J. Dairy Sci. 84:2217–2226

Comparison of Corn Silage Hybrids for Yield, Nutrient Composition, In Vitro Digestibility, and Milk Yield by Dairy Cows

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ABSTRACT

A study was undertaken to compare Novartis N29-F1, a dual-purpose 90-d relative maturity corn hybrid, and Novartis NX3018, a 90-d relative maturity leafy corn silage hybrid for dry matter (DM) yield, in vitro digestibility, plant components, nutrient composition, and lactational performance by Holstein cows. The two corn hybrids were planted in replicated 15.2- × 351-m plots. Plant population and DM yield were similar between the two corn hybrids. Novartis NX3018 had higher content of crude protein and ash, a higher proportion of leaves and stalks, and a lower proportion of grain compared with Novartis N29-F1. The cob, grain, and leaves of Novartis NX3018 had higher in vitro true DM and neutral detergent fiber disappearances compared with the respective plant components of Novartis N29-F1. Thirty-eight midlactation multiparous Holstein cows (78 ± 23.0 days in milk) producing 47.2 ± 8.9 kg of milk per cow per day were blocked and assigned randomly to one of two total mixed ration (TMR) containing (DM basis) approximately 26% Novartis N29-F1 or Novartis NX3018 corn silage. Cows were housed in a free-stall barn and group fed ad libitum. The lactation study was conducted as a crossover design with two 28-d periods. Samples and data were collected during the final 7 d of each period. The total mixed rations were formulated using the Cornell-Penn-Miner Dairy® nutrition model. Cows that were fed the total mixed rations containing Novartis NX3018 corn silage produced higher yields of milk, 3.5% fat-corrected milk (FCM), milk crude protein, and milk lactose compared to cows that were fed the TMR containing Novartis N29-F1 corn silage. In conclusion, the Novartis NX3018 corn hybrid was leafier and more digestible in vitro, and when fed to dairy cows as silage, promoted higher milk yield compared with the Novartis N29-F1 corn hybrid.
(**Key words:** corn silage hybrids, dry matter yield, digestibility, milk yield)

Abbreviation key: IVNDFD = in vitro NDF disappearance, **IVTDMD** = in vitro true DM disappearance, **N29-F1** = Novartis N29-F1, **NX3018** = Novartis NX3018.

INTRODUCTION

Corn silage is a major component of diets fed to dairy cows. Even though the grain:stalk ratio and whole plant DM yields are important determinants of the adaptability of a hybrid to silage production, of greater importance is digestible DM per acre, or for dairy farmers, milk yield per acre or per ton. Hence, in recent years corn hybrids have been developed specifically for silage production (Johnson et al., 1997; Kuehn et al., 1999). The focus has been on enhancing fiber digestibility of corn silage, assuming that this would result in increased DMI and milk yield by the dairy cow. Indeed, several studies have reported improved milk yield by lactating dairy cows from feeding brown midrib corn silage (Block et al., 1981; Frenchick et al., 1976; Keith et al., 1979), with more recent studies reporting increased DMI as well (Oba and Allen, 1997, 1999, 2000). Besides digestibility, the other differences in corn hybrids that have been identified are whole plant yield (Ballard et al., 2001; Hunt et al., 1992; Roth, 1994), and content of CP (Johnson et al., 1985; Roth, 1994; Xu et al., 1995), NDF, ADF, or both (Johnson et al., 1985; Hunt et al., 1993; Xu et al., 1995), and in vitro digestibility (Ballard et al., 2001; Hunt et al., 1993; Roth, 1994). Additional differences in plant composition such as percent ear (Hunt et al., 1992; Roth, 1994) and percent grain (Johnson et al., 1985; Hunt et al., 1992; Xu et al., 1995) have also been reported among corn silage hybrids.

Novartis Seeds, Inc. (Golden Valley, MN) recently developed a corn silage hybrid, Novartis NX3018

Received December 20, 2000.
Accepted May 14, 2001.
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(**NX3018**) for increased leaf content and digestibility compared with the older Novartis corn hybrids. Currently, no published work has compared NX3018 to other corn hybrids in field and animal performance studies. The objectives of this study were therefore to compare Novartis N29-F1 (**N29-F1**), a dual-purpose 90-d relative maturity hybrid, and NX3018, a 90-d relative maturity leafy corn silage hybrid for: 1) DM yield, plant components, nutrient composition, in vitro true DM disappearance (**IVTDMD**), and in vitro NDF disappearance (**IVNDFD**), 2) ensiling characteristics and end products of fermentation of whole-plant corn silages, and 3) milk yield and composition by midlactation, multiparous Holstein cows fed TMR containing whole-plant corn silage.

MATERIALS AND METHODS

Field

The N29-F1 and NX3018 corn silage hybrids (90-d relative maturity) were planted on a tile-drained Hogansburg loam soil (pH 6.9) at the Miner Institute farm on May 3, 1999. Analyses of the Hogansburg loam soil conducted at the Cornell Nutrient Analysis Laboratories (Cornell University, Ithaca, NY) were 14 mg/kg of P and 85 mg/kg of K, which were high levels for the two minerals. The field was divided into three blocks, and each block was subdivided into three 15.2 × 351-m plots, which were then assigned randomly to one of the two corn hybrids, resulting in three replications per treatment. Within each plot, corn was planted in 20 351-m long rows with row spacing of 76 cm. Planting rates were 74,000 seeds/ha for both hybrids. Plots were fertilized with 140-51-123 kg/ha ($N-P_2O_5-K_2O$) as dairy manure in September 1998. The dairy manure was analyzed for nutrient composition before application to the plots. Starter fertilizer was applied at a rate of 38-31-48 kg/ha ($N-P_2O_5-K_2O$) during planting.

Corn hybrids were harvested at similar maturities and moisture content on September 7 for N29-F1 and September 13 for NX3018. Moisture content of whole plant samples was approximately 60% at harvest for both hybrids. Before harvest, the final plant population was determined by counting plants in three rows, 15.2 m in length, and expressing smut-infected ears, barren ears, and lodged plants as a percentage of counts made on 200 plants. In addition, 10 plants per plot were selected at random and fractionated into the following corn plant components: husk, grain, cob, leaves, tassel, and stalk, which were then dried separately for nutrient analysis. Forages from each plot were then harvested with a conventional forage harvester (without a kernel processor) (model 1275; Gehl, West Bend, WI) with a theoretical chop-length of 0.95 cm and collected into a wagon. Total yield was measured by weighing individual wagonloads of chopped corn and measuring the size of the plot. The chopped forages were ensiled in silage bags made of 9-mm thick plastic (Ag-Bag, Int., Warrenton, OR) and allowed to ferment for 5 mo. Forage samples were collected into a 10-L container during the unloading process for each plot and ensiled in a total of nine minisilos for 42 d for silage characterization. The minisilos were made out of polyvinyl chloride and were 0.102 m in diameter and 0.457 m long. The remaining samples of chopped forages for each plot were subsampled for chemical analyses and particle size characterization.

Cows Management, Experimental Design, and Dietary Treatments

Thirty-eight multiparous Holstein cows with an average DIM of 78 ± 23, BW of 627 ± 73 kg, BCS of 3 ± 0.3, and producing 47.2 ± 9 kg of milk per cow per day were used in this study. The 19 cows assigned to each treatment group were put in a pen containing additional nontreatment cows, to make a total of 36 cows per pen. The study was conducted from March 15 to May 17, 2000. As a preventative measure, all multiparous cows received 500 ml of 23% calcium solution, 500 ml of 50% dextrose solution, and 5 cc of oxytocin intravenously, and 10 cc of vitamin E-selenium, 10 cc of vitamin B complex, and 2 cc of *Escherichia coli* vaccine intramuscularly after calving. Cows were checked 20 to 30 d postcalving by a veterinarian, and if no health problems were found, cows were bred on subsequent heat by AI without instituting a voluntary waiting period. Management practices such as the use of prostaglandins were similar for both treatment groups. All cows received 500-mg injections of bST every 2 wk (Posilac; Monsanto, St. Louis, MO) beginning when cows were confirmed pregnant or were 100 DIM. Cows were housed in a free-stall barn for the duration of the study and group fed at 110% of expected intake once a day at 0800 h. The animal stalls were bedded with sawdust, which was changed once weekly. Feed was mixed in a Reel-Auggie mixer wagon (model 3300; Knight, Brodhead, WI). During mixing, dietary ingredients were put into the mixer wagon in the following order: concentrate mixes, ground corn, whole cottonseed, citrus pulp, grass hay, alfalfa grass silage, corn silage, and molasses, and allowed to mix for about 5 min before feeding.

Cows were blocked by parity, DIM, current milk production, and 305-d mature equivalent and assigned randomly to one of two TMR containing 26% Novartis N29-F1 or Novartis NX3018 corn silage. Cows received

Table 1. Composition of TMR containing Novartis N29-F1 or Novartis NX3018 corn silage.

Ingredient	N29-F1	NX3018
	(% of DM)	
Novartis N29-F1 corn silage	25.67	0.00
Novartis NX3018 corn silage	0.00	25.67
Alfalfa-grass silage[1]	15.61	15.61
Mixed grass hay	2.27	2.27
Whole cottonseed	6.99	6.99
Citrus pulp	4.61	4.61
Ca-PFAD[2]	0.55	0.55
Sodium bicarbonate	1.72	1.72
Ground corn	17.89	17.89
Molasses	3.05	3.05
Concentrate mix[3]	21.63	21.63

[1]First-cut alfalfa-grass silage fed for the first 6 wk and third-cut alfalfa-grass silage fed for the last 2 wk of the 8-wk study.

[2]Calcium salts of palm oil fatty acid distillates (Church & Dwight Co. Inc., NJ).

[3]Ingredients of concentrate mix are shown in Table 2.

a standardized TMR not containing any of the test corn silages during a 1-wk adjustment period from March 15 to 22, 2000. The standardized TMR contained corn silage that had been ensiled in a bunk silo, and the other ingredients were similar to those used in the test diets. The study was conducted as a crossover design with two 28-d periods. Period 1 started on March 22 to April 18, and period 2 started on April 19 and ended on May 16, 2000. Samples and data were collected during the final 7 d of each period. The TMR detailed in Table 1 were formulated using the CPM Dairy® nutrition model (version 1.0; Cornell-Penn-Miner, Cornell University, Ithaca, NY), and contained (DM basis) approximately 44% forage and 56% concentrate. All diets were balanced for NDF and utilized the same protein concentrate whose ingredients are shown in Table 2. Apart from differences in corn hybrid for the corn silages, the ingredients used to formulate the TMR were the same. First-cut, alfalfa grass silage was fed during the first 6 wk of the 8-wk study, and third-cut, alfalfa grass silage was fed during the last 2 wk of the study. Rations were adjusted for DM content of forages when this change in alfalfa grass silage was made.

Table 2. Composition of concentrate mix.

Ingredient	% of DM
Soybean hulls	14.28
Canola meal	19.97
Urea	0.81
Solvent extracted soybean meal (55% CP)	39.49
Soy Plus®[1]	5.35
Fish meal	2.56
Blood meal	5.87
Salt	2.07
Sodium bicarbonate	4.02
Calcium carbonate	4.02
Calcium sulfate	0.24
Magnesium oxide	0.40
Biophosphate	0.24
Trace mineral mix[2]	0.62
854 Dairy 5X[3]	0.08

[1]Contains 34% rumen escape protein (Borregaard LignoTech, Rothschild, WI).

[2]Trace mineral mix on DM basis contained 15.0% Ca, 0.2% Mg, 2.5% S, and (mg/kg) 70,000 Mn; 210,000, Zn; 40,600, Cu; 2,400, Co; 11,000, Fe; 825, Se; and 2,000, I.

[3]Dairy 5X contained on DM basis 2.7% CP, 49.9% NDF, 35.1% ADF, 7% fat, 9.8% Ca, 0.06% P, 1.05% Mg, 1.33% K, 0.04% S, 0.53% Na, 0.13% NaCl, 35,946 IU/g vitamin A, 12,247 IU/g vitamin D, and 44,535 kg/IU vitamin E.

Body weight of cows used in the lactation study was measured on an electronic scale on 2 consecutive days at the beginning of period 1 and on the last 2 d of each of the 7-d data collection periods. Body condition scores were measured with the five-point scale where 1 = thin to 5 = fat and determined by two trained investigators 1 d before the start of period 1 and on the last day of each period (Wildman et al., 1982). Cows were milked three times per day in a double-six herringbone milking parlor at 0430, 1230, and 2030 h.

Sampling and Chemical Analyses

Forage and dietary ingredients. Samples of fresh forages collected before ensiling and ensiled forages from the minosilos and silage bags, and samples of mixed cool-season grass hay, whole cottonseed, beet pulp, ground corn, and concentrate mixes collected weekly during each period of the lactation study were sent to Cumberland Valley Analytical Services (Hagerstown, MD) for chemical analysis. Samples of TMR were collected at the beginning and end of last week of each period of the lactation study and stored frozen at −20°C for later chemical analysis. For chemical processing, the TMR samples were thawed and composited by treatment for each period, and subsamples were sent to Cumberland Valley Analytical Services for chemical analysis. All samples were dried at 60°C and ground to pass through a 1-mm screen with a cyclone mill (Udy Co., Fort Collins, CO) for chemical analysis. The ground samples were analyzed for DM (100°C), ash (500°C), CP (AOAC, 1995), NDF (without sodium sulfite), ADF, and ADL (Van Soest et al., 1991). The nonfiber carbohydrates were calculated as the difference between 100 and the sum of CP, NDF, fat, and ash. Sulfur was analyzed using a Leco model SC-432 (Leco, St. Joseph, MI). Calcium, Mg, K, Na, Fe, Zn, Cu, and Mn were analyzed by atomic absorption spectrophotometry (AOAC, 1995). Phosphorus was analyzed by colorimetry (AOAC, 1995), and chloride ion was determined using a Brinkman Metrohm 716 Ti-

Table 3. Plant population, in vitro disappearances, and DM yield, in vitro digestible DM (IVDDM) yield, and chemical composition prior to ensiling of Novartis N29-F1 and Novartis NX3018 corn forages.

Item	N29-F1	NX3018	SE	*P*-value
Plant population				
Plants/ha[1]	73,273	71,261	2376	0.61
Barren ears, %	2.00	2.67	0.31	0.27
Lodged, %	0.00	0.83	0.43	0.30
DM, %	41.3	36.9	1.8	0.23
IVTDMD,[1] %	77.8	79.9	1.0	0.23
IVNDFD,[2] %	49.2	53.9	1.1	0.04
DM yield, tonne/ha	14.7	13.7	0.7	0.41
IVDDM yield, tonne/ha	11.4	11.0	0.5	0.54
	(DM basis)			
Chemical composition				
OM, %	97.2	94.6	0.4	0.04
CP, %	7.67	9.57	0.29	0.04
Soluble protein, % CP	16.8	19.2	2.4	0.55
NDF-CP, %	1.53	2.23	0.15	<0.01
ADF-CP, %	0.90	1.27	0.09	0.09
NDF, %	39.6	41.6	1.3	0.41
ADF, %	21.3	25.2	1.6	0.24
Acid detergent lignin, %	2.90	3.07	0.14	0.50
NSC,[3] %	45.1	41.0	1.5	0.19
Sugar, %	4.51	4.00	0.30	0.35
Starch, %	40.6	37.0	1.3	0.21
Fat, %	3.57	3.53	0.06	0.74
Ash, %	2.77	5.37	0.35	0.04
Ca, %	0.26	0.40	0.01	0.01
P, %	0.21	0.24	0.01	0.02
Mg, %	0.16	0.19	0.01	0.19
K, %	1.06	1.30	0.05	0.08
S, %	0.12	0.15	0.01	0.01
Na, %	0.01	0.05	0.01	0.09
Cl^- ion, %	0.30	0.31	0.01	0.53
Fe, mg/kg	72.7	158.3	25.3	0.14
Mn, mg/kg	14.7	26.0	1.2	0.02
Zn, mg/kg	20.7	31.0	3.1	0.14
Cu, mg/kg	6.7	10.7	0.8	0.07

[1]The NDF residue after in vitro digestion at 30 h of incubation was expressed as a fraction of the initial DM weighed into the bag to determine the undigested fraction, and IVTDMD was then calculated by subtracting the undigested percentage from 100.

[2]The NDF residue after in vitro digestion at 30 h of incubation was expressed as a fraction of the initial NDF weighed into the bag to determine the undigested NDF fraction, and IVNDFD calculated by subtracting the undigested percentage from 100.

[3]Analyses for sugars and starch were done using the enzymatic digestion procedure of Smith (1969).

trino titration unit with a silver electrode (model 716; Brinkman Instruments, Inc., Westbury, NY). In addition, fresh corn forage and silage samples also were analyzed for sugars and starch at West Virginia University (Morgantown, WV) by a modified enzymatic digestion procedure of Smith (1969) that used potassium ferricyanide instead of copper sulfate to bind glucose. Unbound potassium ferricyanide was read at a wavelength of 422 nm with a Hitachi UV/Vis Spectrophotometer (model U-1500; Hitachi Instruments Inc., San Jose, CA).

Subsamples of corn silage samples were also sent to the Miner Institute Forage Laboratory, where after determination of pH with a digital pH meter, samples were processed according to Fenner (1984) to determine VFA and lactic acid using gas chromatography (Supelco Inc., 1975). We used a Varian 3700 gas chromatograph (Varian, Inc., Walnut Creek, CA), a 4% carbowax 20M/80/120 carbopack B-DA column (Supelco, Bellefonte, PA) at the temperature setting of 175°C, and a Perkin Elmer LC-100 intergrator (Perkin-Elmer Corp., Norwalk, CT). The flow rates for the nitrogen, hydrogen, and air, respectively, were 24, 30, and 300 mL/min. Fresh corn forage and silage samples from minisilos and silage bags were also dried at 60°C in a forced air-oven and ground to pass through a 1-mm screen using a Wiley mill (model 3; Arthur H. Thomas Co., Philadelphia, PA). The ground samples were then exposed to in vitro digestion (Goering and Van Soest, 1970) using the ANKOM DAISY^{II} incubator

(ANKOM Technology Corporation, Fairport, NY). Approximately 0.25 g of sample DM was weighed into 4.5 × 5.0-cm ANKOM Dacron bags, which were heat sealed and placed in digestion jars for 30-h incubation with medium containing buffer and mineral solution (Goering and Van Soest, 1970) and ruminal fluid, respectively, mixed in ratio of approximately 4:1. Ruminal fluid was collected from a nonpregnant, dry cow fed a corn silage and alfalfa grass, silage-based TMR ad libitum and strained through four layers of cheesecloth before mixing with buffer. Bags were made from nitrogen-free, white polyester monofilament fabric with 57-μm pore size. At the end of incubation, bags were washed in mild detergent solution and rinsed with reverse osmosis water. The reverse osmosis water was prepared by filtering ordinary tap water through thin film cartridges and a deionizing resin bed with a model MP 750EH MacClean Water Treatment System (MacClean, Churubusco, IN). The washed bags were placed in an ANKOM$^{200/220}$ Fiber Analyzer, and digesta samples were exposed to NDF extraction without sodium sulfite. The NDF residue was expressed as a fraction of the initial DM weighed into the bag to determine the undigested fraction, and IVTDMD (%) was then calculated by subtracting the undigested percentage from 100. The NDF residue was also expressed as a fraction of the initial NDF weighed into the bag to determine the undigested NDF fraction, and IVNDFD (%) was calculated by subtracting the undigested percentage from 100. The initial NDF weighed into each bag for each sample was determined by multiplying the initial sample DM weighed into each bag by the NDF concentration of the sample.

The particle sizes of the ensiled forages from silage bags and chopped mixed cool-season grass hay were characterized with the Penn State forage particle separator (Nasco, Fort Atkinson, WI) as small (<0.79 cm), medium (0.79 to 1.9 cm), and large (>1.9 cm) forage particles. Percentages of particles that were retained on the large screen, medium screen, and in the bottom

Table 4. Plant components at harvest, and in vitro disappearances of fresh Novartis N29-F1 and Novartis NX3018 corn plants.

Plant fraction	Item	N29-F1	NX3018	SE	*P*-value
		(DM basis)			
Cob	Proportion of whole plant, %	7.43	6.51	0.12	<0.01
	NDF, % DM	87.5	84.0	2.0	0.34
	IVTDMD,[1] %	45.3	62.7	2.7	0.04
	IVNDFD,[2] %	37.4	55.8	1.8	0.02
Grain	Proportion of whole plant, %	53.4	49.8	0.9	0.01
	NDF, % DM	10.5	11.0	0.5	0.52
	IVTDMD, %	97.6	98.9	0.1	0.02
	IVNDFD, %	76.9	89.7	1.4	0.02
Husk	Proportion of whole plant, %	6.16	5.61	0.19	0.05
	NDF, % DM	81.7	80.3	1.8	0.63
	IVTDMD, %	59.5	71.0	1.8	0.04
	IVNDFD, %	50.4	62.2	4.1	0.18
Leaves	Proportion of whole plant, %	10.16	12.31	0.21	<0.01
	NDF, % DM	62.4	63.6	1.0	0.50
	IVTDMD, %	71.6	77.4	0.9	0.04
	IVNDFD, %	54.5	64.5	1.4	0.04
Stalks	Proportion of whole plant, %	22.46	25.09	0.81	0.03
	NDF, % DM	81.1	76.7	0.2	<0.01
	IVTDMD, %	42.7	53.4	2.7	0.11
	IVNDFD, %	29.5	39.2	3.2	0.16
Tassel	Proportion of whole plant, %	0.72	0.72	0.03	0.92
	NDF, % DM	76.4	78.1	0.7	0.20
	IVTDMD, %	49.8	47.5	0.8	0.19
	IVNDFD, %	34.2	32.8	1.1	0.43
Whole plant[3]	IVTDMD, %	76.1	80.5	0.4	<0.01
	IVNDFD, %	43.4	54.8	0.3	<0.01

[1]The NDF residue after in vitro digestion at 30 h of incubation was expressed as a fraction of the initial DM weighed into the bag to determine the undigested fraction, and IVTDMD was then calculated by subtracting the undigested percentage from 100.

[2]The NDF residue after in vitro digestion at 30 h of incubation was expressed as a fraction of the initial NDF weighed into the bag to determine the undigested NDF fraction, and IVNDFD calculated by subtracting the undigested percentage from 100.

[3]Calculated from the disappearance of the individual components.

Table 5. The pH, in vitro disappearances, and nutrient composition of Novartis N29-F1 and Novartis NX3018 corn silages fermented in mini-silos.

Item	N29-F1	NX3018	SE	*P*-value
pH	3.84	3.85	0.02	0.69
	(%, DM basis)			
In vitro disappearance				
IVTDMD[1]	76.9	79.7	1.0	0.18
IVNDFD[2]	49.5	54.1	1.4	0.14
Chemical composition				
DM	41.4	37.3	1.0	0.09
NDF	45.2	44.0	0.9	0.42
ADF	23.0	22.0	1.0	0.56
Acid detergent lignin	3.35	3.13	0.14	0.37
NSC[3]	34.3	39.4	2.2	0.24
Sugar	0.86	0.67	0.13	0.41
Starch	33.5	38.8	2.1	0.21
VFA				
Acetate	0.64	0.91	0.01	<0.01
Propionate	0.01	ND[4]	ND	0.42
Butyrate	ND	ND	ND	. . .
Valerate	0.003	ND	ND	0.42
Isovalerate	0.01	0.01	0.01	0.12
Total	0.65	0.92	0.01	0.01
Lactate	3.49	3.69	0.12	0.35
Lactate + total VFA	4.14	4.61	0.12	0.12

[1]The NDF residue after in vitro digestion at 30 h of incubation was expressed as a fraction of the initial DM weighed into the bag to determine the undigested fraction, and IVTDMD was then calculated by subtracting the undigested percentage from 100.

[2]The NDF residue after in vitro digestion at 30 h of incubation was expressed as a fraction of the initial NDF weighed into the bag to determine the undigested NDF fraction, and IVNDFD calculated by subtracting the undigested percentage from 100.

[3]Analyses for sugars and starch (nonstructural carbohydrates) were done using the enzymatic digestion procedure of Smith (1969).

[4]Not detected.

pan were reported. The mesh sizes of the medium and large screens, respectively, were 0.79 and 1.9 cm.

Milk. In the lactation study, milk yield was measured daily, and an average was calculated for the last week of each period for each cow. Milk samples were collected from the same milking on 2 consecutive days of each of the 7-d data collection periods. The samples were then sent to Dairy One (Ithaca, NY) for analysis of total protein, fat composition, lactose, and milk urea nitrogen by infrared procedure (Foss 4000; Foss Technology, Eden Prairie, MN) (AOAC, 1995), and analysis of SCC by infrared procedure (Foss 5000; Foss Technology, Eden Prairie, MN) (AOAC, 1995). Milk samples collected from some commercial dairy farms were used as the internal standards in the analysis of milk components. These standards were stored under refrigeration at 0 to 4°C for a maximum of 14 d.

Statistical Analysis

Data for DM yield, plant population, and plant nutrient traits were analyzed using the GLM procedures of SAS (1993) as a randomized block design with corn hybrid and block as main effects. Least square means are presented for corn hybrid effect. Animal data were analyzed as a switchback design using the GLM procedures of SAS (1993) using the following model:

$$Y_{ijkl} = \mu + S_i + C_j(S_i) + P_k + T_l + e_{ijkl}$$

where

μ = overall mean,
S_i = effect of sequence (i = 1 or 2),
$C_j(S_i)$ = effect of cows nested in sequence (j = 1 to 25),
P_k = effect of period (k = 1 to 2),
T_l = effect of treatment (l = 1 to 2), and
e_{ijkl} = residual, assumed to be normally distributed.

In the statistical analysis of data for BCS and BW, data collected before the beginning of the study was used as covariate for data collected in period 1, and data collected in period 1 was used as covariate for data collected in period 2. In calculating changes in BCS and BW, data collected before the beginning of the study were used as the initial dataset for data collected at the end of period 1, and data collected at the end of period 1 were used as the initial dataset for data collected at the end of period 2. Least square means are presented for corn hybrid effect. Because animals were group fed with no replications of pens within treatment, the investigators assumed 1) no pen effect, and 2) that errors within pens were independent (St-Pierre and Jones, 1999), allowing for cow to serve as the experimental unit.

RESULTS AND DISCUSSION

Plant population, percentage of barren and lodged plants, silage yields, and DM content and IVTDMD of fresh forages at harvest were similar between N29-F1 and NX3018 corn hybrids (Table 3). However, conditions such as excessive rain and heavy winds late in the season, which would have allowed lodging to be intensively evaluated, did not occur. During the growing season (April 1 to September 30, 1999) a total of 37.9 cm of precipitation (85% of 37-yr mean) was received, and the growing degree-days (or heat units) were 2633 (115% of 37-yr mean). The NX3018 corn hybrid had a higher IVNDFD and contents of CP and ash ($P < 0.05$) compared with the N29-F1 corn hybrid. Other workers have also reported differences in IVNDFD (Ballard et al., 2001; Hunt et al., 1993) and content of CP (Johnson et al., 1985; Roth, 1994; Xu et al., 1995) among different corn hybrids. The higher ash content in NX3018 corn hybrid was a result of the higher content of Ca, P, S, and Mn ($P < 0.05$). The contents of soluble protein, NDF, ADF, sugar, starch, and fat were similar between the two corn hybrids.

The NX3018 corn hybrid had higher proportion of the leaves ($P < 0.001$) and stalks ($P < 0.05$), and lower proportion of the cob ($P < 0.001$), grain ($P < 0.01$), and husk ($P < 0.05$) compared with the N29-F1 corn hybrid (Table 4). Other workers have also observed differences in plant components such as percent ear (Hunt et al., 1992; Roth, 1994) and percent grain (Johnson et al., 1985; Hunt et 1992; Xu et al., 1995) among different corn hybrids. The NDF content of the NX3018 stalks was lower than that of stalks of the N29-F1 corn hybrid ($P < 0.05$). The cob, grain, and leaves of the NX3018 corn hybrid had a significantly higher IVTDMD and IVNDFD compared with the respective plant components of the N29-F1 corn hybrid ($P < 0.05$). The husk of the NX3018 corn hybrid had a higher IVTDMD ($P < 0.05$) compared with the husk of the N29-F1 corn hybrid. Differences in in vitro digestibility among corn hybrids have also been observed by Johnson et al. (1985), Hunt et al. (1993), Roth (1994), Xu et al. (1995), and Ballard et al. (2001). Other workers also reported that leafy corn hybrids were more digestible in vitro (Kuehn et al., 1999) and in situ (Hunt et al., 1992) despite containing a lower grain content than other corn hybrids. Results of this study confirm that NX3018 is a more leafy corn hybrid than N29-F1, which is consistent with observations made by Novartis Seeds, Inc. (Golden Valley, MN).

The nutrient traits of silages fermented in minisilos are shown in Table 5. Even though not significant ($P > 0.10$), the NX3018 corn hybrid had numerically higher IVTDMD, IVNDFD, and content of lactate compared with the N29-F1 corn hybrid. The NX3018 corn silage had more acetate ($P < 0.01$) than the N29-F1 corn silage. Concentrations of sugars, starch, NSC, and isovalerate were similar in both silages. Concentrations of propionate, valerate, and butyrate were very low or below detection limits in both silages. The increased NDF and ADF concentration postensiling may have been the result of fermentation of sugars.

Diets used in the lactation study contained similar concentrations of DM, OM, CP, NDF, ADF, and minerals (Table 6), and these analyses were similar to what had been calculated with the CPM Dairy® nutrition model. The chemical composition of the corn silages, alfalfa grass silages, mixed cool-season grass hay, whole cottonseed, citrus pulp, and ground corn used in the lactation study diets (Table 7) were typical of reported values (NRC, 1988). The chemical analyses of the concentrate mix that was used in both diets is

Table 6. Chemical composition of TMR containing Novartis N29-F1 corn silage, TMR containing Novartis NX3018 corn silage, and concentrate mix used in both TMR.

Item	N29-F1	NX3018
	(DM basis)	
DM, %	55.0	55.2
OM, %	92.45	92.35
NE_L, Mcal/kg	1.62	1.63
CP, %	17.7	17.9
Soluble protein, % CP	. . .	. . .
NDF, %	37.1	36.1
ADF, %	25.2	24.9
Lignin, %	5.15	4.95
Fat, %	5.15	5.25
Nonfiber carbohydrates[1], %	32.50	33.10
Ash, %	7.55	7.65
Ca, %	0.78	0.80
P, %	0.34	0.37
Mg, %	0.28	0.30
K, %	1.52	1.52
Cl^- ion, %	0.66	0.63
S, %	0.27	0.27
Na, %	0.82	0.89
Fe, mg/kg	176	188
Mn, mg/kg	67	68
Zn, mg/kg	163	162
Cu, mg/kg	38	41

[1]Nonfiber carbohydrates were calculated as 100 – (CP + NDF + fat + ash). Includes pectins and fructans.

Table 7. Nutrient characteristics of feedstuffs used in diets fed to lactating multiparous Holstein cows.

Item	N29-F1 corn silage	NX3018 corn silage	First-cut alfalfa-grass silage	Third-cut alfalfa-grass silage	Mixed cool season grass hay	Concentrate mix
	(DM basis)					
In vitro true DM and NDF disappearances						
IVTDMD, %	76.95	81.14	79.75	78.89	61.86	
IVNDFD, %	45.70	55.29	60.11	49.21	41.24	
Chemical composition						
DM, %	39.20	36.70	36.24	30.80	87.36	87.50
NE_L, Mcal/kg	1.65	1.65	1.37	1.39	1.19	1.70
CP, %	8.42	8.91	17.97	22.90	10.93	43.77
Soluble protein, % CP	38.81	40.01	58.49	59.20	22.27	18.54
NDF-CP, %	1.43	1.45	2.70		4.00	
NDF, %	40.55	40.66	51.29	40.40	62.26	21.9
ADF, %	23.90	24.18	32.57	33.75	38.14	14.11
Lignin, %	2.87	3.30	4.20	5.70	4.80	
NFC[1], %	44.16	42.82	17.93	20.99	15.47	17.36
NSC[2], %	36.94	36.11	8.84			
Sugar, %	1.48	1.50	3.77			
Starch, %	35.46	34.61	5.07			
Fat, %	2.97	3.20	4.80	5.01	3.55	2.90
Ash, %	3.90	4.41	8.01	10.70	7.79	14.07
Ca, %	0.28	0.29	0.92	1.45	0.48	2.16
P, %	0.21	0.23	0.26	0.36	0.20	0.85
Mg, %	0.16	0.18	0.26	0.33	0.20	0.61
K, %	1.10	1.27	2.18	2.82	1.99	1.59
S, %	0.12	0.13	0.28	0.30	0.23	0.53
Na, %	0.05	0.02	0.06	0.10	0.04	1.59
Cl^- ion, %	0.31	0.33	0.61	1.48	0.58	1.11
Fe, mg/kg	96.90	129.44	306.57	282.00	107.44	647.86
Mn, mg/kg	18.20	20.33	50.86	54.00	35.50	394.71
Zn, mg/kg	29.60	31.78	42.86	68.00	42.80	288.43
Cu, mg/kg	7.60	8.22	12.14	16.50	14.10	210.71
Ensiling characteristics						
pH	3.81	3.75	4.46	4.85		
Acetate, %	1.25	1.12	2.33			
Propionate, %	0.02	0.01	0.10			
Butyrate, %	0.06	0.01	0.16			
Isovalerate, %	0.03	0.02	0.03			
Valerate, %	0.01	0.00	0.03			
Lactate, %	5.78	6.18	9.06			

[1]Nonfiber carbohydrates calculated as 100 – (CP + NDF + fat + ash). Includes pectins and fructans.

[2]Analyses of sugars and starch were done using the enzymatic digestion procedure of Smith (1969).

shown in Table 7. The NX3018 corn silage had a lower DM content, higher IVTDMD, higher IVNDFD, higher lactate, and similar chemical composition compared with N29-F1 corn silage (Table 7). Even though not tested statistically, the two corn hybrids had similar particle size distribution (Table 8). Most of the particles were between 0.79 and 1.91 cm in size for N29-F1 corn silage (62%) and NX3018 corn silage (63%). About 33% of the particles were less than 0.79 cm for both corn silages. Mixed cool-season grass hay had the highest proportion (65%) of the large particles followed by alfalfa grass silage (42%). Mixed cool-season grass hay had fewer small (17%) and medium (18%) particles than the ensiled forages.

Cows that were fed the TMR containing NX3018 corn silage produced higher yields of milk ($P < 0.05$), 3.5% FCM ($P < 0.10$), milk CP ($P < 0.10$), and milk lactose ($P < 0.05$) compared with cows that were fed the TMR containing N29-F1 corn silage (Table 9). The 3.5% FCM data in Table 9 does not include three cows that were regarded as outliers after the data had been evaluated using a Mahalanobis distance multivariate outlier analysis (SAS, 1993), which tested 3.5% FCM as the dependent or response variable (Y) against average milk yield [(prestudy and poststudy)/2] as the independent variable (X). However, when the three cows were included in the analysis of 3.5% FCM data, treatment differences were still significant ($P < 0.10$). The 3.5% FCM (kg/d) produced by cows that were fed TMR containing N29-F1 and NX3018 corn silage, respectively, was 47.8 and 49.4 (SE = 0.67), and the P-values for treatment, period, sequence, and cow(sequence) effects, respectively, were 0.09, 0.07, 0.40, and < 0.01. There were no differences in BCS, change in BCS,

Table 8. Particle size distribution of forages used in diets fed to lactating multiparous Holstein cows.[1]

Particle size distribution	N29-F1 corn silage[2]	NX3018 corn silage[2]	First-cut alfalfa-grass silage[2]	Mixed cool season grass hay
Small (< 0.79 cm)	32.64 ± 1.05	32.76 ± 0.76	19.91 ± 1.54	17.16 ± 2.36
Medium (0.79 to 1.91 cm)	61.52 ± 1.42	63.41 ± 0.88	38.05 ± 1.49	17.58 ± 1.64
Large (> 1.91 cm)	5.84 ± 0.57	3.83 ± 0.31	42.04 ± 2.98	65.26 ± 0.85

[1]Particle size distribution conducted at Miner Institute Forage Laboratory (Chazy, NY) using the Penn State forage particle separator.

[2]Particle size distribution on corn silages and alfalfa-grass silage was done on fresh samples as they were being removed from the silage bags (Ag-Bag, Int., Warrenton, OR) before feeding.

and BW between cows that were fed TMR containing NX3018 and N29-F1 corn silages (Table 9). Period effects were significant for percentage and yield of milk fat, percent milk CP, milk urea nitrogen concentration, and animal BW. Sequence of treatment assignment to the cows during the two periods was significant ($P < 0.01$) for percent milk CP, milk urea nitrogen, and BW. Because cows were group fed, DMI data were not subjected to statistical analysis (Table 9). The average daily DMI by each cow across treatments was approximately 28.2 kg/cow.

The high digestibility of the NX3018 corn silage may partially explain the high milk yield by cows that were fed the TMR containing this corn hybrid. Several studies have reported improved milk yield by lactating dairy cows fed higher digestible corn silages such as brown midrib corn silage compared with cows fed less digestible corn silages even though no differences in DMI were observed (Frenchick et al., 1976; Keith et al., 1979). The high yields of CP and lactose in milk produced by cows that were fed the TMR containing NX3018 corn silage may be explained in part by the high milk yield of these cows compared with cows that were fed TMR containing N29-F1 corn silage. Differences in percentage and yield of milk fat, percent milk CP, milk urea nitrogen concentration, and animal BW between the two periods may be explained in part by changes in forages and the differences in the stages of lactation of the cows. Third-cut alfalfa grass silage was fed during the last 2 wk of the 8-wk study. In period 1, cows were in midlactation, while in period 2 cows were past midlactation and hence past their peak lactation. When cows are past peak lactation, milk yield declines, while appetite and consequently DMI remain relatively constant (Kuehn et al., 1999; Wohlt et al., 1998), leading animals to deposit more body fat, thus partially explaining the higher animal BW in period 2 (649 kg) compared with period 1 (636 kg).

Table 9. Lactational performance by lactating dairy cows fed TMR containing Novartis N29-F1 or Novartis NX3018 corn silages.

				P-value			
Item	N29-F1	NX3018	SE	Treatment[1]	Period	Sequence	Cow (Sequence)
DMI, kg/d	28.6	27.7	. . .	. . .	. . .	. . .	. . .
Milk yield kg/d	45.1	46.6	0.5	0.02	0.84	0.36	<0.01
3.5% FCM yield, kg/d	47.2	48.9	0.6	0.06	0.24	0.70	<0.01
Milk fat							
%	3.90	3.89	0.08	0.97	0.05	0.77	0.06
kg/d	1.74	1.81	0.04	0.24	0.04	0.51	<0.01
Milk CP							
%	3.08	3.06	0.01	0.22	<0.01	<0.01	<0.01
kg/d	1.38	1.42	0.01	0.08	0.10	0.88	<0.01
Milk lactose							
%	4.92	4.94	0.01	0.11	<0.01	0.39	<0.01
kg/d	2.21	2.30	0.02	0.01	0.17	0.24	<0.01
Milk urea nitrogen							
mg/dl	12.7	12.9	0.2	0.41	<0.01	<0.01	<0.01
Linear SCC	3.87	3.92	0.10	0.69	0.28	<0.01	<0.01
BCS	3.09	3.12	0.02	0.33	<0.01	0.52	<0.01
BCS change	0.07	0.09	0.04	0.71	0.38	0.53	0.99
BW, kg	644	641	2	0.27	<0.01	<0.01	<0.01

[1]Corn silage hybrid treatment effect.

Increase in the size of the uterus, placenta, and fetus could also have partly contributed to higher BW in period 2.

CONCLUSIONS

The NX3018 corn hybrid had a higher proportion of the nongrain components and lower proportion of the grain components compared with the NF29-F1 corn hybrid. The two corn hybrids had similar plant populations, DM yields, and percent barren and lodged plants. Even though the nutrient compositions of the two corn hybrids were relatively similar, NX3018 had higher IVTDMD and IVNDFD both before ensiling and postensiling in minisilos and silage bags. Cows that were fed the TMR containing NX3018 corn silage produced higher yields of milk, 3.5% FCM, milk CP, and milk lactose compared with cows that were the TMR containing N29-F1 corn silage.

ACKNOWLEDGMENTS

Authors would like to thank Novartis Seeds, Inc. (Golden Valley, MN) for the donation of seed and for partial funding of this study. Authors are also grateful to William Hoover at West Virginia University for the analyses of sugars and starch, Michael S. Allen at Michigan State University for his contribution during the design of the study and interpretation of some of the data. Authors also thank N. Andrew, the Manager of the Miner Institute Dairy Farm and his crew for taking care of the animals.

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