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Influence of Glyphosate-Tolerant (event nk603) and Corn Rootworm Protected (event MON863) Corn Silage and Grain on Feed Consumption and Milk Production in Holstein Cattle[1]

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ABSTRACT

Two studies were conducted to evaluate the effect of a glyphosate-tolerant (event nk603) and a corn rootworm protected (event MON863) corn hybrid on feed intake and milk production compared with the nontransgenic hybrid and two reference hybrids. In Experiment 1, 16 multiparous Holstein cows were assigned to one of four treatments in replicated 4 × 4 Latin squares with 28-d periods. Diets contained 40% (dry matter [DM] basis) of either 1) glyphosate-tolerant corn silage (GT), 2) nontransgenic control corn silage, or 3) two nontransgenic reference hybrids which are commercially available. Each diet also contained 23% corn grain from the same hybrid that supplied the silage. At ensiling, rapid drying conditions prevailed and the GT hybrid was the last to be harvested which resulted in greater DM content at similar physiological maturity. The 4% fat-corrected milk (FCM) yield and DMI were reduced for cows fed the GT corn diet due to the higher DM content of the GT silage (37.1 vs. 33.2 kg/d and 4.05 vs. 3.61% of BW, respectively). There was no effect of the GT diet on milk composition or efficiency of 4% FCM production that averaged 1.43 kg/kg of DM intake for all diets. In Experiment 2, 16 multiparous Holstein cows were assigned to one of four treatments in replicated 4 × 4 Latin squares with 21-d periods. Diets contained 26.7% (DM basis) corn grain from either 1) corn rootworm protected (event MON863) corn hybrid, 2) nontransgenic control corn hybrid, or 3) the same two nongenetically enhanced reference hybrids used in Experiment 1. The 4% FCM yield (34.8 kg/d) and DM intake (4.06% of BW) were unaffected by diet. Efficiency of FCM production (average 1.32 kg/kg of DMI) was not affected by diet. In summary, these two studies indicated that insertion of a gene for glyphosate tolerance or corn rootworm protection into a corn hybrid did not affect its nutritional value (as measured by efficiency of milk production) for lactating dairy cows compared with conventional corn hybrids.
(**Key words:** Glyphosate tolerant, corn rootworm protection, corn hybrids, dairy cows)

Abbreviation key: CON = nontransgenic corn hybrid, **CRW** = corn rootworm protected (event MON863) corn hybrid, **Cry** = crystalline protein inclusions, **GT** = glyphosate-tolerant (event nk603) corn hybrid, **REF1** = reference corn hybrid 1, **REF2** = reference corn hybrid 2.

INTRODUCTION

Glyphosate is the active ingredient in the herbicide, Roundup, that inhibits the function of 5-enolpyruvyl shikimate-3-phosphate synthase, an enzyme involved in the production of essential aromatic AA (Clark and Ipharraguerre, 2001). Herbicide-tolerant corn plants are produced by the stable insertion of a gene that expresses a modified plant synthase protein in the receptor plant that is tolerant to glyphosate (LeBruns et al., 1997). Currently, glyphosate-tolerant crop varieties have been developed for corn, soybeans, canola, and cotton (Sidhu et al., 2000). Glyphosate-tolerant corn plants offer crop and livestock producers an alternative to the targeted weed control typically practiced by corn growers.

Corn hybrids have also been developed that contain a protein derived originally from *Bacillus thuringiensis* (**Bt**) which is a naturally occurring soil bacterium. Corn hybrids which contain the Bt trait express the crystalline protein inclusions (**Cry**) insect control proteins (Faust, 2002). Following a single acute exposure, Cry proteins bind to specific receptors in the mid gut cells of susceptible insects and form ion-selective channels in the cell membrane (English and Slatin, 1992). The cells swell due to an influx of water which leads to cell lysis and death (Knowles and Ellar, 1987). One such

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corn event (MON863) produces the Cry 3Bb1 protein that targets the corn rootworm (*Diabrotica virgifera* and *D. barberi*).

To-date, there is virtually no published research on the potential effects of silage or grain from glyphosate-tolerant (**GT**) or corn rootworm protected (**CRW**) corn hybrids on feed consumption and milk production in dairy cattle compared with near isolines or other commercially available corn hybrids. Therefore, the objectives of these two experiments were to 1) evaluate the effect of silage and grain prepared from a GT corn hybrid on feed intake, milk production, and milk composition in lactating Holstein cows compared with a genetically related nontransgenic hybrid and two commercial hybrids grown under similar conditions and harvested at the same physiological maturity (Experiment 1); and 2) evaluate the effect of grain prepared from a CRW corn hybrid on feed intake, milk production, and milk composition in lactating Holstein cows compared with a nontransgenic control hybrid and the same two commercial hybrids as Experiment 1 (Experiment 2). Our hypothesis was that there would be no difference in feed intake and milk production by dairy cows fed genetically enhanced or nontransgenic corn hybrids.

MATERIALS AND METHODS

Corn Cultivation, Harvest, and Chemical Composition: Experiments 1 and 2

Five corn hybrids used in both experiments were planted at the University of Nebraska Agricultural Research and Development Center located near Mead, NE in 2000: 1) GT corn hybrid (event nk603; Monsanto Company, St. Louis, MO), 2) CRW corn hybrid (event MON863; Monsanto Company, St. Louis, MO), 3) genetically similar, nontransgenic control line (**CON**) RX670 (Asgrow, Des Moines, IA), and 4) two nontransgenic commercial corn hybrids used as references. The first reference hybrid (**REF1**) was DK647 (DEKALB Seeds, Dekalb, IA) and the second reference hybrid (**REF2**) was RX740 (Asgrow, Des Moines, IA). Days to relative maturity were 108 for GT, CRW, and CON, 111 for REF2, and 114 for REF1. All five hybrids were grown for harvest of silage or grain under comparable agronomic conditions.

The corn for silage was harvested at approximately 2/3 milk-line stage of maturity using a field chopper with knives adjusted to a 1-cm theoretical length of cut. The DM at harvest for each hybrid is shown in Table 1. The chopped corn from each hybrid was ensiled in separate plastic silage bags. Grain was harvested at 87.9, 87.2, 86.8, 87.2, and 87.9% DM for the GT, CRW, CON, REF1, and REF2 corn hybrids, respectively. Representative grain samples were collected at harvest for each hybrid and analyzed for mycotoxins by a combination of HPLC and TLC (Romer Labs, Inc., Union, MO) prior to the start of Experiments 1 and 2.

A weekly composite sample of each corn grain, corn silage, alfalfa hay, whole cottonseed, grain supplement, and TMR was combined by period and these composite samples was analyzed for chemical composition by Dairy One DHI Forage Testing Lab (Ithaca, NY). The following analyses were conducted: ash, CP, ether extract (AOAC, 1990), ADF, NDF (with amylase and sodium sulfite), acid detergent insoluble CP, acid detergent lignin (Van Soest et al., 1991), calculated nonfiber carbohydrates (NRC, 2001), and Ca, P, Mg, and K by inductively coupled plasma spectrometry (Varian, Inc., Palo Alto, CA). For the silage composites only, the following analyses were conducted at Dairy One DHI Forage Testing Lab: pH, in vitro true digestibility (Goering and Van Soest, 1970), ammonia-N, lactic acid, and VFA by GLC (Bolsen et al., 1993). Chemical composition of the dietary ingredients for Experiments 1 and 2 is summarized in Tables 1 to 3.

Experiment 1

Cows, diets, and sampling. Sixteen multiparous Holstein dairy cows (96 ± 7 DIM) were blocked (assigned to square) by DIM and previous 2-wk milk production and assigned randomly to one of four treatments within each square. The design was a replicated 4 × 4 Latin square (squares were conducted concurrently) with 28-d periods; the first 14 d served as adaptation and the last 14 d served as the collection period. Diets contained 40% of the GT, CON, REF1, or REF2 corn silage, 10% alfalfa hay, 23.1% corn grain, 5.1% whole cottonseed, and 21.8% of a concentrate mixture comprised of soybean meal products, blood meal, minerals, and vitamins (DM basis; Table 4). Diets were formulated so that the corn grain and corn silage were from the same hybrid for each diet. All diets were formulated to contain approximately 18% CP and to meet the metabolizable protein requirement as predicted by the Cornell Net Carbohydrate and Protein Model (1994). The four diets were fed as TMR once daily in amounts to ensure 10% feed refusal.

Cows were housed in a tiestall barn equipped with individual feed boxes. Feed offered and refused was recorded daily. Cows were removed from the barn for milking, exercise, and estrus detection twice daily for a total of approximately 4 h. Daily milk yields were recorded electronically. During the last 2 wk of each period, a.m. and p.m. milk samples were collected during four consecutive milkings and analyzed for fat, protein, lactose, SNF (B-2000, Bentley Instruments, Chaska, MN), SCC (SCC 500, Bentley Instruments),

Table 1. Chemical composition of dietary ingredients (Experiment 1).

Item	DM	CP	ADIP[1]	ADF	NDF	ADL[2]	NSC[3]	EE[4]	Ash	NE_L[5]
	(%)	(% of DM)								(Mcal/kg)
Alfalfa hay	90.2	18.6	1.2	28.2	35.6	7.9	34.4	2.5	10.2	1.41
Whole cottonseed	90.4	26.9	1.6	37.8	49.6	11.8	4.3	20.4	4.2	2.18
Grain supplement[6]	89.3	43.6	1.0	4.9	11.3	1.6	24.0	1.2	21.0	1.52
Corn grain, REF1[7]	90.1	9.5	0.5	2.7	8.6	1.4	76.2	5.1	1.2	2.09
Corn grain, REF2[7]	89.8	8.8	0.5	3.1	8.8	1.3	77.4	4.1	1.3	2.14
Corn grain, CON[7]	89.5	8.7	0.4	3.3	9.1	1.3	77.1	4.3	2.0	2.09
Corn grain, GT[7]	89.3	8.4	0.5	3.5	9.6	1.4	77.3	4.0	1.2	2.07
Corn silage, REF1	34.8	8.0	0.9	24.5	39.2	3.9	45.0	3.5	5.2	1.60
Corn silage, REF2	35.1	7.9	0.7	22.7	38.3	3.6	45.7	3.3	5.5	1.59
Corn silage, CON	36.6	7.3	0.6	23.5	39.9	3.1	45.9	3.0	4.5	1.59
Corn silage, GT	42.5	7.9	0.9	26.0	41.6	3.6	43.2	2.7	5.6	1.49

[1]Acid detergent insoluble CP.

[2]Acid detergent lignin.

[3]Nonstructural carbohydrates.

[4]Ether extract.

[5]Calculated using 30-h in vitro fermentation of NDF for silages and summative equations for other ingredients (NRC, 2001).

[6]Grain supplement comprised of 23.5% SoyPass (nonenzymatically browned soybean meal), 56.7% soybean meal (46.5% CP), 2.6% blood meal, 7.7% limestone, 2.6% dicalcium phosphate, 0.9% magnesium oxide, 1.4% salt, 3.4% sodium bicarbonate, and 1.2% trace minerals and vitamins. The supplement was calculated to contain (DM basis) 3.6% Ca, 1.02% P, 0.96% Mg, 1.62% K, 1.50% Na, 0.93% Cl, 0.35% S, 2.01 mg/kg Co, 26.4 mg/kg Cu, 840 mg/kg Fe, 3.49 mg/kg I, 148 mg/kg Mn, 1.3 mg/kg Se, 211 mg/kg Zn, 25,200 IU/kg vitamin A, 5000 IU/kg vitamin D, and 193 IU/kg vitamin E.

[7]REF1= Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), GT = glyphosate-tolerant line (event nk603; Monsanto hybrid).

and milk urea nitrogen (MUN spectrophotometer, Bentley Instruments). Calculation of milk composition was weighted according to a.m. and p.m. milk yields.

One week prior to initiation of the experiment for 3 consecutive d, and on d 26 to 28 of each period, BW and BCS were measured immediately after the a.m. milking. BCS was determined using a 1 (thin) to 5 (obese) system (Wildman et al., 1982) by the same two independent observers throughout the study.

Statistical analysis. Data for feed intake, milk production and composition, BW, and BCS were analyzed as a replicated Latin square design with model effects for period, diet, square, cow within square, and interaction of period and diet using the PROC MIXED procedure of SAS (1996). The PDIFF procedure of SAS (1996) was used to separate means for significant main effects. Unless otherwise stated, significance was declared at $P < 0.05$. Data are reported as least squares means with SEM.

Experiment 2

Cows, diets, and sampling. Sixteen multiparous Holstein dairy cows (117 ± 21 DIM) were blocked (as-

Table 2. Digestibility, pH, and organic acid content of corn silages (Experiment 1).

	Corn silage[1]			
Item	REF1	REF2	CON	GT
pH	4.00	4.10	3.90	4.50
In vitro true digestibility, %	78.7	79.9	78.8	77.3
Digestible NDF, % of NDF	45.7	47.3	47.0	45.4
NH_3-N, % of DM	0.31	0.47	0.36	0.67
Lactic acid, % of DM	3.36	2.96	3.68	2.46
Acetic acid, % of DM	0.89	2.05	0.68	0.44
Propionic acid, % of DM	0.02	0.35	0.01	0.06
Butyric acid, % of DM	0.03	0.04	0.03	0.09
Total acids, % of DM	4.31	5.44	4.42	3.08

[1]REF1 = Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), GT = glyphosate-tolerant line (event nk603; Monsanto hybrid).

Table 3. Chemical composition of dietary ingredients (Experiment 2).

Item	DM	CP	ADIP[1]	ADF	NDF	ADL[2]	NSC[3]	EE[4]	Ash	NE_L[5]
	(%)	(% of DM)								(Mcal/kg)
Alfalfa hay	88.9	24.4	1.1	27.4	35.9	7.0	9.6	2.4	13.0	1.38
Whole cottonseed	91.9	28.4	1.6	30.4	40.6	9.8	8.5	23.3	4.5	2.35
Grain supplement[6]	90.4	44.8	5.5	5.2	13.9	2.0	17.4	1.7	16.0	1.65
Corn grain, REF1[7]	89.6	9.2	0.4	2.9	8.6	1.2	75.8	4.7	1.5	2.12
Corn grain, REF2[7]	90.2	8.7	0.3	2.8	8.2	0.9	77.6	3.2	1.4	2.11
Corn grain, CON[7]	90.2	8.7	0.4	3.1	8.0	1.1	77.6	4.2	1.4	2.11
Corn grain, CRW[7]	90.4	9.6	0.3	4.2	10.1	1.4	74.0	4.0	1.5	2.06
Corn silage, REF2	35.0	8.0	0.7	25.6	41.0	3.8	39.9	3.2	5.9	1.51

[1]Acid detergent insoluble CP.

[2]Acid detergent lignin.

[3]Nonstructural carbohydrates.

[4]Ether extract.

[5]Calculated using 30-h in vitro fermentation of NDF for silages and summative equations for other ingredients (NRC, 2001).

[6]Grain supplement comprised of 23.5% SoyPass (nonenzymatically browned soybean meal), 56.7% soybean meal (46.5% CP), 2.6% blood meal, 7.7% limestone, 2.6% dicalcium phosphate, 0.9% magnesium oxide, 1.4% salt, 3.4% sodium bicarbonate, and 1.2% trace minerals and vitamins. The supplement was calculated to contain (DM basis) 3.6% Ca, 1.02% P, 0.96% Mg, 1.62% K, 1.50% Na, 0.93% Cl, 0.35% S, 2.01 mg/kg Co, 26.4 mg/kg Cu, 840 mg/kg Fe, 3.49 mg/kg I, 148 mg/kg Mn, 1.3 mg/kg Se, 211 mg/kg Zn, 25,200 IU/kg vitamin A, 5000 IU/kg vitamin D, and 193 IU/kg vitamin E.

[7]REF1 = Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), CRW = corn rootworm protected line (event MON863).

signed to square) by DIM and previous 2-wk milk production and assigned randomly to one of four treatments within a square. The design was a replicated 4 $\times$ 4 Latin square (squares conducted concurrently) with 21-d periods; the first 7 d served as adaptation and the last 14 d served as the collection period. Diets contained 26.7% of the CRW, CON, REF1, or REF2 corn grain, 38.2% REF2 corn silage, 8.1% alfalfa hay, 5.1% whole cottonseed, and 21.8% of a concentrate mixture comprised of soybean meal, blood meal, minerals, and vitamins (DM basis; Table 5). All diets were formulated to contain approximately 18% CP and to meet the metabolizable protein requirement as predicted by the Cornell Net Carbohydrate and Protein Model (1994). The four diets were fed as TMR once daily in amounts to ensure 10% feed refusal.

All animal management, sampling procedures, sample nutrient analyses, and data analysis were identical to Experiment 1. All animals in both experiments were managed using protocols approved by the Institutional Animal Care and Use Committee at the University of Nebraska.

RESULTS AND DISCUSSION

Identities of the test and control grains and silages were confirmed using an ELISA procedure (Monsanto Company, St. Louis, MO) prior to initiation of Experiments 1 and 2. There were either no detectable amounts of mycotoxins, or concentrations (<3.4 mg/kg) were well below level of concern, in the grain for hybrids used in Experiments 1 and 2 (data not shown).

Experiment 1

Silage and dietary chemical composition. The chemical composition of the corn grain from the four hybrids was similar and CP ranged from 8.4 to 9.5% of DM (Table 1). The chemical composition of the GT and CON corn silages were similar (Table 1); the range in CP was 0.6 percentage units, NDF was 1.7 percentage units, and ether extract was 0.3 percentage units. A similar range in these chemical fractions has been reported previously for GT and near-isogenic corn hybrids by Sidhu et al. (2000).

The primary difference among the four silages was the substantially greater DM content for the GT silage compared with the other silages (42.5 versus 35.5% DM; Table 1). At the time of ensiling, extremely rapid drying conditions (37.6°C ambient temperature and 15 to 30 km/h wind speed) prevailed and the GT hybrid was the last to be harvested (within a 4-d time period), which explains the higher DM content at similar physiological maturity. The DM content of the silages reflects the order of harvest, which was REF1, REF2, CON, and GT.

Related to the higher DM content at harvest, the GT silage had a higher pH (4.51 versus 3.99), higher ammonia-N, and lower lactic, acetic, and total acid content (Table 2). By comparing the compositional

Table 4. Ingredient and chemical composition of experimental diets (Experiment 1).

Item	REF1[1]	REF2	CON	GT
	(% of DM)			
Ingredients				
Alfalfa hay	10.0	10.0	10.0	10.0
Corn silage, REF1	40.0	. . .	. . .	. . .
Corn silage, REF2	. . .	40.0	. . .	. . .
Corn silage, CON	. . .	. . .	40.0	. . .
Corn silage, GT	. . .	. . .	. . .	40.0
Corn grain, REF1	23.1	. . .	. . .	. . .
Corn grain, REF2	. . .	23.1	. . .	. . .
Corn grain, CON	. . .	. . .	23.1	. . .
Corn grain, GT	. . .	. . .	. . .	23.1
Whole cottonseed	5.1	5.1	5.1	5.1
Grain supplement[2]	21.8	21.8	21.8	21.8
Chemical composition				
DM, %	55.3	54.9	56.3	62.5
CP	18.1	17.9	17.7	17.9
RUP[3]	6.8	6.8	6.8	6.8
ADIP[4]	0.90	0.81	0.75	0.90
ADF	16.2	15.6	16.0	17.0
NDF	26.2	25.9	26.6	27.4
NSC[5]	44.4	45.0	45.0	44.0
Ether extract	4.1	3.8	3.7	3.6
Ash	8.2	8.3	8.1	8.3
Ca	1.42	1.44	1.39	1.44
P	0.53	0.53	0.53	0.51
Mg	0.28	0.28	0.28	0.28
K	1.22	1.34	1.26	1.34

[1]REF1 = Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), GT = glyphosate-tolerant line (event nk603; Monsanto hybrid).

[2]Grain supplement comprised of 23.5% SoyPass (nonenzymatically browned soybean meal), 56.7% soybean meal (46.5% CP), 2.6% blood meal, 7.7% limestone, 2.6% dicalcium phosphate, 0.9% magnesium oxide, 1.4% salt, 3.4% sodium bicarbonate, and 1.2% trace minerals and vitamins. The supplement was calculated to contain (DM basis) 3.6% Ca, 1.02% P, 0.96% Mg, 1.62% K, 1.50% Na, 0.93% Cl, 0.35% S, 2.01 mg/kg C0, 26.4 mg/kg Cu, 840 mg/kg Fe, 3.49 mg/kg I, 148 mg/kg Mn, 1.3 mg/kg Se, 211 mg/kg Zn, 25,200 IU/kg vitamin A, 5000 IU/kg vitamin D, and 193 IU/kg vitamin E.

[3]RUP estimated from values given in NRC (2001).

[4]Acid detergent insoluble CP.

[5]Nonstructural carbohydrates.

data in Tables 1 and 2, it is clear that the GT and CON hybrids were similar in nutritive value at harvest, but that the dissimilar DM contents of the two hybrids at ensiling resulted in less fermentation for the GT silage as evidenced by the lower acid production and higher pH. For a wide range of silage types, increasing DM content typically has reduced the amount of fermentation resulting in a higher final pH and lower concentrations of lactic and other fermentation acids (Muck, 1990). The NE_L content of the corn silages, calculated using a 30-h in vitro fermentation, was 1.59, 1.60, 1.59, and 1.49 Mcal/kg for REF2, REF1, CON, and GT lines, respectively.

All diets contained similar CP, RUP estimated from data in NRC (2001), NDF, and nonstructural carbohydrates (Table 4). The primary difference among the diets was the DM content, which reflected the differences in the DM content of the corn silages.

Lactational performance. The DMI of cows fed the GT diet was less than for cows fed the other diets (Table 6). Milk production reflected DMI and was lowest for the cows fed the GT diet compared with the other diets (Table 6). A similar response has been observed in several studies (reviewed by Johnson et al., 1999) in which increases in DM content of corn silage beyond 35% resulted in reductions in DMI and milk yield.

The content of milk fat, protein, and lactose and SCC were unaffected by diet. Milk urea nitrogen was increased for cows fed the REF1 diet compared with the other diets, although the difference was small (Table 6). Average BW and BCS were unaffected by diet, but change in BW per period was negative for cows fed the GT diet. Previous research has shown small losses in BW when corn silage of greater than 40% DM was fed to lactating dairy cows (St-Pierre et al., 1987).

Table 5. Ingredient and chemical composition of experimental diets (Experiment 2).

Item	REF1[1]	REF2	CON	CRW
	(% of DM)			
Ingredients				
Alfalfa hay	8.1	8.1	8.1	8.1
Corn silage, REF2[2]	38.2	38.2	38.2	38.2
Corn grain, REF1	26.7	. . .	. . .	. . .
Corn grain, REF2	. . .	26.7	. . .	. . .
Corn grain, CON	. . .	. . .	26.7	. . .
Corn grain, CRW	. . .	. . .	. . .	26.7
Whole cottonseed	5.1	5.1	5.1	5.1
Grain supplement[3]	21.9	21.9	21.9	21.9
Chemical composition				
DM, %	58.0	58.9	59.4	59.4
CP	18.8	18.6	18.6	18.9
RUP[4]	6.8	6.8	6.8	6.8
ADIP[5]	1.75	1.72	1.75	1.72
ADF	15.5	15.5	15.5	15.8
NDF	26.0	25.9	25.8	26.4
NSC[6]	40.5	40.9	40.9	40.0
EE[7]	4.2	3.8	4.1	4.1
Ash	7.4	7.4	7.4	7.4
Ca	0.96	0.99	1.03	0.95
P	0.49	0.50	0.51	0.48
Mg	0.26	0.25	0.26	0.25
K	1.47	1.35	1.39	1.40

[1]REF1 = Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), CRW = corn rootworm protected line (event MON863).

[2]Silage contained (% of DM): pH, 4.03; in vitro true digestibility, 77.2; digestible NDF, 44.5; NH_3-N, 3.18; lactic acid, 2.84; acetic acid, 1.24; propionic acid, 0.10; butyric acid, 0.25; and total acids, 4.44.

[3]Grain supplement comprised of 23.5% SoyPass (nonenzymatically browned soybean meal), 56.7% soybean meal (46.5% CP), 2.6% blood meal, 7.7% limestone, 2.6% dicalcium phosphate, 0.9% magnesium oxide, 1.4% salt, 3.4% sodium bicarbonate, and 1.2% trace minerals and vitamins. The supplement was calculated to contain (DM basis) 3.6% Ca, 1.02% P, 0.96% Mg, 1.62% K, 1.50% Na, 0.93% Cl, 0.35% S, 2.01 mg/kg Co, 26.4 mg/kg Cu, 840 mg/kg Fe, 3.49 mg/kg I, 148 mg/kg Mn, 1.3 mg/kg Se, 212 mg/kg Zn, 25,200 IU/kg vitamin A, 5000 IU/kg vitamin D, and 193 IU/kg vitamin E.

[4]RUP estimated from values given in NRC (2001).

[5]Acid detergent insoluble CP.

[6]Nonstructural carbohydrates.

[7]Ether extract.

Efficiency of 4% FCM production (FCM/DMI) was similar for all four diets. Donkin et al. (2000) fed GT (event GA21) corn silage and grain to lactating dairy cows and found no differences in DMI, milk production, or milk composition compared with cows fed the near-isogenic line of corn. Ipharraguerre et al. (2002) fed the same GT corn silage and grain as in our study (event nk603); however, silage DM contents were similar in their study and consequently they observed no differences in milk yield compared with the nontransgenic control line.

In experiment 1, treatment (glyphosate tolerance) and DM content (and resulting fermentation) of corn silage were confounded. Higher DM silage with less extensive fermentation can result in reduced DMI, and lowered milk production, due to reduced nutritive value of the corn silage as discussed by Johnson et al. (1999). Johnson et al. (2002) summarized data from lactation trials that indicated a relationship of reduced corn silage NE_L content with higher DM percentage; the breakpoint for peak milk yield or estimated silage NE_L occurred at approximately 35% DM. Using the equations developed by Johnson et al. (2002), the estimated NE_L content of the GT corn silage, adjusted for DM effects, was lower than the other silages (1.59, 1.58, 1.54, and 1.38 Mcal/kg for REF1, REF2, CON, and GT, respectively).

Further evidence that silage quality (DM content, pH, and acid content) explains the reduced DMI observed in this study for cows fed the GT corn treatment is that no previous study in which genetically modified crops were fed to dairy cattle resulted in depressed DMI (reviewed by Clark and Ipharraguerre, 2001).

Experiment 2

Silage and dietary chemical composition. The chemical composition of the corn grain from the four

Table 6. Lactational performance as influenced by experimental diets (Experiment 1).

Item	REF1[1]	REF2	CON	GT	SEM
Diet DM, %[2]	55.3	54.9	56.3	62.5	
DMI					
kg/d	26.6[a]	25.6[a]	25.6[a]	22.8[b]	1.3
% of BW	4.14[a]	4.00[a]	4.00[a]	3.61[b]	0.28
BW, kg	642	645	640	634	17
BW change, kg/28-d period	7.6[a]	8.4[a]	6.6[a]	–5.6[b]	3.7
BCS[3]	3.25	3.23	3.21	3.19	0.13
Body condition change, per 28-d period	0.07	0.05	0.03	–0.02	0.03
Milk yield, kg/d	37.5[a]	37.3[a]	36.6[a]	33.3[b]	1.0
Milk fat, %	3.91	3.93	3.94	3.85	0.12
Milk true protein, %	3.05	3.08	3.09	3.04	0.07
Milk lactose, %	4.67	4.65	4.64	4.66	0.07
Milk SNF, %	8.61	8.64	8.62	8.59	0.11
4% FCM, kg/d	37.2[a]	37.3[a]	36.9[a]	33.2[b]	1.3
FCM/DMI, kg/kg	1.40	1.44	1.43	1.45	0.09
SCC, × 10,000 per ml	94.7	166.0	94.0	104.3	62.8
Milk urea nitrogen, mg/dl	22.2[a]	20.7[b]	20.3[b]	20.3[b]	1.4

[a,b]Means within a row with unlike superscripts differ ($P < 0.05$).

[1]REF1 = Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), GT = glyphosate-tolerant line (event nk603; Monsanto hybrid).

[2]The DM content of the GT-nk603 silage was substantially higher than the average of the other three silages (42.5 versus 35.5%) and resulted in less silage fermentation, higher pH, and less total acid production.

[3]Measured using a 1 (thin) to 5 (obese) scale (Wildman et al., 1982).

hybrids was similar and CP ranged from 8.7 to 9.6% of DM, NDF ranged from 8.0 to 10.1%, ether extract ranged from 3.2 to 4.7%, and nonstructural carbohydrates ranged from 74.0 to 77.6% (Table 3). As with Experiment 1, a similar range in these chemical fractions has been reported for genetically enhanced and near-isogenic corn hybrids by Sidhu et al. (2000). All diets contained the same corn silage (REF2) which averaged 35.0% DM, 8.0% CP, 41.0% NDF, and 39.9% NSC (Table 3).

All diets contained similar CP, RUP estimated from data in the NRC (2001), NDF, and nonstructural carbohydrates (Table 5).

Lactational performance. Dry matter intake, average BW, and average BCS were not affected by diet (Table 4). Cows fed the CON and CRW diets gained more BW during each 21-d period than did cows fed the reference hybrid diets. Production of milk was not different for cows fed the CRW, CON, and REF1 diets, but was lower for cows fed the REF2 diet. There is no obvious explanation for the reduced milk yield for cows fed the REF2 diet because chemical composition was similar for all diets.

There was no effect of diet on milk fat, protein, and lactose percentage (Table 7). Milk urea nitrogen was highest for cows fed the REF1 diet and lowest for cows fed the REF2 and CRW diets; however, the range in values was small and likely of no biological importance. Production of 4% FCM and efficiency of FCM production (FCM/DMI) were not affected by diet.

Previous studies with corn hybrids that contained the Bt trait and expressed the Cry insect control proteins also found no effect on feed intake and milk production in dairy cattle (Barriere et al., 2001; Folmer et al., 2002). Our study used a corn hybrid that expressed Cry3Bb1 protein that targets corn rootworm. The study of Folmer et al. (2002) used corn that expressed the Cry1Ab protein (targets European corn borer, *Ostrinia nubilalis*) from transformation event Bt-11 and Barriere et al. (2001) used corn that also expressed Cry1Ab protein from event Bt-176. Results from our study and these previous reports indicate that production of Cry proteins in corn hybrids from several transformation events has no effect on feed intake or milk production in dairy cattle. Clark and Ipharraguerre (2001) reviewed all of the reported data (both peer reviewed and in abstract form) on the feeding value of Bt and glyphosate-tolerant crops and concluded that these genetically enhanced crops are substantially equivalent to their nongenetically enhanced counterparts.

CONCLUSIONS

At harvest, the GT, CON, REF1, and REF2 hybrids had equivalent chemical composition, except for DM

Table 7. Lactational performance as influenced by experimental diets (Experiment 2).

Item	REF1[1]	REF2	CON	CRW	SEM
DMI					
kg/d	26.3	26.0	26.6	27.3	0.8
% of BW	4.10	3.98	4.00	4.14	0.12
BW, kg	647	658	670	669	17
BW change, kg/21-d period	–7.8[b]	–0.1[b]	21.2[a]	23.5[a]	6.2
BCS[2]	3.28	3.28	3.27	3.27	0.05
BCS change, kg/21-d period	0.07	0.06	0.02	0.04	0.02
Milk yield, kg/d	36.6[ab]	35.6[b]	37.2[a]	37.3[a]	0.6
Milk fat, %	3.65	3.73	3.56	3.75	0.13
Milk true protein, %	3.18	3.19	3.19	3.18	0.05
Milk lactose, %	5.05	5.02	5.07	5.05	0.06
Milk SNF, %	9.58	9.55	9.58	9.54	0.08
4% FCM, kg/d	35.0	34.1	35.0	35.1	1.1
FCM/DMI, kg/kg	1.34	1.32	1.32	1.29	0.04
SCC, $\times$ 10,000 per ml	95.7	118.5	78.1	85.4	35.5
Milk urea nitrogen, mg/dl	20.5[a]	17.4[c]	18.6[b]	17.6[c]	0.4

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

[1]REF1 = Reference line 1 (Asgrow hybrid RX740), REF2 = reference line 2 (DEKALB hybrid DK647), CON = nontransgenic line (Asgrow hybrid RX670), CRW = Corn rootworm protected line (event MON863; Monsanto hybrid).

[2]Measured using a 1 (thin) to 5 (obese) scale (Wildman et al., 1982).

content, and were presumably of similar nutritive value in Experiment 1. At ensiling, rapid drying conditions prevailed, and the GT hybrid was harvested last which explains the greater DM content of this hybrid at similar physiological maturity. The high DM content of the GT corn plant resulted in a reduced silage fermentation and higher pH than the other silages. Previous research suggests that reduced DMI, milk production, moderate loss of BW, but unchanged FCM/DMI are to be expected when cows are fed higher DM silage. From these data, we can conclude that GT and CON corn hybrids resulted in equivalent FCM/DMI and milk composition. However, the DM content of the GT silage and resulting fermentation had a predictably negative effect on DMI and milk yield. Previously reported research (Ipharraguerre et al, 2002) has consistently shown no effect of genetically modified crops on DMI or milk production. In Experiment 2, grain from a CRW hybrid resulted in lactational performance similar to the nontransgenic control line and two commercially available corn hybrids. Therefore, the nutritional value of the grain from a CRW corn hybrid was equivalent to grain from nontransgenic corn hybrids.

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