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K. J. Vander Pol
University of Nebraska - Lincoln

Galen E. Erickson
University of Nebraska - Lincoln, gerickson4@unl.edu

N. D. Robbins
University of Illinois, Urbana

L. L. Berger
University of Illinois, Urbana, lberger2@unl.edu

C. B. Wilson
University of Nebraska - Lincoln

See next page for additional authors

Authors
K. J. Vander Pol, Galen E. Erickson, N. D. Robbins, L. L. Berger, C. B. Wilson, Terry J. Klopfenstein, E. P. Stanisiewski, and G. F. Hartnell

Effects of grazing residues or feeding corn from a corn rootworm-protected hybrid (MON 863) compared with reference hybrids on animal performance and carcass characteristics[1]

K. J. Vander Pol,* G. E. Erickson,*[2] N. D. Robbins,† L. L. Berger,† C. B. Wilson,* T. J. Klopfenstein,* E. P. Stanisiewski,‡ and G. F. Hartnell‡

*Department of Animal Science, University of Nebraska, Lincoln 68583-0908; †Department of Animal Science, University of Illinois, Urbana 61801; and ‡Monsanto Company, St. Louis, MO 63167

ABSTRACT: One grazing and two feeding experiments were conducted to compare the feeding value of corn residue or corn grain from a genetically enhanced corn hybrid (corn rootworm-protected; event MON 863) with nontransgenic, commercially available, reference hybrids. In Exp. 1, two 13.7-ha fields, containing corn residues from either a genetically enhanced corn rootworm-protected hybrid (MON 863), or a near-isogenic, nontransgenic control hybrid (CON) were divided into four equal-sized paddocks. Sixty-four steer calves (262 ± 15 kg) were stratified by BW and assigned randomly to paddock to achieve a stocking rate of 0.43 ha/steer for 60 d, with eight steers per paddock and 32 steers per hybrid. A protein supplement was fed at 0.45 kg/steer daily (DM basis) to ensure protein intake did not limit performance. Steer ADG did not differ (P = 0.30) between steers grazing the MON 863 (0.39 kg/d) and CON (0.34 kg/d) corn residues for 60 d. The four treatments for the feeding experiments (Exp. 2 and 3) included two separate reference hybrids, the near-isogenic control hybrid (CON), and the genetically enhanced hybrid (MON 863) resulting in two preplanned comparisons of CON vs. MON 863, and MON 863 vs. the average of the reference hybrids (REF). In Exp. 2, 200 crossbred yearling steers (365 ± 19 kg) were fed in 20 pens, with five pens per corn hybrid. In Exp. 3, 196 crossbred yearling steers (457 ± 33 kg) were fed in 28 pens, with seven pens per corn hybrid. In Exp. 2, DMI and G:F did not differ (P > 0.10) between MON 863 and CON; however, steers fed MON 863 had a greater (P = 0.04) ADG than steers fed CON. Gain efficiency was greater (P = 0.05) for MON 863 cattle than for REF cattle in Exp. 2, but other performance measurements (DMI and ADG) did not differ (P > 0.10) between MON 863 and REF. No differences (P > 0.10) were observed for performance (DMI, ADG, and G:F) between MON 863 and CON or MON 863 and REF in Exp. 3. In terms of carcass characteristics, no differences (P > 0.10) were observed between MON 863 and CON, as well as MON 863 and REF, for marbling score, LM area, or 12th rib fat thickness in both Exp. 2 and 3. Overall, performance was not negatively affected in the corn residue grazing or feedlot experiments, suggesting the corn rootworm-protected hybrid (event MON 863) is similar to conventional, nontransgenic corn grain and residues when utilized by beef cattle.

Key Words: Cattle, Corn Residue, Finishing, Corn, Transgenic Plant

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Introduction

Agricultural biotechnology has led to the development of innovations such as corn, soybeans, cotton, and other agronomic crops that are tolerant to herbicides (glyphosate or glufosinate) and protected from insects such as the European corn borer and corn rootworm.

The adoption of genetically enhanced crops by growers has increased substantially. According to James (2002), the use of genetically enhanced crops increased from 0.69 million ha in 1996 to 23.76 million ha in 2002 at a sustained growth rate of more than 10% per year. In 2002, 51% of the soybean and 12.4% of the corn hectares grown globally were in some way enhanced through recombinant DNA technology (James, 2002). Transgenic corn planted in the United States was 40% in 2003 and 46% in 2004 based on planting projections by USDA Agricultural Statistics Service (USDA, 2004).

Corn rootworm complex is the most damaging insect pest confronted by US corn growers (Wright et al.,

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[2]Correspondence: C220 Animal Sciences (phone: 402-472-6402; fax: 402-472-6362; e-mail: geericks@unlnotes.unl.edu).

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1999). Damage caused by rootworm larval feeding can be detrimental to crop yields and can complicate harvesting of a crop because of lodging. Corn rootworms are very expensive to control (Wright et al., 1999). Genetically enhanced corn hybrids have recently been introduced that contain transformation event MON 863 and express a gene from the common soil bacterium, *Bacillus thuringiensis* (**Bt**). This gene encodes the Bt crystal protein, Cry 3Bb1, which is selectively toxic to a number of coleopteran insects, including corn rootworms (Wright et al., 1999). Few data exist on the effect of feeding corn rootworm-protected corn to livestock. No data are available for event MON 863 when fed to beef cattle or when corn crop residue is grazed.

The objectives of these experiments were: 1) to compare grazed corn residue from MON 863 corn rootworm-protected hybrid and conventional nontransgenic hybrid, as well as performance of cattle grazing these residues; and 2) compare the performance and carcass characteristics of finishing steers fed MON 863 corn to the average of two nontransgenic reference hybrids or a near-isogenic parental hybrid. The hypothesis was that grazed calf performance and feedlot steer performance would not be influenced by insertion of the gene that encodes for Cry 3Bb1 protein.

Materials and Methods

Steers used in these experiments were managed according to guidelines recommended by FASS (1999). Procedures and animal care were approved by the University of Nebraska Institute for Animal Care and Use Committee (Exp. 1 and Exp. 2) and the University of Illinois Laboratory Animal Care Committee (Exp. 3).

Experiment 1

Animals. Sixty-four crossbred steer calves were used in a completely randomized design to evaluate the effects of grazing corn crop residue from a corn rootworm-protected hybrid (MON 863) or the near-isogenic, nontransgenic parental hybrid. The steers were received at the University of Nebraska Agricultural Research and Development Center, Ithaca, NE, in the fall of 2001, and were weaned and backgrounded on stockpiled smooth bromegrass pastures. In late November, cattle were housed in pens and limit-fed a 50% alfalfa:50% wet corn gluten feed (DM basis) diet for 5 d at 2% of BW (DM basis). Body weights were recorded individually on two consecutive days in the morning before feeding for determination of initial BW (262 ± 15 kg). No implants were administered to these cattle before or throughout the duration of grazing. At the conclusion of trial (late January 2002), steers were again housed in a drylot and limit fed the 50:50 alfalfa hay and wet corn gluten feed (DM basis) diet at 2% of BW (DM basis) for 5 d, after which individual BW were taken for two consecutive days for final BW determination. All steers were supplemented with 0.45 kg/d (DM basis) of a protein supplement (Table 1), which was formulated to meet the degradable intake protein (**DIP**) and metabolizable protein (**MP**) requirement of the cattle (NRC, 1996; Level 1), to ensure that protein intake did not limit performance. Supplementation allowed for energy differences to limit performance rather than protein intake (Fernandez-Rivera and Klopfenstein, 1989a).

Table 1. Protein supplement fed to steers in Exp. 1

Ingredient	% of DM[a]
Soybean meal (48% CP)	77.93
Urea	8.80
Salt	4.00
Dicalcium phosphate	5.00
Molasses	2.70
Trace mineral premix[b]	0.70
Bovatec premix[c]	0.27
Vitamin premix[d]	0.40
Selenium premix[e]	0.20

[a]Supplement fed in meal form for an intake of 0.45 kg/(animal·d).
[b]Premix contained10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co, DM basis.
[c]Premix contained 150 g/kg lasalocid, DM basis (Alpharma, Inc., Fort Lee, NJ).
[d]Premix contained 1,500 IU vitamin A, 3,000 IU vitamin D, and 3.7 IU vitamin E per gram, DM basis.
[e]Premix contained 0.6 g/kg sodium selenite, DM basis.

Treatments. Steers were assigned to treatment by stratified weight recorded on d 0, and allocated to one of four 3.4-ha paddocks within two separate 13.7-ha fields (eight steers per paddock; 32 steers per field) by random number. Fields consisted of corn crop residues from either the corn rootworm protected hybrid (**MON 863**), or the near-isogenic, nontransgenic parental hybrid (RX670; **CON**). A stocking rate of 0.43 ha/steer for 60 d was used to achieve adequate grazing pressure. Steers grazed the corn crop residues for 60 d, and similar to previous grazing experiments, paddock was the experimental unit (Folmer et al., 2002).

Corn crop residues were sampled in all paddocks at the initiation and termination of grazing to estimate OM residue (kg/ha), initial stalk strength, IVDMD, and residue CP. All residues were collected from 3.05 m of row within each paddock, dried (48 h at 60°C), and separated into husk, leaf, and stem fractions. Stalk diameter was measured with calipers (Fowler Tools and Instrument, Boston, MA). Stalks were then tested for breaking strength using an Instron 5500R compression tester (Instron, Canton, MA). In vitro DM disappearance analysis was performed on each residue fraction using the procedures outlined by Tilley and Terry (1963) by incubating 0.3 g (DM) of sample for 48 h with 30 mL of buffer and ruminal fluid mixture (50:50), with ruminal fluid collected from a fistulated steer consuming a mixed diet (30% dry-rolled corn, 70% roughage; DM basis). Nitrogen content was quantified for each sample by combustion (LECO Model FP-528; Leco Corp., St. Joseph, MI) and converted to CP by multiplying the N content of the sample by 6.25.

Experiment 2

Animals. Two hundred crossbred British yearling steers (initial BW = 366 kg) were used in a completely randomized design to evaluate effects of corn rootworm-protected corn (MON 863) on performance and carcass composition. Steers were received at the University of Nebraska Agricultural Research and Development Center (Ithaca, NE) in the fall of 2000. On arrival, steers were weighed, vaccinated (Pyramid-4+Presponse; Fort Dodge Animal Health, Overland Park, KS; *Haemophilus somnus* Bacterin, Schering Plough, Animal Health, Union, NJ; and Vision-7 with Spur, Intervet, Millsboro, DE), and weaned on stockpiled smooth bromegrass pastures. After weaning, these steers were managed in a yearling production system that consisted of grazing corn crop residues supplemented with wet corn gluten feed for 90 d, limit-feeding a forage-based diet in pens for 90 d, and grazing summer pastures for 120 d. In fall 2001, steers were limit-fed (6.8 kg/[animal·d]; 2% of BW; DM basis) for 5 d a 50% wet corn gluten feed:50% alfalfa hay (DM basis) diet in pens to minimize the effects of gastrointestinal fill on initial BW. Steers were then weighed for two consecutive days in the morning before feeding to obtain an accurate initial BW. Steers were stratified by BW based on d 0 BW, and assigned randomly to one of 20 pens (four treatments, with five replications per treatment). Pen dimensions were 14.5 m wide × 49.9 m long and consisted of clay-based soil with a 2% slope from front to back. Each pen provided 72.4 m^2 of area/steer and was equipped with a 9.1-m fence line feed bunk, which equated to 91.4 cm of bunk/steer.

Treatments. Treatments consisted of four corn hybrids, corn rootworm protected corn (MON 863), the nontransgenic near isogenic parental hybrid RX670 (CON), reference hybrid DK647 (**REF1**), and reference hybrid RX740 (**REF2**). Before the feeding trial, each corn hybrid was designated a letter, and treatments were blinded to all feedlot employees. All diets were balanced to meet or exceed animal requirements as outlined by the NRC (1996, Level 1) for DIP, MP, Ca, P, and K. Before diet formulation, all corn hybrids were analyzed for CP (AOAC, 1999) by combustion (LECO Model FP-528) and the hybrid with the least CP value (CON and REF1; 9.0% CP, DM basis) was used for formulation of supplemental protein, so that any differences in performance would not be attributable to protein level. Steers were then allowed 21 d for adaptation to a high-concentrate diet. Adaptation diets consisted of 45, 35, 25, and 15% roughage (DM basis), and were fed for 3, 4, 7, and 7 d, respectively. Feed was delivered once daily to pen at approximately 0930. Final diet composition is presented in Table 2. Dry-rolled corn and alfalfa hay were relatively dry (94.4 and 94.3% DM, respectively); therefore, steep liquor was added to the diet to decrease the potential for fines and sorting. All diets contained monensin (29.7 mg/kg of DM; Elanco Animal Health, Indianapolis, IN) and tylosin (11 mg/kg of DM; Elanco Animal Health). All steers were implanted once with Revalor-S (Intervet) on d 28.

Table 2. Finishing diet composition fed to steers in Exp. 2 and 3 (corn grain was the variable changed in each treatment diet)[a]

Ingredient	Exp. 2[b]	Exp. 3[b]
Reference 1 (REF1)	77.5	68.0
Reference 2 (REF2)	77.5	68.0
Near-isogenic control (CON)	77.5	68.0
Corn rootworm-protected (MON 863)	77.5	68.0
Corn silage	—	12.0
Corn steep liquor	10.0	5.0
Alfalfa hay	7.5	
Dry supplement[c]		
Soybean meal (48% CP)	—	7.58
Fine ground milo	2.61	—
Oats	—	3.51
Limestone	1.55	2.25
Urea	0.45	0.75
Salt	0.30	—
Copper sulfate	—	0.008
Potassium chloride	—	0.17
Trace mineral salt[d]	—	0.45
Trace mineral premix[e]	0.05	—
Rumensin 80 premix[f]	0.017	0.25
Tylan 40 premix[g]	0.013	0.02
Vitamin premix[h]	0.01	0.016
Composition[i]		
CP	13.3 to 13.9	14.8 to 16.3
Ca	0.65	0.82 to 1.04
P	0.49 to 0.53	0.36 to 0.43
K	0.84 to 0.92	0.86 to 0.93

[a]Percentage of dietary DM.
[b]REF1 = reference hybrid DK647; REF2 = reference hybrid RX740; CON = near isogenic parental hybrid RX670; and MON 863 = corn rootworm-protected hybrid containing event MON 863.
[c]Supplement fed in meal form at 5% (Exp. 2) or 15% (Exp. 3) of dietary DM and was identical across treatments within each experiment.
[d]Premix contained 81 to 86% salt, 2.57% Fe, 2.86% Zn, 5,710 mg/kg Mn, 2,290 mg/kg Cu, 100 mg/kg I, and 85.7 mg/kg Se, DM basis.
[e]Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co, DM basis.
[f]Premix contained 176 g/kg monensin, DM basis.
[g]Premix contained 88 g/kg tylosin, DM basis (Elanco Animal Health, Indianapolis, IN).
[h]Premix contained 1,500 IU vitamin A, 3,000 IU vitamin D, and 3.7 IU vitamin E per gram (Exp. 2) and 3,300 IU vitamin A, 330 IU vitamin D, and 44 IU vitamin E, per gram (Exp. 3; DM basis).
[i]Based on composited ingredient samples (analysis by Dairy One, Ithaca, NY).

Steer BW and feed refusals were measured every 28 d. Twenty-eight-day BW were shrunk 4% to minimize errors associated with gastrointestinal fill. Ingredients and diets were sampled weekly, composited by month, and analyzed for CP, crude fat (AOAC, 1999), and minerals (Ca, P, K) by inductively coupled plasma spectrometry at a commercial laboratory (Dairy One, Ithaca, NY).

Each hybrid was stored individually in a commodity bay to minimize contamination across corn hybrids. Each hybrid was dry-rolled individually, and the roller was cleaned between each hybrid by rolling a nontransgenic commodity corn hybrid. Feed truck contamination was prevented by mixing and feeding a verified nontransgenic load for another trial at the research facility between each load.

Steers were slaughtered based on weight projections, as well as visual appraisal of BW and fat thickness. Steers were slaughtered at a commercial abattoir (IBP, West Point, NE) on d 112. Hot carcass weights and liver scores were taken on the day of slaughter. Marbling score and yield grade were called by a USDA grader, and fat thickness and LM area were measured after a 24-h chill. A sample of the brachiocephalicus muscle (neck) was collected from each steer to determine muscle composition via proximate analysis. Five samples from each pen were selected randomly and shipped on ice to an independent laboratory for testing (ESCL, University of Missouri-Columbia, Columbia, MO). Analyses conducted included moisture, CP, and fat (AOAC, 1999).

Final BW, ADG, and G:F were calculated based on HCW adjusted to a common dressing percent of 63. This adjustment was done to minimize error associated with gastrointestinal fill, and to provide an accurate estimate of final BW.

Experiment 3

Animals. One hundred ninety-six continental-crossbred yearling steers (initial BW = 457 kg) were allotted to 28 pens for a dietary adjustment period at the University of Illinois Beef Research Unit in Urbana. On being received into the feedlot, steers were given vaccinations including *Clostridium* and *Haemophilus somnus* (Ultrabac 7/Somubac; Pfizer, Exton, PA), infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza-3, bovine syncytial respiratory virus (ViraShield 5; Grand Laboratories, Freeman, SD), and *Pasteurella haemolytica* (One Shot, Pfizer). Steers were implanted with Component TE-S (Vetlife-Ivy Laboratories, Overland Park, KS) before the adjustment period. Steers were weighed individually for two consecutive days at the start and end of the experiment in the morning before feeding, and individual interim BW measurements were taken at 28-d intervals. Final live weights were calculated by dividing HCW by an average dressing percent (61.4%), which was determined by dividing HCW by the average of two consecutive final live weights taken at the end of the trial. One steer was removed from the REF1 treatment due to a hoof injury on January 28, 2002. Steers were housed in pens with solid concrete floors (dimensions 4.3 m × 12.2 m) under an open-front building facing south. All steers were placed in clean pens with 5 to 8 cm of wood shavings for bedding. Environmental conditions for the animals were consistent between treatments (i.e., floor space, temperature, lighting, animal density, and feeder and water space). Feed and water were offered ad libitum. Feed was delivered once daily in the morning via a Data Ranger mixer (Model B113C; American Calan, Northwood, NH) with an onboard scale to deliver total mixed diets to individual pens. Scales were calibrated before initiation of the experiment.

Treatments. Pens were assigned randomly to treatment, with seven pens each being fed the reference hybrids, parental line hybrid, or transgenic hybrid, similar to that in Exp 2. Due to a limited supply of the test corns, a standard commercial source was fed to all steers during the diet adjustment period. Corn silage was replaced with cracked corn (45 to 12%, DM basis) at regular intervals over a 3-wk period. The four treatment diets consisted of 68% corn (DM basis) from one of either reference hybrid DK647 (REF1), reference hybrid RX740 (REF2), nontransgenic near-isogenic parental RX670 (CON), or the test hybrid containing genetic modification for corn rootworm resistance event MON 863. All corn hybrids were grown in Illinois, ground through a tub grinder (1.9-cm screen, AGCO, Farmhand; Duluth, GA), and stored in bottom unloading silos as dry corn (<15% moisture). Particle size analysis was conducted by the dry sieving method and no differences existed between corn hybrids after processing. Feed mixing equipment (Data Ranger) was flushed with corn silage between each batch to avoid cross contamination. Diets were formulated to meet or exceed the NRC (1996) recommendations for finishing steers. Samples of total mixed diets were sampled weekly and saved for nutrient analysis. The four corns were analyzed for CP, ash, ether extract (AOAC, 1999), and Ca, P, Mg, and K by inductively coupled plasma spectrometry to determine the nutrient profile of each hybrid (Dairy One). The lowest nutrient concentrations of the four corns were used in formulating the supplement to meet dietary requirements. All diets contained monensin (29.8 mg/kg of DM) and tylosin (11.1 mg/kg of DM).

Carcasses. Steers were slaughtered after 102 d on feed at a commercial abattoir (Tyson IBP, Joslin, IL) when visually appraised to have 1.0 cm of subcutaneous fat. Individual carcass measurements were taken for carcass weight and incidence of liver abscesses on the day of slaughter. After a 24-h chill, 12th rib fat thickness, KPH fat, USDA-called marbling score, and LM area data were collected. Dressing percent and yield grade were calculated using these data. A cross-section (0.8-cm thick) of longissimus thoracis muscle was collected randomly from 100 carcasses with an equal number of samples from each treatment and pen, and analyzed for fat by acid hydrolysis, protein by Kjeldahl N, and for water content (AOAC, 1999). Longissimus muscle area was determined by use of images transposed onto chromatography paper and then traced and counted on a grid. Yield grade was calculated using fat depth, LM area, carcass weight, and KPH fat (AMSA, 2001).

Statistical Analyses. Grazing performance, feedlot performance, and carcass characteristic data were analyzed using the GLM (Exp. 1 and Exp. 2) and MIXED (Exp. 3) procedures of SAS (Version 8.0; SAS Inst., Inc., Cary, NC). A completely randomized design was used, for which pen or paddock was the experimental unit

Table 3. Performance by steers grazing corn crop residues (Exp. 1)

Item[a]	MON 863	CON	SEM	*P*-value
Initial BW, kg	261	262	0.5	0.42
Final BW, kg	280	285	2.6	0.25
ADG, kg	0.33	0.39	0.03	0.30
Grain yield, kg of DM/ha	5,761	6,768	—	—
Residual corn grain, kg of DM/ha	16.2	32.4	—	—

[a]MON 863 = corn rootworm-protected hybrid containing event MON 863; CON = near-isogenic parental hybrid (RX670).

for all data. In Exp. 2 and 3, two preplanned contrasts (MON 863 vs. the average of REF1 and REF2; MON 863 vs. CON) were used to compare the influence of corn rootworm protection on performance and carcasses. An α-level of 0.05 was assumed for significance to minimize Type I errors.

Results

Experiment 1

Steer ADG and final BW were not influenced ($P > 0.25$) by the presence of event MON 863 in corn crop residues in Exp. 1 (Table 3). Corn husk quantity was greater ($P = 0.04$) for the CON field at the initiation of grazing; however, corn husk quantity at the end of grazing was essentially zero for both hybrids (Table 4). Corn leaf and stem quantity did not differ ($P > 0.18$) at the initiation and termination of grazing for both MON 863 and CON (Table 4). Furthermore, corn stalk diameter (mm) was greater ($P = 0.04$) for the CON corn stalks than for the MON 863 corn stalks; however, total force (mJ) required to break the stalks and, in turn, the force:diameter ratio (mJ/mm) did not differ ($P > 0.08$) for the residues from both hybrids (Table 5).

In terms of IVDMD (Table 4), the husk portions of the residues did not differ ($P = 0.57$) for both hybrids at the initiation of grazing, whereas due to the preference of the husk portion by the steers (Gutierrez-Ornelas and Klopfenstein, 1991), no husk samples were available for analysis at the end of grazing. There was no effect ($P > 0.45$) of the transgenic hybrid in terms of leaf or stem IVDMD at the initiation or at the termination of grazing; however, within each hybrid, leaf and stem IVDMD was greater ($P < 0.01$ for MON 863; $P < 0.01$ for CON) at the initiation of grazing than the termination of grazing.

Crude protein (% of DM; Table 4) was greater ($P < 0.01$) for the husk portion of the residues for the MON 863 hybrid at the start of grazing, whereas no samples were available for analysis after grazing. No differences ($P = 0.05$ to 0.79) in CP were observed for the leaf or stem portions of the residue between hybrids whether before or after grazing.

Experiment 2

The final diet and nutrient compositions are presented in Table 2. The nutrient analysis of the treatment diets was calculated from composited ingredient values included at the corresponding proportion of each ingredient in the diet. There were no differences ($P > 0.10$) due to treatments (i.e., based on *F*-test statistic) for initial BW, final weight calculated from HCW using

Table 4. Corn residue yield measurements for MON 863 grazing trial (Exp. 1)[a]

	Husk		Leaf			Stem		
Corn[b]	Before	After	Before	After	Time[c]	Before	After	Time[c]
Corn residue yield, kg/ha								
MON 863	322.5	NA[e]	1,650.9	1,138.3	0.34	2,481.4	2,036.1	0.19
CON	454.3	NA[e]	1,903.1	1,649.5	0.18	1,799.3	1,705.7	0.48
Hybrid[d]	0.04	—	0.18	0.19		0.06	0.11	
Corn residue IVDMD, %								
MON 863	57.6	NA[e]	45.4	38.7	0.01	49.9	40.5	<0.01
CON	56.5	NA[e]	46.8	39.5	<0.01	50.9	39.1	<0.01
Hybrid[d]	0.57	—	0.57	0.66		0.63	0.45	
Corn residue CP, % of DM								
MON 863	7.25	NA[e]	7.77	7.14	0.08	6.97	6.02	0.25
CON	4.84	NA[e]	7.48	7.72	0.39	7.18	6.66	0.25
Hybrid[d]	0.01	—	0.41	0.05		0.79	0.34	

[a]Time designates when the residue samples were taken (before or at the termination of grazing).
[b]Corn hybrid treatments were: MON 863 = corn rootworm-protected hybrid containing event MON 863; and CON = near-isogenic parental hybrid (RX670).
[c]Time = *P*-value for contrast between before and after grazing within hybrid.
[d]Hybrid = *P*-value for contrast between hybrids within time.
[e]NA = residue samples were not available due to grazing or loss of all residue material.

Table 5. Corn stalk break strength for MON 863 grazing trial (Exp. 1)[a]

Item[b]	MON 863	CON	SEM	*P*-value
Diameter, mm	23.1	27.5	1.34	0.04
Total force, mJ	2,482.1	3,300.1	304.4	0.08
Force/diameter, mJ/mm	107.7	119.6	10.6	0.44

[a]Measurements taken on corn stalks after grain harvest but before grazing.
[b]MON 863 = corn rootworm-protected hybrid containing event MON 863; and CON = near-isogenic parental hybrid (RX670).

a 63% common dressing percent, ADG, G:F, marbling score, 12th rib fat thickness, or LM area (Table 6). Significant variation was observed for DMI between treatment means, with a significant *F*-test ($P = 0.03$; Table 6).

In terms of the preplanned contrasts (MON 863 vs. CON, MON 863 vs. the average of REF1 and REF2), several trends and small numerical differences were observed. There were no differences between the MON 863 and the CON hybrid for initial BW ($P = 0.09$), DMI ($P = 0.11$), G:F ($P = 0.14$), marbling ($P = 0.91$), 12th rib fat thickness ($P = 0.82$), or LM area ($P = 0.27$). Interestingly, cattle fed MON 863 had greater ADG ($P = 0.04$) and heavier final BW ($P = 0.03$) than cattle fed CON. Clearly no negative effects were associated with MON 863, and there was no significant difference in G:F between CON and MON 863.

No differences were detected in performance when the average of the two reference hybrids were contrasted with the MON 863 hybrid (initial BW, $P = 0.09$; calculated final weight, $P = 0.16$; HCW, $P = 0.16$; DMI, $P = 0.44$; ADG, $P = 0.20$). Similarly, carcass characteristics did not differ between MON 863 and the reference hybrids (Table 6). There was a difference between MON 863 and the average of the REF1 and REF2 hybrids for G:F ($P = 0.05$), with the cattle being fed the MON 863 hybrid having an improved G:F. This difference in G:F is related to nutritional composition and is certainly not negative. Presumably this result was not related to transgenic hybrid because no difference was detected between MON 863 and CON for G:F, which were of near identical germplasm.

Values for muscle composition are reported. The moisture, CP, and fat levels are reported on an as-is basis. There were no differences ($P > 0.49$) for muscle composition among treatments, and no differences ($P > 0.37$) were detected for the contrasts (MON 863 vs. CON, MON 863 vs. the average of REF1 and REF2).

Experiment 3

Steer ADG was not influenced ($P = 0.36$) by the genetically enhanced corn hybrid in Exp. 3 (Table 7). Furthermore, no differences ($P > 0.48$) were detected in the preplanned contrasts between the MON 863 and CON, or MON 863 and the reference hybrids. The G:F did not differ ($P > 0.70$) among hybrids, suggesting no negative effects on performance due to insertion of the genes responsible for corn rootworm prevention. Averaged across treatments, G:F was 0.192 kg of ADG/kg of DMI.

Table 6. Performance and carcass characteristics in Exp. 2 for steers fed commercial reference hybrids, near-isogenic control hybrid, or corn rootworm-protected hybrid containing event MON 863 for 112 d

	Treatment[a]					*P*-values		
Item	REF1	REF2	CON	MON 863	SEM	*F*-test	CON vs. MON 863	REF vs. MON 863
Performance								
Pens per treatment	5	5	5	5				
Initial BW, kg	365	366	366	367	0.5	0.10	0.09	0.09
Final BW, kg[b]	605	614	602	618	5	0.10	0.03	0.16
DMI, kg/d	12.7	13.1	12.4	12.7	0.1	0.03	0.11	0.44
ADG, kg	2.14	2.21	2.11	2.25	0.04	0.13	0.04	0.20
G:F	0.169	0.169	0.170	0.176	0.003	0.24	0.14	0.05
Carcass characteristics								
HCW, kg	381	387	379	390	4	0.10	0.03	0.16
Marbling score[c]	575	552	551	550	11	0.34	0.91	0.32
LM area, cm^2[d]	83.8	84.7	84.0	86.2	1.4	0.66	0.27	0.33
Fat depth, cm	1.23	1.28	1.25	1.23	0.05	0.84	0.82	0.70

[a]REF1 = reference hybrid DK647; REF2 = reference hybrid RX740; CON = near-isogenic parental hybrid RX670; and MON 863 = corn rootworm-protected hybrid containing event MON 863.
[b]Based on HCW adjusted to a 63% common dress.
[c]Marbling score, where Small 0 = 500, and Small 50 = 550.
[d]LM area was measured between the 12th and 13th rib.

Table 7. Performance and carcass characteristics in Exp. 3 for steers fed commercial reference hybrids, near-isogenic control hybrid, or corn rootworm-protected hybrid containing event MON 863 for 102 d

	Treatment[a]					*P*-values		
Item	REF1	REF2	CON	MON 863	SEM	*F*-test	CON vs. MON 863	REF vs. MON 863
Performance								
Pens per treatment	7	7	7	7				
Initial BW, kg	456	458	458	457	3	0.94	0.78	0.98
Final BW, kg[b]	598	609	614	609	7	0.38	0.59	0.48
DMI, kg/d	7.57	7.46	7.94	7.76	0.16	0.29	0.50	0.29
ADG, kg	1.39	1.49	1.53	1.49	0.06	0.36	0.62	0.48
G:F	0.184	0.198	0.193	0.193	0.008	0.70	0.96	0.85
Carcass characteristics								
HCW, kg	367	374	377	374	4	0.38	0.59	0.49
Marbling score[c]	484	471	489	493	9	0.22	0.69	0.11
LM area, cm^2 [d]	97.2	99.5	95.6	97.3	1.5	0.46	0.50	0.60
Fat depth, cm	0.85	0.89	0.99	0.92	0.05	0.12	0.21	0.33
Yield grade[e]	2.1	1.9	2.3	2.1	0.1	0.08	0.15	0.30

[a]REF1 = reference hybrid DK647; REF2 = reference hybrid RX740; CON = near-isogenic parental hybrid RX670; and MON 863 = corn rootworm-protected hybrid containing event MON 863.
[b]Based on HCW adjusted to a 61.4% common dress.
[c]Marbling score, where Slight 50 = 450.
[d]LM area was measured between the 12th and 13th ribs.
[e]Calculated as described by AMSA (2001).

Carcasses from cattle fed all treatment hybrids did not differ ($P > 0.08$) in terms of fat thickness, yield grade, and quality grade, suggesting that equal feeding endpoints were achieved.

Values for muscle composition are reported in Table 8. As for Exp. 2, values are reported on an as-is basis. Besides moisture ($P = 0.04$), there were no differences ($P > 0.44$) for muscle composition among treatments, and furthermore, no differences ($P > 0.40$) were detected for the contrasts (MON 863 vs. CON, MON 863 vs. the average of REF1 and REF2).

Discussion

The inability of all three experiments to detect differences between the transgenic grain and the nontransgenic grain used agrees with previous research evaluating transgenic corn or soybeans fed to grazing cattle (Hendrix et al., 2000; Russell et al., 2001), feedlot cattle (Folmer et al., 2002; Erickson et al., 2003), dairy cattle (Folmer et al., 2002; Grant et al., 2003; Ipharraguerre et al., 2003), swine (Gaines et al., 2001a; Stanisiewski et al., 2001; Fischer et al., 2002), and poultry (Gaines et al., 2001b; Piva et al., 2001; Taylor et al., 2003).

Russell et al. (2001) conducted an experiment that compared the BCS of crossbred cows in midgestation grazing Bt (Pioneer 34R07, Novartis NX6236 with Monsanto event MON 810, and Novartis N64Z4 with the Knockout event) corn residues to that of similar cows grazing either nonBt (Pioneer 3489) corn residues or drylotted and fed alfalfa hay over the winter (126 d). No differences in BCS changes were observed between any of the treatment wintering systems.

Table 8. Muscle composition of selected muscles from Exp. 2 and Exp. 3[a]

	Treatment[b]					*P*-value		
Item	REF1	REF2	CON	MON 863	SEM	*F*-test	CON vs. MON 863	REF vs. MON 863
Exp. 2: Brachiocephalicus muscle								
Moisture	74.6	74.2	74.5	74.8	0.5	0.88	0.71	0.58
Protein	21.5	20.8	20.6	20.8	0.5	0.49	0.37	0.61
Fat	3.8	4.7	4.6	3.9	0.5	0.59	0.79	0.57
Exp. 3: Longissimus thoracis								
Moisture	73.0	73.8	73.1	72.9	0.2	0.04	0.64	0.09
Protein	22.6	22.5	23.0	22.8	0.3	0.69	0.74	0.44
Fat	3.3	2.7	3.1	3.3	0.3	0.44	0.64	0.40

[a]Expressed as g/100 g of wet tissue.
[b]REF1 = reference hybrid DK647; REF2 = reference hybrid RX740; CON = near-isogenic parental hybrid RX670; and MON 863 = corn rootworm-protected hybrid containing event MON 863.

In an experiment designed similarly to Exp. 1, Folmer et al. (2002) found no negative effect of grazing a different corn borer-protected Bt hybrid. In their experiment, cattle gains were similar to those in Exp. 1, averaging 0.28 kg/d. Fernandez-Rivera and Klopfenstein (1989a) observed an ADG of 0.42 kg/d on irrigated stalks for calves grazing 54 d. Similarly, stalk breaking strength in their experiment was similar (2,350 to 2,700 mJ) to that observed in Exp. 1 (2,480 to 3,300 mJ). Numerically, the breaking strength of stalks was less for the Bt hybrid in our study, which is certainly not a negative result.

The IVDMD data for husks, leaves, and stem (Table 4) for Exp. 1 are similar to previous studies averaging 50 to 52% for leaves and husks and 43 to 48% for stems (Fernandez-Rivera and Klopfenstein, 1989b), but present results are lower than those of Fernandez-Rivera and Klopfenstein (1989a), who observed IVDMD values ranging from 58 to 71% for leaves and husks. The CP of leaf and husk in Exp. 1 ranged from 4.8 to 7.7%, which is intermediate to results observed by Fernandez-Rivera and Klopfenstein (1989b; 3 to 6%) and Fernandez-Rivera and Klopfenstein (1989a; 6 to 10%).

Residue amounts were influenced by grazing but were dependent on residue type (husk, leaf, or stem). Compared with previous work by Fernandez-Rivera and Klopfenstein (1989b), residue amounts of leaf and husks were less in Exp. 1, totaling 2,000 to 2,400 kg of DM/ha compared with 2,700 to 3,500 kg of DM/ha in irrigated fields in the work of Fernandez-Rivera and Klopfenstein (1989b). In previous work with dryland corn acres, however, only 1,400 to 2,400 kg of DM/ha were available from leaves and husks (Fernandez-Rivera and Klopfenstein, 1989b).

Recently, Grant et al. (2003) and Taylor et al. (2003) reported no differences in dairy cattle performance and milk composition or broiler performance and meat quality, respectively, when animals were fed corn rootworm-protected (event MON 863) corn. Kerley et al. (2001) fed corn borer-protected corn in a feedlot finishing diet and reported no differences on performance (ADG, DMI, or G:F) or carcass characteristics (yield and quality grades). Their conclusions indicated no nutritional difference between the transgenic corn borer-protected corn and the conventional hybrid corn. Folmer et al. (2002) evaluated the efficacy of corn borer-protected corn silage for growing beef steers, and the effect of Bt-protein in corn borer-protected corn on fiber digestion and milk production for lactating dairy cows. In the beef growing trial, steers fed the corn borer-protected corn silage diet had significantly greater ADG than steers fed a nontransgenic corn silage diet; however, the authors concluded that the observed difference for ADG was more likely caused by the chemical composition of the silage (NDF, ADF, lignin, starch, and IVDMD) rather than inclusion of the Bt gene into the chromosomal DNA of the parental hybrid.

Erickson et al. (2003) conducted three experiments designed to evaluate the feeding value of Roundup Ready corn for feedlot steers. Two of those trials used the same CON (RX670) and reference hybrids (DK647, RX740) as in Exp. 2 and 3 of the current study. The performance and carcass characteristic values generated from the CON and reference hybrids in Exp. 2 and 3 are consistent with the same hybrids used by the Erickson et al. (2003), indicating that the data generated from Exp. 2 and 3 were repeatable.

Implications

Based on results from these experiments, insertion of a *Bacillus thuringiensis* gene coding for corn rootworm resistance had little effect on performance or carcasses for beef cattle grazing corn residues or feedlot cattle fed corn grain. No differences in muscle composition of the animals fed the transgenic corn hybrid would be expected. The *Bacillus thuringiensis* corn hybrid (event MON 863) used in this trial should produce similar feeding values for both grazing and feedlot cattle compared with conventional corn hybrids.

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