2 milkline (1/2 **ML**) stage of maturity using a Gehl 8-knife chopper (model 860) set for 0.93-cm theoretical length of cut (**TLC**). Treatment WPCS were stored in separate 2.4-m diameter silo bags. Moisture concentrations at harvest were 65.4 and 70.0% for CH and LFY, respectively. Actual plant populations and DM yields at harvest were 61,000, 79,500, 61,000, and 71,400 plants/ha and 15.1, 21.1, 17.8, and 18.3 tonne/ha for CH at low and high and LFY at low and high plant populations, respectively.

Twenty-four multiparous Holstein cows averaging 75 DIM (SD = 22; range 46 to 112 d) at trial initiation were assigned randomly to a replicated 4 × 4 Latin square in a 2 × 2 factorial arrangement of treatments. Periods were 28 d long; the first 14 d of each period were for dietary adaptation with sampling during d 15 to 28 of each period. All cows were injected with bST (Posilac, Monsanto Company, St. Louis, MO) every 14 d starting on d 1 of the experiment. Treatment WPCS, alfalfa silage, and concentrate mixture were fed as TMR once daily. Cows were housed and fed individually in tie stalls. The TMR comprised 33.5% treatment WPCS, 16.5% alfalfa silage, and 50% concentrate mixture (DM basis; Table 1). The forage mixture was limited to two-thirds corn silage to keep it practical relative to dairy producers in the region and to minimize potential digestive problems that may arise when feeding an all corn silage diet. Diets were formulated to contain 17.5% CP (DM basis) and to meet or exceed NRC (1989) requirements for minerals and vitamins.

Cows were milked twice daily, and production was recorded at each milking. Milk fat, CP, and urea-nitrogen concentrations were determined on a.m. and p.m. samples taken on 3 consecutive days during wk 3 and 4 of each period by infrared analysis (AgSource Milk Analysis Laboratory, Menomonie, WI). Milk composition was calculated as an average of a.m. and p.m. samples using the proportion of daily production at that milking as a weighting factor. Body weights were recorded on d 26 to 28 of each period at the same time each day.

Treatment WPCS and alfalfa silage DM concentrations were measured weekly using toluene distillation (Dewar and McDonald, 1961) for adjustment of as-fed ratios of dietary ingredients. Treatment WPCS, alfalfa silage, and concentrate mixture were sampled on d 15 and 16 and d 21 and 22 of each period and composited by treatment within period for nutrient analysis. Diet refusal samples were collected on d 26 to 28 of each period and composited by cow within period for nutrient analysis. Samples were dried in a 60°C forced-air oven for 48 h and then ground through a Wiley mill (1-mm screen; Arthur H. Thomas, Philadelphia, PA). Feed and refusal samples were analyzed for DM, OM, and CP (AOAC, 1990), NDF using α-amylase (Sigma no. A3306; Sigma Chemical Co., St. Louis, MO) and sodium sulfite (Van Soest et al., 1991), ADF (Goering and Van Soest, 1970), and lignin (Goering and Van Soest, 1970). Crude protein was determined by measuring total nitrogen us-

Table 1. Diet ingredient and nutrient composition for trial 1.

Ingredient, % of DM		Nutrient, % of DM	Treatment[5]			
			CHL	CHH	LFYL	LFYH
Corn silage	33.5					
Alfalfa silage[1]	16.5	OM	92.1	92.1	92.0	92.1
Shelled corn	26.5	CP	16.5	16.4	16.6	16.5
Soybean meal	18.6	NDF	30.5	30.8	30.8	31.1
Meat meal	1.7	ADF	19.7	20.1	20.1	20.0
Urea	0.2	Starch	28.4	28.4	28.8	27.6
Limestone	0.8					
Sodium bicarbonate	0.8					
Dicalcium phosphate	0.4					
Trace-mineralized salt[2]	0.4					
Dynamate[3]	0.2					
Magnesium oxide	0.2					
Vitamin premix[4]	0.2					

[1] Contained 18.1% CP, 54.4% NDF, and 47.4% ADF (DM basis).

[2] Contained 0.55% Mn, 0.55% Zn, 0.35% Fe, 0.14% Cu, 0.008% I, 0.006% Se, and 0.002% Co.

[3] 18% K, 11% Mg, 22% S, Pitman Moore, Inc. (Mundelein, IL).

[4] Contained 2665 IU/g of vitamin A, 900 IU/g of vitamin D, and 3.52 IU/g of vitamin E.

[5] CHL = Conventional hybrid at low plant population, CHH = Conventional hybrid at high plant population, LFYL = Leafy hybrid at low plant population, and LFYH = Leafy hybrid at high plant population.

ing the thermoconductance method in a LECO FP-2000 (Leco, St. Joseph, MI). Starch determination on feed, orts, and fecal samples was by endoamylase and exoglucosidase incubation before glucose oxidase assay (Sigma no. 510-A; Sigma Chemical Co.) as described by Herrera-Saldana et al. (1990). Treatment WPCS were analyzed for pH, lactic acid, and VFA as described by Muck and Dickerson (1988).

Total-tract digestibilities of DM, OM, CP, NDF, ADF, and starch were measured using Yb as an external marker. Ytterbium (876 g) was mixed in solution as described by Shaver et al. (1986) and sprayed onto 136 kg of wheat middlings in a horizontal ribbon mixer to prepare labeled premix for the trial. Each cow received 135 g of labeled wheat middlings mixed in TMR on d 18 through 28 of each period to provide 35 mg/kg of Yb in dietary DM. Samples of feces (1000, 1600, and 2200 h) and orts were collected daily during the last 3 d of each period. Samples were dried in a forced-air oven at 60°C for 96 h and then ground through a Wiley mill (1-mm screen). Samples of feces and orts were composited for each cow within period and analyzed for DM, OM, CP, ADF, NDF, and starch as described previously. The concentrations of Yb in fecal and orts composites were determined by direct current plasma emission spectroscopy after dry-ashing at 500°C for 16 h (Combs and Satter, 1992). Nutrient digestibilities were calculated using Yb and nutrient concentrations in diet, orts, and fecal samples.

Animal performance and digestibility data were analyzed using the general linear models procedure of SAS (1998) for a replicated Latin square design. Hybrid, plant population, and hybrid by plant population effects were tested for all variables. All mean comparisons were by the least significant difference method after a significant ($P < 0.05$) F-test.

Trial 2

Conventional (Pioneer 3563) and bm3 (Cargill F657) corn hybrids were both planted at 80,000 plants/ha in two 2.4-ha plots within one 4.8-ha field at the University of Wisconsin West Madison Agricultural Research Station in late April, 1997. The bm3 was compared to CH rather than its isogenic normal counterpart, because bm3 versus CH has the most practical significance to dairy farmers and others (Oba and Allen, 1998, 1999) have recently evaluated bm3 versus its isogenic normal counterpart. Harvest was as WPCS at 1/2 ML stage of maturity using a Gehl 8 knife chopper (model 860) set for 0.93-cm TLC. Harvest maturity was at 1/2 ML and 5 d earlier for CH compared to bm3. Moisture concentrations at harvest were 68.6 and 69.4% for CH and bm3, respectively. Treatment WPCS were stored in upright concrete-stave silos.

Table 2. Diet ingredient and nutrient composition for trial 2.

Item	Treatment[1] CH	bm3
	% of DM	
Ingredient		
Corn silage	32.0	40.2
Alfalfa silage[2]	15.5	20.2
Whole cotton seed	6.7	6.7
Shelled corn	27.3	15.4
Soybean meal, solvent	7.3	6.5
Soybean meal, expeller[3]	7.4	7.4
Urea	0.3	0.3
Limestone	1.1	0.9
Sodium bicarbonate	0.8	0.8
Dicalcium phosphate	0.7	0.7
Trace-mineralized salt[4]	0.4	0.4
Dynamate[5]	0.1	0.1
Magnesium oxide	0.2	0.2
Vitamin premix[6]	0.2	0.2
	% of DM	
Nutrient		
OM	91.9	91.2
CP	17.2	17.1
NDF	27.5	29.4
ADF	16.9	19.1
Starch	29.1	19.9

[1] CH = Conventional WPCS diet and bm3 = Brown-midrib WPCS diet.

[2] Contained 19.9% CP, 35.2% NDF, and 28.3% ADF (DM basis).

[3] Soy Plus, West Central Cooperative, Ralston, IA.

[4] Contained 0.55% Mn, 0.55% Zn, 0.35% Fe, 0.14% Cu, 0.008% I, 0.006% Se, and 0.002% Co.

[5] 18% K, 11% Mg, 22% S, Pitman Moore, Inc. (Mundelein, IL).

[6] Contained 2665 IU/g of vitamin A, 900 IU/kg of vitamin D, and 3.52 IU/g of vitamin E.

Twenty-six multiparous Holstein cows averaging 120 DIM (SD = 35; range 63 to 159 d) at trial initiation were assigned randomly to CH or bm3 diets in a crossover design with 8-wk periods. Our supply of bm3 corn silage ran short, so the trial was terminated after the seventh week of period 2. Treatment WPCS, alfalfa silage, whole cottonseed, and concentrate mixture were fed as TMR once daily. Cows were housed and fed individually in tie stalls. All cows were injected with bST (Posilac, Monsanto Company, St. Louis, MO) every 14 d starting on d 1 of the experiment. Dietary ingredient composition is presented in Table 2. Diets containing 47.5 and 60.4% forage (DM basis) for CH and bm3, respectively, were formulated to contain 17.5% CP (DM basis) and to meet or exceed NRC (1989) requirements for minerals and vitamins. A higher concentration of dietary forage was used in the bm3 diet than the CH diet, because Oba and Allen (1998) observed that feeding bm3 reduced milk fat percentage in normal-NDF diets but not in high-NDF diets.

Cows were milked twice daily, and production was recorded at each milking. Milk fat, CP, and urea-nitrogen concentrations were determined on a.m. and p.m. samples taken on 2 consecutive days during wk 5, 6, 7 and 8 of period 1, and wk 13, 14, and 15 of period 2 by infrared analysis (AgSource Milk Analysis Laboratory). Milk composition was calculated as described previously. Body weights were recorded on 3 consecutive days at the same time each day during wk 1, 8, and 15.

Treatment WPCS and alfalfa silage DM concentrations were measured weekly using toluene distillation (Dewar and McDonald, 1961) for adjustment of as-fed ratios of dietary ingredients. Treatment WPCS, alfalfa silage, and concentrate mixtures were sampled weekly and composited by period for nutrient analysis. Feed composites were dried in a 60°C forced-air oven for 48 h, ground to pass a 1-mm Wiley mill screen (Arthur H. Thomas, Philadelphia, PA), and analyzed for DM, OM, CP, NDF, ADF, and lignin as described previously and starch (Bal et al., 2000a). The WPCS treatments were analyzed for pH, lactic acid, and VFA as described by Muck and Dickerson (1988).

Data were analyzed as a crossover design using the general linear models procedure of SAS (1998). Mean comparisons were by least significant difference method after a significant ($P < 0.05$) treatment effect.

Trial 3

Normal-NDF (**39NDF**; Garst 8751) and low-NDF (**33NDF**; Cargill 3677) corn silage hybrids were planted at 80,000 plants per hectare in two separate 10-ha plots within one 20-ha field at the University of Wisconsin Arlington Agricultural Research Station on the same day in May, 1998. These two hybrids were used because of their large 6-yr average difference in whole-plant ADF (4% units) and NDF (6% units) when compared in agronomic corn hybrid performance trials conducted in southern Wisconsin (Lauer et al., 1997). Treatments were harvested on the same day as WPCS using a Gehl crop-processing harvester set at 1.27-cm TLC and 2-mm roll clearance. The stage of maturity at harvest was 1/3 ML for 39NDF and 1/2 ML for 33NDF, reflecting slight differences in relative maturity ratings for these hybrids. Corn silage treatments were stored in separate 2.4-m-diameter silo bags with 0.2% propionic acid-based preservative (Ultra-Curb, Kemin Industries, Des Moines, IA) added at ensiling to improve aerobic stability during feed-out.

Twenty-four multiparous Holstein cows averaging 75 DIM (SD = 15; range 54 to 101) at trial initiation were assigned randomly in a replicated 4 × 4 Latin square design with 28-d periods. Both treatment WPCS were fed in normal- (53% forage and 19 to 21% NDF from forage) and high- (61 to 67% forage and 24% NDF from forage) forage diets. Corn silage hybrid and diet were main effects in the 2 × 2 factorial design. The first 14 d of each period were for diet adaptation. and sampling was during d 15 to 28 of each period. All cows were injected with bST (Posilac) every 14 d starting on d 1 of the experiment. The ingredient composition of diets is presented in Table 3. Dietary ingredients were fed as TMR once daily. Cows were housed and fed individually in tie stalls. Diets were formulated to contain 18.0% CP (DM basis) and to meet or exceed NRC (1989) requirements for minerals and vitamins.

Cows were milked twice daily, and production was recorded at each milking. Milk fat, CP, and urea-nitrogen concentrations were determined on a.m. and p.m. samples taken on 3 consecutive days during wk 3 and 4 of each period by infrared analysis (AgSource Milk Analysis Laboratory). Milk composition was calculated as described previously. Body weights were recorded on 3 consecutive days at the same time each day at the start of the trial and on d 26 to 28 of each period.

Treatment WPCS and alfalfa silage DM concentrations were measured weekly with a 60°C forced-air oven to adjust as-fed ratios of diet ingredients. Treatment WPCS, alfalfa silage, and concentrate mixtures were sampled during wk 3 and 4 of each period and composited by period for nutrient analysis. Feed refusal samples were collected on d 26 to 28 of each period and composited by cow within period. Samples were dried in a 60°C forced-air oven for 48 h, ground to pass a 1-mm Wiley mill screen, and analyzed for DM, OM, CP, NDF, ADF, and lignin as described previously. Starch content of feed and ort samples was determined as described by Bal et al. (2000a). Treatment WPCS were analyzed for pH, lactic acid, and VFA as described by Muck and Dickerson (1988).

Ruminal fluid was sampled before the morning feeding (0800 h) and at 3, 6, 9, and 12 h after feeding on d 25 of each period. Samples were taken from five different locations of the rumen via the cannula using a custom-made metal filter probe, and pH was determined immediately (Twin pH meter Model B-213, Spectrum Technologies Inc., Plainfield, IL). Duplicate 10-ml samples of rumen fluid were acidified with 0.2 ml of 50% H_2SO_4 and frozen until analysis for VFA. These samples were prepared and analyzed as described by Bal et al., (2000a).

Total-tract digestibilities of DM, OM, CP, ADF, NDF, and starch were measured using La as an external marker. Lanthanum (960 g) was mixed in solution as described by Hartnell and Satter (1979) and sprayed on to 120 kg of wheat middlings in a horizontal ribbon mixer to prepare labeled premix for the trial. Each cow received 114 g of labeled wheat middlings mixed in TMR on d 18 through 28 of each period to provide 35 mg/kg of La in

Table 3. Diet ingredient and nutrient composition for trial 3.

	Diet[1]			
	High forage		Normal forage	
Item	39NDF	33NDF	39NDF	33NDF
	% of DM			
Ingredient				
Corn silage	40.4	44.4	35.6	35.6
Alfalfa silage[2]	20.2	22.1	17.5	17.5
Shelled corn	17.2	12.1	24.0	24.7
Soybean meal, solvent	7.6	5.8	9.0	8.6
Soybean meal, expeller[3]	10.6	11.5	9.8	9.6
Urea	0.4	0.4	0.4	0.4
Limestone	1.2	1.2	1.2	1.2
Sodium bicarbonate	0.8	0.8	0.8	0.8
Dicalcium phosphate	0.5	0.5	0.5	0.5
Salt	0.4	0.4	0.4	0.4
Trace-mineralized salt[4]	0.2	0.2	0.2	0.2
Dynamate[5]	0.2	0.2	0.2	0.2
Magnesium oxide	0.2	0.2	0.2	0.2
Vitamin premix[6]	0.2	0.2	0.2	0.2
	% of DM			
Nutrient				
OM	91.6	91.3	91.8	91.6
CP	17.5	17.4	18.2	17.2
NDF	29.2	28.2	27.2	24.8
NDF from forage	23.9	23.5	20.9	18.6
ADF	19.0	18.8	17.3	15.6
Starch	22.6	22.8	24.4	28.2

[1] High forage = 61 to 67% forage; Normal forage = 53% forage; 39NDF = Normal NDF corn silage; 33NDF = Low NDF corn silage.

[2] Contained 21.2% CP, 40.0% NDF, and 35.8% ADF (DM basis).

[3] Soy Plus, West Central Cooperative, Ralston, IA.

[4] Contained 0.55% Mn, 0.55% Zn, 0.35% Fe, 0.14% Cu, 0.008% I, 0.006% Se, and 0.002% Co.

[5] 18% K, 11% Mg, 22%, S. Pitman Moore, Inc. (Mundelein, IL).

[6] Contained 2665 IU/g of vitamin A, 900 IU/g of vitamin D, and 3.52 IU/g of vitamin E.

diet DM. Fecal and orts samples were collected daily as described previously. Sample processing and marker analysis on fecal and orts samples and nutrient digestibility calculations were as described previously.

Animal performance and digestibility data were analyzed as a replicated Latin square design using the general linear models procedure of SAS (1998). Effects of hybrid, diet, and their interaction were tested. Ruminal pH and VFA data were analyzed using PROC MIXED of SAS (Littell et al., 1996) for repeated measures. All mean comparisons were by the least significant difference method after a significant ($P < 0.05$) treatment effect.

RESULTS AND DISCUSSION

Trial 1

Chemical composition and fermentation characteristics of WPCS treatments are presented in Table 4. Although harvested at a similar kernel milkline positioning, the moisture content of LFY was higher than CH at both low and high plant populations. This trend for higher whole-plant moisture content for LFY versus CH is in agreement with Dwyer et al. (1998). Silage pH tended to be lower and lactate concentration higher for LFY than CH, which was likely related to its higher moisture and sugar contents (McDonald et al., 1991). Concentrations of NDF and starch varied little among treatments, but NDF was highest and starch lowest for LFY at the high plant population. Cox et al. (1998) reported that NDF concentration of WPCS increased as plant population increased.

Diet nutrient composition appears in Table 1, and varied little among treatments. Diet CP concentrations were lower than as formulated due to lower CP concentration of soybean meal and alfalfa silage than anticipated when doing pretrial formulations. Diet NDF and ADF concentrations slightly exceeded NRC (1989) minimum guidelines.

Treatment effects on DMI and milk production are presented in Table 5. There was a trend ($P < 0.1$) for higher DMI for CH compared with LFY. Yields of milk,

Table 4. Chemical composition and fermentation characteristics of treatment corn hybrids harvested as whole-plant corn silage in trials 1, 2, and 3.

Treatment[1]	% Moisture	pH	CP	NDF	ADF	Lignin	Starch	Lactate	Acetate	Propionate
	% of DM									
Trial 1										
CHL	64.6	3.94	7.0	44.6	26.8	3.3	28.5	5.55	1.44	0.39
CHH	63.6	3.93	6.9	45.7	28.0	3.0	28.6	5.81	1.38	0.40
LFYL	67.1	3.86	7.4	45.5	27.9	3.0	29.6	6.51	1.74	0.23
LFYH	68.1	3.85	7.1	46.5	27.7	3.0	26.2	6.38	1.86	0.29
Trial 2										
CH	65.7	3.90	6.9	41.6	24.0	2.5	26.6	4.54	1.64	0.39
BMR	67.8	3.84	7.8	38.1	23.0	1.6	24.3	5.74	1.24	. . .
Trial 3										
39NDF	63.3	3.89	7.7	39.2	22.7	2.6	24.0	5.19	1.36	0.34
33NDF	65.8	3.93	7.2	32.8	18.9	2.3	33.8	6.24	1.47	0.24

[1] CHL = Conventional hybrid at low plant population, CHH = conventional hybrid at high plant population, LFYL = leafy hybrid at low plant population, LFYH = leafy hybrid at high plant population, CH = conventional hybrid, BMR = brown-midrib hybrid, 39NDF = High-NDF hybrid, and 33NDF = Low-NDF hybrid.

4% FCM, fat, and protein did not differ among treatments, averaging 40.4, 37.5, 1.43, and 1.37 kg/d, respectively. These findings for LFY versus CH agree with those of Kuehn et al. (1999) and Mandebvu et al. (1999). There was a trend ($P < 0.1$) for higher milk fat percentage for LFY compared to CH. This trend was most pronounced at the high plant population (hybrid by plant population effect; $P < 0.05$), which was possibly related to higher NDF and lower starch concentrations for this WPCS treatment. Valdez et al. (1989) reported higher milk fat percentage (3.5 vs. 3.2%) when a late maturing hybrid was planted at a high versus low plant population. In our trial, milk CP percentage was higher for the low plant population. This may be related to a higher proportion of grain at low plant populations (Dwyer et al., 1998).

Treatment effects on total-tract nutrient digestibility and intake are presented in Table 6. Digestibilities of DM and OM were higher for CH than LFY. Both NDF and ADF digestibilities were higher for CH than LFY. These differences were greater (hybrid by plant population effect; $P < 0.05$) at the low plant population. Kuehn et al. (1999) found no differences between CH and LFY for total-tract DM digestibility or in vitro NDF digestibility. Mandebvu et al. (1999) found no differences between CH and LFY for in vitro DM and NDF digestibilities. Starch digestibility was higher in LFY than in CH. This was possibly related to higher grain moisture content or softer kernel texture for LFY (Dwyer et al., 1998; Shaver, 1983). Bal et al. (2000b) reported greater ruminal starch disappearance for LFY than CH corn silage. Using diet and WPCS starch concentrations found in Tables 1 and

Table 5. Treatment effects on DMI, BW, and milk production for trial 1.

	Treatment[1]					
Item	CHL	CHH	LFYL	LFYH	SEM	Effect[2]
DMI						
kg/d	27.4	27.7	27.1	26.8	0.3	NS
% of BW	4.16	4.24	4.14	4.09	0.05	NS
BW, kg	659	655	655	657	2.4	NS
Production, kg/d						
Milk	40.2	40.8	40.4	40.2	0.5	NS
4% FCM	37.6	37.4	37.7	37.4	0.5	NS
Fat	1.43	1.41	1.44	1.42	0.02	NS
CP	1.37	1.37	1.38	1.34	0.02	NS
Composition, %						
Fat	3.56	3.45	3.55	3.60	0.04	H*PP
CP	3.41	3.36	3.42	3.36	0.02	PP
Urea nitrogen, mg/dl	14.6	14.9	15.1	14.9	0.3	NS

[1] CHL = Conventional hybrid at low plant population, CHH = conventional hybrid at high plant population, LFYL = leafy hybrid at low plant population, and LFYH = leafy hybrid at high plant population.

[2] H = Hybrid, PP = planting population, and interaction effects at $P < 0.05$ and NS = nonsignificant.

Table 6. Treatment effects on total-tract nutrient digestibility for trial 1.

Total tract nutrient digestibility, %	Treatment[1] CHL	CHH	LFYL	LFYH	SEM	Effect[2]
DM	61.8	59.9	58.7	58.9	0.7	H
OM	65.1	63.1	62.4	62.3	0.6	H
CP	63.3	61.6	61.0	60.8	1.0	NS
NDF	33.6	29.2	26.7	28.1	1.3	H, H*PP
ADF	35.8	31.1	29.0	29.9	1.4	H, H*PP
Starch	92.3	92.4	94.2	94.4	0.6	H

[1] CHL = Conventional hybrid at low plant population, CHH = conventional hybrid at high plant population, LFYL = leafy hybrid at low plant population, and LFYH = leafy hybrid at high plant population.

[2] H = Hybrid, PP = plant population, and interaction effects at $P < 0.05$, and NS = nonsignificant.

4, respectively, and assuming 95% starch digestibility for non-WPCS starch (Bal et al., 1997), we calculated WPCS starch digestibilities of 86% for CH and 93% for LFY. Intake of digestible DM, OM, NDF, and ADF followed the same pattern as respective digestibilities (data not presented in table). However, intake of digestible starch did not differ between CH and LFY, averaging 7.2 kg/d. Although starch digestibility was higher for LFY, the trend for higher DMI for CH caused similar intakes of digestible starch.

Trial 2

The chemical composition and fermentation characteristics of WPCS treatments are presented in Table 4. Moisture content was 2.1 percentage units higher for bm3 than CH. Crude protein concentration was higher for bm3 than CH. Lower NDF, ADF, and lignin concentrations for bm3 than CH in this experiment are in agreement with the comparison of bm3 to its isogenic counterpart by Oba and Allen (1999). There were trends for lower pH and starch concentration but higher lactate concentration for bm3 than CH. Lower pH and higher lactate concentration for bm3 could be related to its higher moisture and sugar contents (McDonald et al., 1991).

Dietary ingredient and nutrient composition appear in Table 2. Dietary concentrations of NDF and ADF were higher, but starch content was lower for bm3 than CH. This was related to the higher proportion of dietary forage (60.4 vs. 47.5%) and lower proportion of shelled corn (15.4 vs. 27.3%) in bm3 diet than CH diet.

Treatment effects on DMI and milk production are presented in Table 7. Dry matter intake was not different between treatments. This may have been related to the higher forage content of the bm3 diet. Other studies reported either higher DMI (Block et al., 1981; Oba and Allen, 1999; Rook et al., 1977) or no change in DMI (Keith et al., 1979) for bm3. Milk production was 1.4 kg/d higher for CH than BMR. Oba and Allen (1999) reported a 2.8 kg/d milk production increase for bm3 compared with its isogenic normal counterpart in 56% forage diets. Keith et al. (1979) reported that milk production increased 1.3 and 1.6 kg/d for bm3 compared with its isogenic normal counterpart in 75 and 60% forage diets, respectively. However, others (Block et al., 1981; Rook et al., 1977) reported no milk production response to bm3. Milk fat percentage and yield increased by 0.08 percentage units and 0.28 kg/d, respectively, for bm3 compared to CH. Two studies (Oba and Allen, 1999; Rook et al., 1977) reported higher milk fat percentage, but not yield, for bm3. Keith et al. (1979) reported no milk fat percentage or yield difference between bm3 and its isogenic normal counterpart. However, Block et al. (1981) found a 0.28 percentage unit reduction in milk fat test for bm3 compared to its isogenic normal counterpart. Variable milk fat responses could be due to differences in dietary forage and fiber concentrations among experiments. The higher forage content (60 vs. 48%) of bm3 diet may explain the higher milk fat percentage for this treatment. Feeding bm3 in 29% NDF diets increased DMI and milk yield but reduced fat percentage (Oba and Allen, 1998), while feeding bm3 in 38% NDF diets did not reduce milk fat test. Their (Oba and Allen, 1998) comparison of bm3 in the high-NDF diet versus its iso-

Table 7. Treatment effects on DMI, BW change, and milk yield, composition, and component yields for trial 2.

Item	Treatment[1] CH	bm3	SEM	*P*
DMI, kg/d	28.4	28.4	0.1	NS[2]
BW change, kg/d	0.53	0.57	0.06	NS
Milk, kg/d	44.5	43.1	0.2	0.001
4% FCM, kg/d	38.6	39.1	0.4	NS
Fat, %	3.18	3.46	0.05	0.001
Fat, kg/d	1.40	1.48	0.02	0.02
CP, %	3.27	3.20	0.01	0.001
CP, kg/d	1.43	1.35	0.01	0.001
Urea nitrogen, mg/dl	16.1	16.5	0.2	NS

[1] CH = Conventional WPCS diet and bm3 = brown-midrib WPCS diet.

[2] NS = Nonsignificant.

genic normal counterpart in the normal-NDF diet gave similar results to ours. Milk protein percentage and yield were lower for bm3 compared with CH. Others (Block et al., 1981; Keith et al., 1979; Rook et al., 1977) reported no difference in milk protein percentage or yield between bm3 and its isogenic normal counterpart. However, Oba and Allen (1999) found a slight increase in milk protein percentage (2.99 vs. 2.95%) for bm3 compared with CH. In our study, the lower protein percentage observed for bm3 was likely related to the lower starch content of this diet.

Trial 3

Chemical composition and fermentation characteristics of WPCS treatments are presented in Table 4. Moisture content was 2.5 percentage units higher for 33NDF than 39NDF. Concentrations of CP, NDF, ADF, and lignin were 0.5, 6.4, 3.8, and 0.3 percentage units higher, respectively, for 39NDF than 33NDF. Differences in NDF and ADF concentrations between the two hybrids were as expected based on agronomic performance trials from prior years, but fiber values were lower than expected for both hybrids (Lauer et al., 1997). Coors (1996) reported year and hybrid × year effects ($P < .01$) for whole-plant NDF percentage, which may explain the low fiber values observed in our trial. Starch concentration was 9.8 percentage units lower for 39NDF than 33NDF. Higher lactate and acetate concentrations for 33NDF compared to 39NDF were likely related to its higher moisture and sugar contents (McDonald et al., 1991).

Dietary nutrient composition is presented in Table 3. Dietary NDF (28.7 vs. 26.0%) and ADF (18.9 vs. 16.5%) concentrations were higher but starch concentration (22.7 vs. 26.3%) was lower for high- than normal-forage diets. Average dietary NDF concentrations were above NRC (1989) minimum guidelines. Average dietary ADF concentrations fell below NRC (1989) minimum guidelines for the normal-forage diets. Dietary NDF from forage averaged 23.7% for high-forage diets and 19.8% for normal-forage diets.

Treatment effects on DM and NDF intakes and milk production are presented in Table 8. Intakes of DM (27.2 vs. 26.7 kg/d) and NDF (7.7 vs. 7.0 kg/d) were higher for 39NDF than 33NDF. Since there was increased dietary NDF digestibility for 39NDF compared with 33NDF (Table 9), higher DMI for this treatment might be related to higher dietary fiber digestibility. Feeding normal-forage diets increased DMI (27.7 vs. 26.2 kg/d) compared with high-forage diets, but reduced NDF intake (7.1 vs. 7.5 kg/d). Increased DMI associated with increased concentrate supplementation in lactating dairy cows is in agreement with (Friggens et al., 1998; Robinson and McQueen, 1997). Body weight change was not affected by treatment. Feeding low-fiber corn silage tended to increase average daily gain and feed efficiency in growing steers compared to feeding high-fiber corn silage (Mueller et al., 1998).

There was no effect of hybrid on milk yield or composition. Feeding normal-forage diets increased yields of milk and FCM by 2.4 and 1.2 kg/d, respectively, compared with high-forage diets. Others (Friggens et al., 1998; Robinson and McQueen, 1997) have observed increased milk yield associated with increased concentrate supplementation. Feeding normal-forage diets reduced milk fat content (3.46 vs. 3.61%) compared with high-forage diets, but CP content was increased (3.14 vs. 3.06%). Yields of milk CP (1.40 vs. 1.30 kg/d) and lactose (2.15 vs. 2.02 kg/d) were higher for cows fed normal-forage than high-forage diets.

Treatment effects on ruminal pH and VFA are presented in Table 10. There were no treatment × time interactions, so data presented in the table are average values from the five sampling times. Ruminal pH was reduced (6.21 vs. 6.31) for cows fed normal-forage compared with high-forage diets. Total VFA concentration did not differ between treatments, averaging 135.0 m*M*. Molar percentage of acetate was lower (54.2 vs. 56.6%) and propionate molar percentage was higher (24.7 versus 22.4%) for cows fed normal-forage compared with high-forage diets. Average acetate to propionate ratios (2.3 vs. 2.6) were reduced for cows fed normal-forage compared with high-forage diets, particularly for 33NDF (hybrid × diet effect; $P < 0.05$).

Treatment effects on total-tract nutrient digestibilities are presented in Table 9. Total-tract digestibilities of DM (67.3 vs. 65.6%) and CP (67.0 vs. 65.3%) were increased for normal-forage compared with high-forage diets. Both NDF and ADF digestibilities were higher (38.5 vs. 31.9% and 39.7 vs. 33.8%, respectively) for 39NDF compared with 33NDF diets, but starch digestibility was lower (97.8 vs. 98.5). Bal et al. (2000b) reported higher ruminal in situ NDF disappearance for the 39NDF compared with 33NDF corn silage treatments. Total-tract starch digestibility was reduced (97.7 vs. 98.7%) for cows fed normal-forage compared with high-forage diets.

CONCLUSIONS

There were no animal performance benefits to feeding LFY in midlactation cows averaging 40 kg of milk/d. Selection of LFY hybrids can be based on DM yield per hectare relative to conventional hybrids. Higher starch digestibility for LFY was offset by its lower NDF digestibility. Plant population effects on WPCS nutrient composition and animal performance were minimal for LFY and CH hybrids. The bm3 corn silage fed in a high forage

Table 8. Treatment effects on DMI and NDFI, BW, and milk production for trial 3.

	Diet[1]					
	High forage		Normal forage			
Item	39NDF	33NDF	39NDF	33NDF	SEM	Effect[2]
DMI, kg/d	26.6	25.7	27.7	27.6	0.2	H, D, H*D
% of BW	3.86	3.73	4.05	3.99	0.03	H, D
BW, kg	691	690	688	695	2.5	NS
BW change, kg/d	0.34	0.34	0.25	0.44	0.1	NS
NDF intake, kg/d	7.8	7.2	7.5	6.8	0.05	H, D
% of BW	1.13	1.05	1.10	1.00	0.007	H, D, H*D
Forage NDFI, kg/d	6.3	6.0	5.8	5.1	0.04	H, D, H*D
% of BW	0.92	0.88	0.85	0.74	0.005	H, D, H*D
Milk, kg/d	42.8	42.2	44.6	45.2	0.5	D
4% FCM, kg/d	40.1	39.7	40.9	41.3	0.4	D
Fat, %	3.60	3.61	3.48	3.44	0.03	D
Fat, kg/d	1.53	1.52	1.54	1.55	0.02	NS
CP, %	3.09	3.03	3.14	3.14	0.01	D, H*D
CP, kg/d	1.31	1.28	1.39	1.41	0.01	D
Lactose, %	4.77	4.76	4.80	4.78	0.01	NS
Lactose, kg/d	2.03	2.01	2.14	2.16	0.02	D
Urea nitrogen, mg/dl	16.1	16.2	16.1	15.8	0.3	NS

[1] High forage = 61 to 67% forage; Normal forage = 53% forage; 39NDF = Normal NDF corn silage; 33NDF = Low NDF corn silage.

[2] H = Hybrid, D = diet, and interaction effects at $P < 0.05$ and NS = nonsignificant.

Table 9. Treatment effects on total-tract nutrient digestibilities for trial 3.

	Diet[1]					
	High forage		Normal forage			
Digestibility, %	39NDF	33NDF	39NDF	33NDF	SEM	Effect[2]
DM	66.5	64.6	66.7	67.9	0.8	D, H*D
OM	68.8	66.9	68.6	69.7	0.7	H*D
CP	65.9	64.6	67.3	66.6	0.7	D
NDF	39.5	32.0	37.5	31.8	1.7	H
ADF	40.8	34.8	38.6	32.7	1.7	H
Starch	98.5	98.8	97.1	98.2	0.2	H, D

[1] High forage = 61 to 67% forage; Normal forage = 53% forage; 39NDF = Normal NDF corn silage; 33NDF = Low NDF corn silage.

[2] H = Hybrid, D = diet, and interaction effects at $P < 0.05$.

Table 10. Treatment effects on ruminal pH and VFA for trial 3.

	Diet[1]					
	High forage		Normal forage			
Item	39NDF	33NDF	39NDF	33NDF	SEM	Effect[2]
pH	6.29	6.33	6.23	6.18	0.06	D
Total VFA, m*M*	129.3	134.1	143.3	134.2	8.0	NS
VFA, mol/100 mol						
Acetate	55.8	57.4	55.4	53.0	1.3	D, H*D
Propionate	23.2	21.6	23.4	26.0	1.2	D, H*D
Butyrate	14.8	13.6	15.2	14.8	0.7	NS
Others[3]	6.4	7.5	6.0	6.3	0.4	D
Acetate:Propionate	2.4	2.7	2.4	2.1	0.1	D, H*D

[1] High forage = 61 to 67% forage; Normal forage = 53% forage; 39NDF = Normal NDF corn silage; 33NDF = Low NDF corn silage.

[2] H = Hybrid, D = diet, and interaction effects at $P < 0.05$ and NS = nonsignificant.

[3] Isobutyrate, isovalerate, and valerate.

diet increased milk fat percentage and yield compared with CH corn silage fed in a normal forage diet with similar DMI between diets in mid lactation cows averaging 44 kg of milk/d. The bm3 hybrid appears to offer a means of increasing the proportion of dietary forage for lactating dairy cows, but its agronomic limitations (Coors et al., 1994) should be considered. There were no animal performance benefits to feeding low-NDF corn silage compared with normal-NDF corn silage when fed at either normal or high concentrations of dietary forage in mid lactation dairy cows averaging 44 kg of milk/d. Total tract digestibility of dietary NDF and ADF were higher for normal-NDF than low-NDF corn silage treatments. Because of year and hybrid × year effects ($P < .01$) for whole-plant NDF percentage and in vitro NDF digestibility (Coors, 1996), more research investigating animal performance differences between hybrids of varying NDF content is warranted.

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