NutriDense Corn Grain and Corn Silage for Dairy Cows

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ABSTRACT

Twenty multiparous Holstein cows, 4 of them surgically fitted with ruminal cannulas, were used in a replicated 4 × 4 Latin square to compare the effects of whole-plant silage and grain produced from NutriDense (ND), leafy NutriDense (LND), or a conventional yellow dent (YD) hybrid on ruminal fermentation, total tract nutrient digestibility, and performance of lactating dairy cows. On a DM basis, diets contained 30.6% corn silage and 27.7% corn grain provided from the 3 hybrids according to the following combinations: 1) YD grain and YD silage, 2) YD grain and LND silage, 3) ND grain and YD silage, and 4) ND grain and LND silage. The average concentrations of crude protein, neutral and acid detergent fiber, and ether extract of LND silage and ND grain were higher, but the contents of nonfibrous carbohydrates and starch were lower than those of their YD counterparts. Although DM intake was similar among treatments, feeding ND grain, LND silage, or both reduced the intakes of nonfibrous carbohydrates and starch but increased the intake of ether extract. Apparent digestibility of starch in the total tract was highest for the diet that contained LND silage and YD grain, whereas the amount and percentage of ether extract that were apparently digested in the total tract was increased and tended to be increased, respectively, by the addition of ND grain, LND silage, or both to the diets. Ruminal fermentation parameters were unaffected by treatments except for the concentration of ammonia nitrogen in the ruminal fluid, which tended to be increased by the feeding of ND grain, LND silage, or both. Production of milk, crude and true protein, fat, lactose, and total solids did not differ among diets. Concentration of milk urea nitrogen increased when the ND grain, LND silage, or both were fed to the cows. Results indicate that ND grain and LND silage were similar to the conventional grain and silage for the feeding of lactating dairy cows.

Key words: specialty corn, NutriDense, dairy cow

INTRODUCTION

At the present time, corn hybrids of enhanced nutritional quality for livestock are emerging in the marketplace. These hybrids are the result of breeding programs that focus on improving nutrient content, profile, and digestibility, or a combination of these factors supplied by the grain or the whole plant preserved as silage. Examples of outcomes from such breeding programs are the corn hybrids NutriDense (ND) and leafy NutriDense (LND). The ND hybrid was developed through conventional breeding to produce kernels with a larger embryo (germ) and, consequently, higher contents of oil ($\geq 1\%$), protein (1 to 2%), and some essential amino acids (Lys, Met, Cys, Thr, and Trp) than conventional yellow dent (YD) corn hybrids (Akay and Jackson, 2001). More recently, the LND hybrid also was bred to produce grain with a nutrient content that was greater than that for YD but also to contain more leaves above the ear than ND. These traits were combined in LND with the goal of increasing the concentration and digestibility of nutrients supplied to dairy cows from whole-plant corn silage.

Data from 2 experiments designed to assess the nutritional value of ND for ruminants are available in the literature. In one trial, Akay and Jackson (2001) reported that feeding ND or YD as grain and whole-plant silage (28 and 33% of dietary DM, respectively) to lactating dairy cows resulted in similar DMI and yields of milk, 3.5% FCM, protein, and fat. Cows fed ND, however, showed higher efficiency of feed use (i.e., FCM/DMI) than cows fed YD (1.49 vs. 1.43, respectively), which was associated with a numerically larger output of FCM (1.3 kg/d). In a second experiment, Akay et al. (2002) observed that the extent and site of OM and starch digestion as well as the ruminal outflow of N fractions were similar in sheep fed a diet in which YD grain was totally replaced with ND grain (44% of the dietary DM). Although the impact of LND on animal performance has not been examined, several reports regarding the nutritional value for dairy cows of corn silage prepared from leafy corn hybrids have been published in recent years. Significant improvements in milk production related (Clark et al., 2002) or not related (Thomas et al., 2001) to increases in DMI were observed when dairy cows were fed whole-plant silage (~40% of the dietary DM) produced from either leafy or conventional corn hybrids. In a larger

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number of studies, however, feeding leafy or conventional corn silage resulted in similar DMI and yields of milk and milk components (Bal et al., 2000a; Ballard et al., 2001; Nennich et al., 2003).

Even though the performance of dairy cattle fed grain, whole-plant silage, or both prepared from ND and leafy corn hybrids has not been consistently enhanced, it is important to address whether the combination of these technologies is useful for achieving significant improvements in the lactational response of dairy cows. Therefore, the objectives of this study were to compare the effects of whole-plant silage and grain produced from LND, ND, and YD on rumen fermentation, nutrient digestibility in the total tract, and performance of lactating dairy cows.

MATERIALS AND METHODS

Corn Grain and Corn Silage Production

On May 26 and 27, 2002, 3 corn hybrids were planted in nonadjacent plots at the Agricultural Research Farm of the University of Illinois at Urbana-Champaign. The hybrids were 1) a YD hybrid [BASF Plant Science (BPS) EX 6485] used to produce grain and whole-plant silage (control), 2) LND (BPS EX 6275) used to prepare whole-plant silage, and 3) ND (BPS EX 6413) committed to produce grain. The size of the plots was 13.8 ha for YD, 6.8 ha for LND, and 6.8 ha for ND. Days to relative maturity were 113 to 115 for each of the corn hybrids studied. All hybrids were planted, grown, and harvested under similar agronomic conditions using the same procedures by personnel of the University of Illinois. Corn plots committed to produce grain were harvested between October 30 and November 1, 2002 at 87.9 and 88.1% DM content for the YD and ND hybrids, respectively. After harvest, the grain was stored separately at the feed mill of the University of Illinois until initiation of the experiment. Corn plots dedicated to produce silage were harvested on September 10 and 11, 2002 at about one-half milk line stage of maturity, chopped (New Holland model 1900 Forage Harvester without a kernel processor; New Holland, PA; harvester setting for a 12.7-mm length cut), and stored using a bagger (Ag-Bagger, St. Nazianz, WI) in separate bags (TriDura Storage Bags, 2.73 m wide and made of #4 plastic with a white exterior and black inner layer, Cottage Grove, MN) at the dairy farm of the University of Illinois. At harvest, the DM percentages of whole fresh-cut plants were 38.5 and 36.1 for YD and LND, respectively.

Animals, Experimental Design, and Diets

Twenty multiparous Holstein cows, 4 of them surgically fitted with ruminal cannulas, were used in a repli-

cated 4×4 Latin square conducted concurrently according to procedures approved by the University of Illinois Laboratory Animal Care Advisory Committee. At the onset of the experiment, cows averaged 41.8 kg of milk (SD = 6.4), 79 DIM (SD = 28), and 648 kg of BW (SD = 72). Cows were initially assigned to squares according to DIM at the beginning of the experiment and milk production during the previous 2 wk. Cows within each square were randomly assigned to 1 of 4 dietary treatment sequences. Each experimental period consisted of 28 d; the first 14 d were used to adapt the cows to treatments, and the remaining 14 d were used for sample and data collection.

Four experimental diets containing the same forage-to-concentrate ratio (DM basis) were prepared with different sources of corn supplied as whole-plant silage and grain (Table 1). Specifically, diets contained 30.6% corn silage and 27.7% corn grain (DM basis) provided from the 3 hybrids in the following combinations: 1) YD grain and silage (YDG + YDS), 2) YD grain and LND silage (YDG + LND), 3) ND grain and YD silage (NDG + YDS), and 4) ND grain and LND silage (NDG + LND). The remaining dietary ingredients were provided from the same source to meet the NRC (2001) nutrient requirements (Table 1). Requirements were established using BW, production and composition of milk, and DMI determined during the 2 wk prior to the start of the experiment. Diets were fed as TMR twice daily at 1000 and 1700 h in amounts to ensure 5 to 10%orts. Additionally, TMR were adjusted weekly to reflect changes in DM content of forages and concentrate mixtures determined by drying the forages and concentrates for 24 h at 105°C.

Cows were housed in individual tie stalls equipped with water bowls and bedded with sawdust. During the experiment, cows were milked twice daily at 0300 and 1500 h and were allowed to exercise outside in a dry lot from 0700 to 0900 h daily.

Sampling, Measurements, and Analyses

The amount of TMR offered and refused was recorded daily. During the last 2 wk of each period, samples of orts from all cows were collected daily, and DM content was determined by drying samples from individual cows at 105°C for 24 h. Before drying orts samples from cannulated cows, representative subsamples (200 g) were separated and frozen at -20°C for later analysis. Samples of forages, concentrates, and TMR were collected at least once weekly and divided into 2 representative subsamples. One subsample of each forage, concentrate, and TMR was used to determine DM as described for orts, and the other subsample was stored frozen at -20°C. At the end of each experimental period, samples of orts from cannulated cows and each forage, concentrate, and

Table 1. Ingredient composition of the experimental diets (DM basis)

Ingredient	Treatment ¹			
	YDG + YDS	YDG + LND	NDG + YDS	NDG + LND
Alfalfa silage, %	19.65	19.65	19.65	19.65
Corn silage				
Control, %	30.56	—	30.56	—
NutriDense, %	—	30.56	—	30.56
Ground shelled corn				
Control, %	27.65	27.65	—	—
NutriDense, %	—	—	27.65	27.65
Soybean meal (48% CP), %	9.17	9.17	9.17	9.17
Soyhulls, %	10.04	10.04	10.04	10.04
Sodium bicarbonate, %	1.01	1.01	1.01	1.01
Dicalcium phosphate, %	0.59	0.59	0.59	0.59
Limestone, %	0.40	0.40	0.40	0.40
Sodium sulfate, %	0.30	0.30	0.30	0.30
Sodium chloride, %	0.26	0.26	0.26	0.26
Mineral and vitamin mix, ² %	0.22	0.22	0.22	0.22
Magnesium oxide, %	0.16	0.16	0.16	0.16

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

²Contained 5.0% Mg, 7.5% K, 10.0% S, 3.0% Zn, 3.0% Mn, 2.0% Fe, 0.5% Cu, 0.025% I, 0.015% Se, 0.004% Co, 2,200 IU of vitamin A/g, 660 IU of vitamin D₃/g, and 22 IU of vitamin E/g.

TMR from the weekly collections were thawed, combined on an equal weight basis, and sent to Dairy One, Inc., Forage Testing Laboratory (Ithaca, NY), where they were analyzed for Kjeldahl N, ether extract (EE; AOAC, 1990), ADF, NDF (with heat-stable α -amylase and sodium sulfite; Van Soest et al., 1991), and starch (Kartchner and Theurer, 1981). Alfalfa silage samples were also assayed for acid detergent insoluble CP (Van Soest et al., 1991), and their NFC concentration was determined by calculation (NRC, 2001). Ash was not determined, and the NRC (2001) default value was used to calculate NFC in Tables 2, 3, and 4 according to the NRC (2001). The DM concentration of the TMR and orts was used to calculate DMI. Subsequently, intakes of CP, ADF, NDF, EE, NFC, starch, and NE_L were estimated using the measured DMI and the analytically measured or calculated (i.e., NFC and NE_L) chemical composition of the TMR (NRC, 2001). Default values of the NRC (2001) for ash and acid detergent insoluble CP were used for all feeds except alfalfa silage to calculate NE_L.

Milk production was recorded electronically at each milking throughout the experiment. Milk samples were collected for 4 consecutive milkings during each of the last 2 wk of each period, preserved with 2-bromo-2-nitropropane-1,3-diol, and stored at 4°C. At the end of each week, samples were sent to Dairy One Cooperative, Inc., Milk Check Laboratory (Ithaca, NY) for analyses of fat, CP, true protein, lactose, total solids, MUN (infrared procedures; Foss 4000, Foss North America, Eden Prairie, MN), and SCC (Foss 5000, Foss North America). Daily milk composition was estimated as the average of

the a.m. and p.m. milk samples corrected by the proportion of daily production at that milking.

Body weights were recorded 2 d prior to the start of the experiment and on d 27 and 28 of each period. Body condition scores were recorded on d 1 and 28 of each period by the same 3 individuals using a scale of 1 to 5 in quarter-point increments, where 1 = thin to 5 = obese (Wildman et al., 1982).

To assess nutrient digestibility, fecal grab samples from cannulated cows were collected twice daily at 0600 and 1800 h and frozen at -20°C from d 22 to 26 of each period. Previous data (Smith and Reid, 1955; Schauff et al., 1991) have indicated that this sampling scheme is adequate for measuring nutrient digestibility in the total gastrointestinal tract of dairy cows. At the end of the experiment, samples were thawed, mixed, composited on an equal wet weight basis, dried at 55°C (until no loss of weight occurred), ground through a 1-mm screen, and assayed by Dairy One, Inc., Forage Testing Laboratory for Kjeldahl N, EE, ADF, NDF, and starch as described above. Chromic oxide was used as an indigestible marker to assess fecal excretion by the cows. Gelatin capsules that contained 10 g of Cr₂O₃ powder were administered via the ruminal cannula at 0600 and 1800 h from d 17 to 26 of each period. Concentration of Cr in fecal samples was quantified by atomic absorption spectroscopy (air plus acetylene flame, Perkin-Elmer, Norwalk, CT) after preparation of samples by the procedure of Williams et al. (1962).

Samples of ruminal fluid were collected at 0, 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 13, 19, and 23 h after the morning

feeding on d 27 of each period. Samples were taken from multiple sites in the rumen, and the pH of ruminal fluid was measured immediately by glass electrode (model AP50, Denver Instrument, Denver, CO). After measurement of pH, a subsample of 40 mL was acidified to pH <2 with 50% H₂SO₄ (vol/vol) and frozen at -20°C for later analyses. At the end of the experiment, samples were thawed and centrifuged at 27,000 × *g* for 20 min at 4°C; an aliquot of 4 mL was diluted with 25% metaphosphoric acid (4 mL of sample:1 mL of metaphosphoric acid). These subsamples were assayed with a gas chromatograph (model 5890 Series II, Hewlett-Packard, Avondale, PA) equipped with a 1.8-m glass column packed with 10% SP 1200:1% H₃PO₄ on 80/100 chromosorb W AW (Supelco, Inc., 1975) to determine the concentration of VFA. Nitrogen was the carrier gas, and the temperatures of the injection port and column were 175 and 125°C, respectively. The concentration of ruminal NH₃N was determined according to the procedures outlined by Chaney and Marbach (1962) as modified by Cotta and Russell (1982).

Statistical Analyses

Before analysis, data for DMI, nutrient intake and digestibility, milk production, and milk composition were reduced to period means for each cow. Thereafter, data were analyzed using the MIXED procedure of SAS (2000) for a replicated 4 × 4 Latin square; square and cow were treated as random variables. The following model was used for all dependent variables:

$$Y_{ijkl} = \mu + S_i + C_j(S)_i + P_k + SP_{ik} + T_l + ST_{il} + \varepsilon_{ijkl}$$

where

μ = overall mean,

S_i = effect of square *i* (*i* = 1, 2, 3, 4),

$C_j(S)_i$ = effect of cow *j* nested within square *i* (*j* = 1, 2, 3, 4),

P_k = effect of period *k* (*k* = 1, 2, 3, 4),

SP_{ik} = interaction of square *i* and period *k*

T_l = effect of treatment *l* (*l* = 1, 2, 3, 4),

ST_{il} = interaction of square *i* and treatment *l*, and

ε_{ijkl} = residual error.

Least squares means were separated into significant main effects by the PDIF option of SAS (2000). Ruminal VFA, NH₃N, and pH data were analyzed as repeated measures in time using the MIXED procedure of SAS (Littell et al., 1996). Based on the smallest value for Akaike's information criterion, the compound symmetric structure type was selected as the appropriate covariance structure (Littell et al., 1996). The model was simi-

lar to the model described above except for the removal of the effect of square and the addition of the effect of hour and the interaction of treatment and hour. Because the treatment by hour interaction was not significant ($P > 0.25$) for the ruminal parameters, treatment effects were compared across sampling times using the procedure just described.

Differences among treatments were considered significant when $P \leq 0.05$, whereas when $P > 0.05$ but < 0.10 differences were considered to indicate a trend toward a significant effect.

RESULTS AND DISCUSSION

Chemical Composition of Feed Ingredients and Diets

As shown in Table 2, the chemical composition of the ND grain was substantially different from that of the YD control. The ND grain had 3.0 (39%) and 1.5 (31%) more percentage units of CP and EE, respectively, than its control counterpart. These changes, however, were paralleled by an increase in the content of NDF (40%) and ADF (104%) and a decrease in the concentration of NFC (8%) and starch (15%) in the ND grain. Although of different magnitude, similar changes in the concentration of CP (+6%), EE (+46%), and starch (-3%) were reported in an earlier comparison between ND and YD grain (Akay and Jackson, 2001). In relation to other specialty corn hybrids, the nutrient composition of ND grain closely resembled that of high-oil corn grain (Dado, 1999). As proposed by Akay and Jackson (2001), these alterations originated mainly from the larger germ and smaller endosperm of the ND grain.

Relevant differences were also observed for the chemical composition of corn silage produced either from the LND or YD hybrid. The LND corn silage had higher CP (10%), NDF (13%), ADF (14%), and EE (25%) contents, but lower concentrations of NFC (16%) and starch (32%), when compared with the conventional corn silage. Previous research (Akay and Jackson, 2001) showed that corn silage prepared from the ND hybrid contained similar concentrations of CP, ADF, and NDF, but a higher percentage of starch (6%), than corn silage produced from a YD hybrid. In this experiment, because both corn silages were prepared and managed similarly, differences in their content of carbohydrate fractions, principally of starch and CP, could be attributed to the leafiness of the LND hybrid. Although the proportion of plant components (leaves, stalks, ears) was not assessed in this experiment, the YD hybrid appeared to contain considerably more ears per unit of land area and more kernels per ear at harvest. Certainly, leafy corn hybrids have been shown to contain more leaves and stalks but less grain, cobs, and husks than their conventional counter-

Table 2. Chemical composition of forages, corn grains, and soyhulls (DM basis)^{1,2}

Item	Alfalfa	YDS	LND	YDG	NDG	Soyhulls
DM, %	46.9 ± 2.2	40.4 ± 1.1	36.4 ± 1.4	89.4	88.5	85.8 ± 0.2
CP, %	24.1 ± 0.8	7.7 ± 0.2	8.5 ± 0.3	7.7	10.7	11.0 ± 0.4
ADICP, ³ %	1.4 ± 0.2	ND ⁴	ND	ND	ND	ND
NDF, %	39.5 ± 1.6	41.0 ± 3.4	46.5 ± 3.9	7.9	11.1	68.3 ± 1.1
ADF, %	30.8 ± 1.3	22.2 ± 1.4	25.3 ± 1.5	2.2	4.5	46.5 ± 0.5
NFC, ⁵ %	27.3 ± 1.4	42.1 ± 4.1	35.5 ± 2.9	78.7	72.1	14.4 ± 1.5
Starch, %	1.3 ± 0.9	35.7 ± 5.4	24.2 ± 4.7	68.6	58.2	0.6 ± 0.5
EE, ⁶ %	4.2 ± 0.5	4.0 ± 0.3	5.0 ± 0.5	4.9	6.4	2.7 ± 0.1

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

²Means ± SD (n = 4).

³ADICP = Acid detergent insoluble CP.

⁴ND = Not determined.

⁵Nonfibrous carbohydrates = 100 - (% NDF + % CP + % ether extract + % ash).

⁶EE = Ether extract.

parts (Kuehn et al., 1999; Thomas et al., 2001). It should be noticed, however, that these differences in plant composition have resulted in small or even negligible differences in the nutrient composition of whole-plant silages prepared from leafy or conventional hybrids (Thomas et al., 2001; Clark et al., 2002; Nennich et al., 2003).

Because experimental diets were formulated to contain the same proportions of feed ingredients, their chemical composition reflected the aforementioned differences between sources of corn grain and silage (Table 3). With the exception of NDF, the percentages of CP, ADF, and EE were highest for the NDG + LND treatment, intermediate for the YDG + LND and NDG + YDS diets, and lowest for the YDG + YDS treatment. The percentages of NFC and starch followed the opposite trend. The magnitude of differences among treatments was more pronounced for those nutrients (CP and starch) whose concentration in corn grain and silage differed the most.

Intake of DM and Nutrients

The DMI was not affected by dietary treatments and averaged 27.1 kg/d (Table 4). In agreement with these findings, Akay and Jackson (2001) reported that when dairy cows in early lactation were fed diets that contained 33% corn silage and 28% corn grain from either ND or a YD control, differences in DMI (23.8 and 23.9 kg/d, respectively) were not significant. With the exception of one experiment (Clark et al., 2002), several researchers also observed that the feeding of leafy or conventional corn silage to lactating cows resulted in similar DMI (Bal et al., 2000a; Ballard et al., 2001; Nennich et al., 2003).

Regardless of the source of corn silage, the intake of N was highest for cows fed the ND grain (Table 4). This effect arose from the markedly higher content of CP (39%) in the ND grain compared with the YD control. Intakes of ADF and NDF were greater for cows fed the

Table 3. Chemical composition of the experimental diets (DM basis)

Item	Treatment ¹			
	YDG + YDS	YDG + LND	NDG + YDS	NDG + LND
DM, %	55.5	52.8	55.4	52.9
CP, %	14.7	14.9	15.7	16.0
NDF, %	32.7	34.4	32.6	34.3
ADF, %	19.3	20.2	19.5	20.5
NFC, ² %	43.9	41.9	42.1	40.1
Starch, %	29.0	25.4	27.2	23.7
EE, ³ %	3.6	3.9	4.1	4.4
NE _L , ⁴ Mcal/kg of DM	1.55	1.56	1.57	1.58

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

²Nonfibrous carbohydrates = 100 - (% NDF + % CP + % ether extract + % ash).

³EE = Ether extract.

⁴Calculated (NRC, 2001) using analyzed ingredient composition (Table 2) and least squares means for intakes (Table 4).

Table 4. Least squares means for intakes of DM, N, carbohydrates, ether extract (EE), and NE_L by lactating dairy cows fed the experimental diets (all cows)

Intake	Treatment ¹				SEM	P<
	YDG + YDS	YDG + LND	NDG + YDS	NDG + LND		
DM, kg/d	27.0	26.9	26.7	27.2	0.7	0.70
N, g/d	633 ^b	642 ^b	673 ^a	696 ^a	22	0.01
ADF, kg/d	5.2 ^b	5.4 ^a	5.2 ^b	5.6 ^a	0.1	0.01
NDF, kg/d	8.8 ^b	9.2 ^a	8.7 ^b	9.3 ^a	0.2	0.01
NFC, ² kg/d	11.9 ^a	11.3 ^b	11.3 ^b	10.9 ^c	0.3	0.01
Starch, kg/d	7.8 ^a	7.1 ^b	7.3 ^b	6.6 ^c	0.4	0.01
EE, g/d	958 ^d	1,037 ^c	1,084 ^b	1,185 ^a	33	0.01
NE _L , Mcal/d	41.9	42.0	42.0	43.0	1.0	0.36

^{a-d}Values within the same row with uncommon superscript are different ($P < 0.05$).

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

²Nonfibrous carbohydrates = $100 - (\% \text{ NDF} + \% \text{ CP} + \% \text{ EE} + \% \text{ ash})$.

LND silage in combination with either the ND or YD grain than for the YD silage treatments because of the slightly greater ADF and NDF content of the LND diets. The intakes of NFC and starch by cows fed the YDG + LND and NDG + YDS treatments were intermediate compared with the intakes by cows fed the other 2 diets. Intakes of these carbohydrate fractions were lowest for cows fed the NDG + LND treatment because the NFC and starch concentrations of the ND grain and silage were lower than those of their YD counterparts. Consequently, the intake of NFC and starch reached a maximum when the YDG + YDS diet was fed. In contrast, the highest and lowest intakes of EE were achieved by cows fed the NDG + LND and YDG + YDS treatments, respectively. Because the ND grain provided more EE per unit of DM than the LND silage, the NDG + YDS diet resulted in larger intakes of EE than the YDG + LND, whereas the amount of EE consumed by cows fed these 2 treatments exceeded that of cows fed the control diet. Because DMI and the NE_L content of the diets were similar among treatments, the intake of NE_L was not affected by the source of corn grain and whole-plant silage.

Rumen Fermentation and Apparent Digestibilities

Dietary treatments did not alter significantly the ruminal fermentation parameters examined in this experiment (Table 5). Feeding the NDG + YDS diet tended to decrease the molar proportion of propionate, but an explanation for this trend is not evident. In addition, the molar proportion of isovalerate ($P < 0.08$) and the concentration of NH₃N ($P < 0.09$) in the ruminal fluid of cows fed the control diet tended to be lower than those for the other 3 treatments. This might have occurred 1) because of the lower intake of CP, 2) because less true protein was degraded in the rumen, 3) because more

NH₃N was incorporated into microbial protein, because of a higher availability of fermentable substrates (i.e., NFC and starch) in the rumen of cows fed the control diet, or 4) because of a combination of these factors. A reduction in the amount of protein degraded in the rumen could be explained by a lower intake of CP by cows fed the YDG + YDS diet than by those fed diets containing ND grain, although the difference between the control and the YDG + LND treatment still would remain unexplained. Alternatively, less CP might have been degraded in the rumen of cows fed the control diet because of a higher degradability of corn protein of ND origin compared with that supplied by the YD hybrid. In a previous experiment (Akay and Jackson, 2001), the feeding of corn grain and whole-plant silage produced from the ND hybrid increased the molar proportion of isobutyrate and the concentration of NH₃N in the rumen of dairy cows, albeit the ND and control diets contained similar percentages of CP (18.0 and 17.6, respectively) and starch (21.9 and 22.2, respectively). In a later experiment by the same research group (Akay et al., 2002), the complete replacement of YD grain with ND grain (44% of dietary DM) in the diet of sheep decreased the intake of starch (15%) without affecting the intake of N and yet resulted in a numerically higher concentration of NH₃N (14%) in the rumen. Collectively, data support the hypothesis that CP supplied by the ND hybrid is more degradable in the rumen than CP provided by conventional YD hybrids.

The amount and percentage of DM, N, ADF, and NDF that were apparently digested in the total digestive tract were unaffected by dietary treatments (Table 6). Similarly, changes in apparent total tract digestibility of OM, ADF, NDF, and CP were not detected in experiments in which dairy cows (Akay and Jackson, 2001) or sheep (Akay et al., 2002) were fed corn grain, corn silage, or both prepared either from the ND hybrid or a YD control.

Table 5. Least squares means for rumen fermentation parameters of lactating dairy cows fed the experimental diets (cannulated cows)

Item	Treatment ¹				SEM	P<	
	YDG + YDS	YDG + LND	NDG + YDS	NDG + LND		TRT ²	TRT × h ³
pH	6.14	6.15	6.24	6.23	0.08	0.48	0.96
VFA, mM	107	108	105	103	5.53	0.51	0.41
Acetic (A), mol/100 mol	65.6	65.2	66.1	64.6	1.19	0.56	0.78
Propionic (P), mol/100 mol	19.7	19.4	18.6	20.2	0.83	0.08	0.82
A:P	3.46	3.43	3.59	3.30	0.18	0.11	0.99
Isobutyric, mol/100 mol	1.00	1.04	1.10	1.02	0.08	0.25	0.96
Butyric, mol/100 mol	11.27	12.17	11.41	11.22	0.66	0.46	0.90
Isovaleric, mol/100 mol	1.69	1.80	1.91	1.70	0.14	0.08	0.69
Valeric, mol/100 mol	1.61	1.59	1.54	1.54	0.09	0.47	0.78
NH ₃ N, mg/dL	13.50	15.02	15.91	15.50	0.67	0.09	0.99

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

²TRT = Treatment effect.

³TRT × h = Treatment × hour interaction.

Less consistent findings have been reported for the *in vivo* nutrient digestibility of leafy corn silages. For instance, Kuehn et al. (1999) reported that feeding diets that contained either leafy or conventional corn silage (40.6% of dietary DM) to lactating dairy cows did not affect the percentages of DM, OM, and NDF that were apparently digested in the total tract. However, Bal et al. (2000a) observed that replacing conventional corn silage with its leafy counterpart to provide 33.5% of dietary DM decreased the proportion of DM, OM, and fiber fractions that were digested in the gastrointestinal tract of dairy cows in midlactation. In contrast, Nennich et al.

(2003) found that feeding leafy rather than conventional corn silage (40.4% of the dietary DM) to lactating cows improved the apparent digestibility of NDF and CP without influencing that of DM.

Total tract disappearance of starch (amount and percentage) was greater for the YDG + LND diet than for the other 3 treatments (Table 6). Changes in starch digestibility were not observed in previous studies designed to compare grain, whole-plant silage, or both produced from the ND hybrid or a YD control (Akay and Jackson, 2001; Akay et al., 2002). In contrast, some researchers (Bal et al., 2000a,b), but not others (Nennich

Table 6. Least squares means for DMI and apparent total tract digestibility of DM, N, carbohydrates, and ether extract (EE) by lactating dairy cows fed the experimental diets (cannulated cows)

Item	Treatment ¹				SEM	P<
	YDG + YDS	YDG + LND	NDG + YDS	NDG + LND		
DMI, kg/d	27.6	27.2	26.1	27.5	1.3	0.40
DM						
kg/d	18.6	18.9	17.6	19.1	1.0	0.28
%	67.9	69.1	66.5	68.0	1.8	0.72
N						
g/d	400	381	334	369	40	0.31
%	61.0	59.7	55.5	57.5	2.8	0.34
ADF						
kg/d	2.5	2.5	2.6	3.0	0.4	0.39
%	48.8	48.4	48.9	53.2	4.6	0.60
NDF						
kg/d	5.3	5.3	4.9	5.5	0.5	0.53
%	56.4	56.8	54.8	57.5	3.3	0.90
Starch						
kg/d	6.2 ^b	6.8 ^a	5.9 ^b	6.1 ^b	0.5	0.01
%	87.5 ^b	94.5 ^a	89.0 ^b	88.7 ^b	1.7	0.03
EE						
g/d	524 ^b	751 ^a	765 ^a	729 ^a	97	0.01
%	65.2	71.4	71.8	69.4	4.2	0.11

^{a,b}Values within the same row with uncommon superscripts are different ($P < 0.05$).

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

Table 7. Least squares means for milk production, milk composition, BW, BW change, and BCS of lactating dairy cows fed the experimental diets (all cows)

Item	Treatment ¹				SEM	P<
	YDG + YDS	YDG + LND	NDG + YDS	NDG + LND		
Milk, kg/d	36.7	36.5	36.0	36.7	2.69	0.80
FCM/DMI	1.40	1.41	1.38	1.40	0.08	0.90
FCM/NE _L intake	0.90	0.90	0.88	0.88	0.05	0.77
Fat						
%	3.72	3.71	3.68	3.72	0.10	0.89
kg/d	1.35	1.35	1.31	1.36	0.09	0.61
3.5% FCM, ² kg/d	37.8	37.7	36.8	37.9	2.51	0.73
CP						
%	3.31	3.32	3.30	3.34	0.09	0.69
kg/d	1.21	1.21	1.18	1.22	0.07	0.67
True protein						
%	3.12	3.13	3.13	3.15	0.09	0.90
kg/d	1.13	1.14	1.12	1.15	0.07	0.82
MUN, mg/dL	11.13 ^b	11.09 ^b	12.13 ^a	12.04 ^a	0.42	0.01
Lactose						
%	4.79	4.80	4.81	4.84	0.04	0.60
kg/d	1.76	1.75	1.73	1.78	0.13	0.79
TS						
%	12.56	12.57	12.53	12.64	0.20	0.82
kg/d	4.58	4.58	4.49	4.62	0.31	0.67
SCC, 10 ⁴ cells/mL	247.7	368.3	383.3	387.6	527.9	
SCC, log10	5.13	5.15	5.18	5.23	0.15	0.80
BW	683	681	683	685	17.93	0.62
BW change						
Total kg/28 d	-13.2	-15.8	-7.1	-14.9	5.89	0.40
kg/d	-0.47	-0.56	-0.26	-0.53	0.21	0.44
BCS ³	2.81	2.93	2.86	2.82	0.12	0.81

^{a,b}Values within the same row with uncommon superscripts are different ($P < 0.05$).

¹LND = Leafy NutriDense corn silage; NDG = NutriDense corn grain; YDG = yellow dent corn grain; YDS = yellow dent corn silage.

²3.5% FCM = 0.4324(kilograms of milk) + 16.216(kilograms of fat).

³Scale of 1 to 5 in quarter-point increments where 1 = thin to 5 = fat.

et al., 2003), also have found greater ruminal or total tract starch digestibilities for leafy corn silages than for their conventional controls. As suggested by Bal et al. (2000b), the softer kernel of leafy hybrids compared with that of conventional YD hybrids might have accounted for the improvements in starch digestibility. Although this theory appears plausible, it is unclear why the disappearance of starch from the total tract did not change when the LND silage was fed along with the ND grain. The lack of congruent results among published reports may be related in part to the influence of the genetic background of the corn hybrid on the expression of the leafy trait (Nennich et al., 2003), to the methodology (i.e., diet composition, markers, etc.) used by different labs to assess apparent digestibility, or both. Feeding ND grain, LND silage, or both to cows increased the amount ($P < 0.01$) and proportion ($P < 0.1$) of EE that were digested in the total tract (Table 6). Similar results were obtained when high-oil corn was used to increase the intake of fat by dairy cows (Elliott et al., 1993),

suggesting that the extra oil provided by the ND grain diluted dietary lipids of poor digestibility and losses of endogenous fatty acids, as proposed by Elliott et al. (1993).

Production of Milk and Milk Composition

The production of milk and 3.5% FCM averaged 36.5 and 37.5 kg/d, respectively, and was not significantly different among treatments (Table 7). Similarly, efficiency of feed use (FCM/DMI and FCM/NE_L intake) and the concentrations of fat, CP, true protein, lactose, and total solids in milk did not differ among treatments. Consequently, the production of milk components was unchanged by experimental diet. Regardless of the source of corn silage, the concentration of MUN was higher for cows fed diets that contained the ND grain compared with those fed YD grain. This response is consistent with a trend for an increase in the concentration of NH₃N in ruminal fluid of cows fed ND grain, sug-

gesting that the amount of NH_3N absorbed from the rumen into the blood, converted to urea in the liver, and released back into blood increased when the ND grain replaced its conventional counterpart in the diets. As proposed earlier, potentially higher rumen degradability of CP supplied by the ND hybrid vs. the YD control along with increased N intake, but reduced starch intake, by cows fed ND grain compared with those fed the YD grain might have played a role in explaining this finding. Somatic cell counts averaged $347 (10^4/\text{mL})$ for all treatments, and significant differences were not evident when SCC were transformed ($\log 10$) before performing statistical analyses (Table 7).

All experimental diets resulted in similar losses of BW, which averaged 0.46 kg/d (Table 7). Additionally, BCS averaged 2.86 and remained unaffected among cows fed the 4 dietary treatments (Table 7).

These findings support published data showing that the performance of lactating dairy cows is frequently not affected by the feeding of grain, whole-plant silage, or both prepared from ND (Akay and Jackson, 2001) or leafy (Bal et al., 2000a; Ballard et al., 2001; Nennich et al., 2003) corn hybrids.

CONCLUSIONS

In this experiment, the concentrations of CP, NDF, ADF, and EE of the grain and whole-plant silage prepared from the ND and LND hybrids, respectively, were higher than those of the conventional YD hybrid. The content of NFC and starch showed the opposite trend. These differences in nutrient composition between sources of corn grain and silage led to similar differences in nutrient composition and intake among treatments. The inclusion of ND grain, LND silage, or both in the diets increased the intake and total tract digestibility of EE. This effect, however, was not sufficient to improve the lactational performance of cows fed the experimental diets. These findings confirm that the response of lactating dairy cows fed ND grain, LND silage, or both is not different from the response of lactating dairy cows fed conventional corn lines.

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