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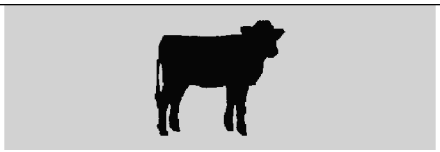

Effect of Corn Containing the Cry1F Protein on Performance of Beef Heifers Fed a Finishing Diet Based on Steam-Flaked Corn[1,2]

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ABSTRACT

Corn (maize; Zea mays) lines with the Herculex I trait have been modified to express both the Cry1F protein from Bacillus thuringiensis subsp. aizawai and the phosphinothricin-N-acetyltransferase (PAT) protein from Streptomyces viridochromogenes. Hybrids containing event TC1507 express the Cry1F protein that controls European corn borer and certain other lepidopteran pests. Event TC1507 also expresses the PAT protein that confers tolerance to glufosinate-ammonium herbicides. The current study was conducted to evaluate the nutritional value of grain containing the TC1507 event by comparing the growth performance and carcass traits of beef heifers fed diets containing grain from a hybrid containing the TC1507 event to that of grain obtained from the near-isoline (control) as well as 2 nontransgenic commercial corn grain controls (Pioneer hybrids 33J56 and 33R77). Diets composed of steam-flaked corn were individually fed to 80 beef heifers (360 kg) for 118 d. Dry matter intake, ADG, and G:F were not different (P > 0.05) between groups of heifers fed diets containing different sources of corn grain. Carcass traits, incidence of liver abscesses, and yield grade and quality grade were not affected by dietary treatment. In summary, growth performance and carcass characteristics of beef heifers were not significantly altered by feeding diets containing TC1507 corn grain vs. grain from its near-isoline or 2 other nontransgenic commercial corn grain hybrids.

Key words: corn, *Bacillus thuringiensis* subsp. *aizawai*, beef heifers, Cry1F

INTRODUCTION

In the United States, farmers have readily adopted the use of genetically engineered (**GE**) corn hybrids since their introduction in 1996. Over 73% of the corn acres in 2007 were planted to GE corn hybrids (USDA, 2007). The use of GE corn hybrids has reduced the dependency of agriculture on pesticides.

A new generation biotech corn hybrid marketed as Herculex I contains the *cry*1F gene (event TC1507) encoding the Cry1F protein from *Bacillus thuringiensis* var. *aizawai* and has insecticidal activity toward European corn borer, southwestern corn borer, fall armyworm, black cutworm, corn earworm, and western bean cutworm. This insect-resistance trait was developed through collaboration between Pioneer Hi-Bred, a DuPont business, and Dow AgroSciences LLC. Widespread use of transgenic crops for improving agronomic productivity has led to an abundance of modified grains. Ultimately, transgenic grain is fed to livestock; therefore, the nutritional equivalency between grains derived from transgenic corn hybrids and nontransgenic hybrids needs to be examined.

The objective of this experiment was to compare the growth performance and carcass quality of beef heifers fed finishing diets containing flaked-corn grain produced from a hybrid containing the event TC1507 vs. grain from a near iso-

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[2]Herculex used in this study is a trademark of Dow AgroSciences LLC. Herculex I, Herculex RW, Herculex XTRA insect protection were developed by Dow AgroSciences and Pioneer Hi-Bred, a DuPont business.
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genic conventional hybrid and grain from 2 nontransgenic commercial hybrids.

MATERIALS AND METHODS

Pioneer Hi-Bred International Inc. (Johnston, IA) supplied all corn grain from a field production trial in 2002 conducted in Richland, IA. The event TC1507 corn grain was sourced from plants that received 2 sequential applications of glufosinate-ammonium herbicide (Liberty; Bayer Crop Science, Research Triangle Park, NC). The nontransgenic control corn with comparable genetic background (Pioneer hybrid 33P66; control) and 2 nontransgenic commercial corn hybrid grains (Pioneer hybrids 33J56 and 33R77) were produced in plots physically isolated (201 m) from the TC1507 corn production plot but in the same field.

Due to the extreme dryness (7 to 11% moisture) of grain from 3 of the hybrids (TC1507, control, and 33J56), all corn was tempered with water to 16% moisture before being flaked. A sufficient quantity of each hybrid was flaked 3 times each week for feeding purposes. Corn grain was conditioned with steam (99°C) for 40 min prior to flaking and flaked so that hot flake density, determined with a Winchester cup, was approximately 335 kg/m^3 (25 lb/bu). The 2 nontransgenic commercial corn hybrids 33J56 and 33R77 were always flaked before TC1507 or control to avoid Cry1F contamination of the nontransgenic hybrids, and several hundred kilograms of commercial corn grain was flaked between each flaking run with test grains. Whole grain, flaked grain, and total mixed diets were sampled weekly and composited within a month for nutrient (moisture, CP, starch, crude fiber, NDF, ash, Ca, and P) analysis (Woodson-Tenant Laboratories, Des Moines, IA).

Treatment diets contained steam-flaked corn from event TC1507 (containing the *cry*1F gene), its near-isoline counterpart (not containing the *cry*1F gene), or 2 commercial nontransgenic hybrids (33J56 and 33R77). Diets were reformulated on d 53 due to shortage of the nontransgenic soybean meal; values reflecting the reformulated amounts are also reported. All diets were formulated to meet or exceed NRC requirements (2000).

Cattle were fed from February 5 until June 4, 2003, once daily at approximately 1400 with a sufficient amount of feed so that only traces of unconsumed feed remained in the bunk the following morning. Excess feed was removed from the bunk, weighed, and discarded; refused feed was subtracted from feed delivered to calculate feed intake. Grain concentration in the diet was increased during the initial 21 d, decreasing alfalfa content from 50 to 8% of diet DM. Feed intakes and G:F were calculated on a DM basis using diet DM determined from the DM composition of individual feed ingredients and their relative proportions in the diet. This avoided the errors involved with obtaining a representative sample of a mixed diet.

One hundred crossbred beef heifers (mean BW = 330 kg) were transported to the Kansas State University Beef Cattle Research Center located at Manhattan, KS. Upon arrival, cattle were weighed, vaccinated against common viral and bacterial diseases, and treated for internal and external parasites; heifers were identified with individually numbered ear tags. Prior to the start of the trial, cattle were group-

Table 1. Analyzed nutrient composition of whole and flaked corn grains[1,2]

Item	TC1507	Control	33J56	33R77	SEM
Whole grain[3]					
DM, g/kg	897.8	898.5	906.7	864.9	2.4
CP, g/kg DM	78.6	74.9	83.4	86.7	0.6
Crude fiber, g/kg DM	20.0	20.6	19.6	20.8	0.6
NDF, g/kg DM	71.3	81.8	74.5	83.2	5.1
Total starch, g/kg DM	684.2	739.5	728.9	764.9	6.6
Ash, g/kg	12.3	11.5	12.1	13.9	0.3
Flaked grain[4]					
DM, g/kg	752.9	744.4	742.3	755.0	9.2
CP, g/kg DM	74.8	73.6	83.0	88.2	1.1
Total starch, g/kg DM	730.3	765.2	753.7	691.0	14.1
Crude fiber, g/kg DM	18.6	19.4	18.9	21.6	0.7
NDF, g/kg DM	75.1	79.0	82.0	88.7	2.1
Starch availability,[5] g/kg DM	531	553	537	537	—

[1]Analysis by Woodson-Tenant Laboratories, Des Moines, IA.

[2]TC1507 = grain from a hybrid containing the TC1507 event; control = the nontransgenic control corn with comparable genetic background (Pioneer hybrid 33P66); 33J56 and 33R77 = nontransgenic commercial corn hybrid grains.

[3]Reported values are the average of 4 samples collected over the entire feeding period.

[4]Reported values, with the exception of starch availability, are the average of 5 samples collected over the entire feeding period.

[5]Data analysis provided by Kansas State University: TC1507 vs. control, $P < 0.001$, SEM = 4.4; 107 samples/hybrid analyzed.

Table 2. Composition of test diets fed to heifers (g/kg diet DM)[1]

Ingredient	TC1507	Control	33J56	33R77
Steam-flaked corn	749 (764)	744 (760)	753 (769)	768 (784)
Alfalfa hay	77 (77)	77 (77)	77 (77)	76 (76)
Soybean meal	68 (53)	73 (57)	64 (48)	51 (35)
Cane molasses	47 (47)	47 (47)	47 (47)	46 (46)
Tallow	30 (30)	30 (30)	30 (30)	30 (30)
Limestone	14 (14)	14 (14)	14 (14)	14 (14)
Urea	11 (11)	11 (11)	11 (11)	11 (11)
Salt	3 (3)	3 (3)	3 (3)	3 (3)
Premix[3]	1 (1)	1 (1)	1 (1)	1 (1)
Calculated energy content of test diets				
Mcal/kg diet	3.51	3.50	3.51	3.52

[1]Values in parentheses are for the reformulated diet fed from d 53 to 118.

[2]TC1507 = grain from a hybrid containing the TC1507 event; control = the nontransgenic control corn with comparable genetic background (Pioneer hybrid 33P66); 33J56 and 33R77 = nontransgenic commercial corn hybrid grains.

[3]Formulated to provide (per kg total diet DM): 580 IU vitamin A; 7 IU vitamin E; 0.1 mg Co; 8.3 mg Cu; 0.5 mg I; 0.1 mg Fe; 50.0 mg Mn; 0.25 mg Se; 67.0 mg Zn; 33 g Rumensin (monensin sodium, Elanco Animal Health, Indianapolis, IN); 10 g Tylan (Tylosin phosphate, Elanco Animal Health); and 0.055 g MGA (Melengestrol acetate, Pharmacia & Upjohn Company, Kalamazoo, MI).

penned (15 to 30 head/pen) and fed a standard diet (50% alfalfa, 50% concentrate) for 14 to 21 d to minimize variation in gastrointestinal tract fill. Cattle were weighed (d 0) following the acclimation period and ranked from heaviest to lightest in BW. Following removal of heifers with the heaviest and the lightest weights, a subset of 80 heifers (average BW = 360 kg) was stratified by weight into 4 groups. Each group was assigned to 1 of 4 barns and individual heifers within each barn were randomly assigned to 1 of the 4 treatment diets. Each barn contained 20 individual pens that allowed each animal access to feed and water. The number of animals per treatment was determined adequate for detecting a 10% difference as significant ($P < 0.05$) 80% of the time as suggested in published ILSI (2003) guidelines. Cattle were reweighed the following day (d 1), implanted with Revalor-H (trenbolone acetate and estradiol, Intervet Inc., Millsboro, DE) and placed in their respective pens. Initial BW was calculated as the average of weights taken on d 0 and d 1. This study was conducted in accordance with the Kansas State University Institutional Animal Care and Use Committee protocol No. 1977.

Cattle exhibiting symptoms of common ailments or disorders were treated according to standard operating procedures of the Kansas State Beef Cattle Research Center, and a veterinarian was consulted for any observed conditions not covered by these procedures.

Diets were fed for 118 d when cattle were estimated to have a mean 12th-rib fat thickness of 10 to 11 mm. Cattle were transported to a commercial abattoir in Emporia, KS where they were processed randomly without regard to treatment and traced through slaughter. Performance data were calculated on both a live and carcass-adjusted basis. Carcass-adjusted final BW was calculated using individual hot carcass weight divided by the mean dressing percent of all cattle in this trial (63.5%). Hot carcass weights and liver abscess scores were obtained at harvest. The percentage of KPH, subcutaneous fat thickness (12th rib), and LM area were determined after 24-h chill. Marbling scores and USDA quality and yield grades were determined after a 24-h chill by a USDA grader. Dietary NE_m and NE_g values were calculated based on heifer performance using equivalent BW-based equations (NRC, 2000) in the formula described by Zinn and Shen (1998).

All continuous data were analyzed with PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC, version 8.2 software). The model's fixed effect was dietary treatment whereas barn (weight) grouping was considered the blocking factor and was treated as a random effect. Planned comparisons between fixed effects were by Fisher's Protected LSD. Differences between treatment means were considered significant at $P \leq 0.05$. Ordered categorical data (e.g., yield grade, liver abscess, and carcass quality data) were analyzed using the PROC FREQ procedure of SAS with differences being tested using Mantel-Haenszel Chi-Square; differences were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Nutrient profiles of the whole and flaked corn grain are shown in Table 1. Analyses from each month were considered to be independent observations for statistical analysis. Diet composition is shown in Table 2. Diets were formulated to meet nutrient requirements (NRC, 2000). Analyzed nutrient compositions of the test diets are shown in Table 3. Most nutrient values were similar for the 4 grains; among the test diets, starch content differed statistically with diets ranging from approximately 52 to 56%.

Growth performance results are presented in Table 4. No differences ($P > 0.05$) between treatment groups were detected in BW, BW gains, or

Table 3. Analyzed nutrient composition of test diets[1,2,3]

Nutrient	TC1507	Control	33J56	33R77	SEM
DM, g/kg	761.8	770.1	747.6	763.3	5.4
CP, g/kg DM	140.7	148.9	148.2	149.2	4.1
Starch, g/kg DM	562.1	526.4	546.4	520.6	6
Crude fiber, g/kg DM	45.5	45.4	45.7	48	2.7
NDF, g/kg DM	98.6	96.1	96.6	105.5	3.9
Ash, g/kg DM	55.8	65.8	60.2	58.9	3
Ca, g/kg DM	9.8	13.2	11.7	11	0.9
P, g/kg DM	2.7	2.8	2.8	2.9	0.1

[1]Analysis by Woodson-Tenant Laboratories, Des Moines, IA.

[2]Reported values are the average of 5 samples collected over the entire feeding period.

[3]TC1507 = grain from a hybrid containing the TC1507 event; control = the nontransgenic control corn with comparable genetic background (Pioneer hybrid 33P66); 33J56 and 33R77 = nontransgenic commercial corn hybrid grains.

G:F. In other trials of nutritional equivalency with transgenic corn hybrids, performance responses have been similar for transgenic and near-isogenic hybrids for feedlot cattle (Erickson et al., 2003), dairy cattle (Donkin et al., 2003), pigs (Hyun et al., 2004), and poultry (Gaines et al., 2001; Taylor et al., 2003). Carcass-adjusted final BW (hot carcass weight divided by the mean dressing percent for all cattle), ADG, and feed efficiency were not different among groups of cattle fed different diets. The ME, NE_m, and NE_g value of the diet fed to each animal was calculated based upon carcass-weight adjusted BW gain, mean BW, and DMI. Although these estimated energy values were numerically lower for heifers fed the control diet than for cattle fed other diets, differences in performance between heifers fed flaked corn from event TC1507 and heifers fed flaked corn from the other hybrids were not significant. One heifer from the event TC1507 treatment group was found dead in her pen on d 23 of the study. The Veterinary Diagnostic Laboratory, Kansas State University College of Veterinary Medicine, performed the necropsy and concluded that death was caused by acute ruminal bloat due to the low roughage content of the heifer's diet and not the corn source of the diet. A heifer from the 33R77 reference treatment group was discovered to have a lame left rear leg on d 84 of the study. An extension was placed on the sole of her left rear hoof, but the heifer never fully recovered. The data for both heifers were removed prior to statistical analysis.

Table 4. Growth performance of heifers fed test diets[1]

Item	TC1507	Control	33J56	33R77	SEM
Growth performance[2]					
Initial BW, kg	361	360	359	360	14
Final BW, kg	539	541	545	554	15
ADG, kg/d	1.51	1.53	1.57	1.64	0.06
DMI, kg/d	8.0	8.2	8.0	8.2	0.3
G:F	0.189	0.187	0.196	0.200	0.006
Carcass adjusted data[2,3]					
Final adjusted BW, kg	538	536	540	545	17
ADG, kg/d	1.50	1.49	1.54	1.57	0.06
G:F	0.189	0.182	0.191	0.191	0.006
ME, mcal/kg diet DM	3.51	3.39	3.50	3.48	0.06
NE_m, mcal/kg diet DM	2.80	2.70	2.80	2.78	0.06
NE_g, mcal/kg corn DM	1.85	1.75	1.84	1.81	—

[1]TC1507 = grain from a hybrid containing the TC1507 event; control = the nontransgenic control corn with comparable genetic background (Pioneer hybrid 33P66); 33J56 and 33R77 = nontransgenic commercial corn hybrid grains.

[2]Treatment means not different ($P > 0.05$).

[3]Final BW was calculated from individual hot carcass weights based on the mean dressing percent for all cattle (63.5%).

Carcass traits, liver abscess scores, and yield and quality grades are presented in Table 5. None of the carcass traits were affected by dietary treatment. The number of carcasses scored as YG 1, 2, and 4 was numerically lower for heifers fed the control diet, but no significant treatment effect on the number of carcasses in any category was observed. Likewise Erickson et al. (2003) noted similar carcass traits between steers fed transgenic glyphosate-tolerant corn grain and conventional corn grain. The lower number of carcasses for the control in the YG 1 and 2 categories may have been due to the greater starch availability of the diet containing that hybrid (Table 1). Liver abscess incidence was very low in this trial with only 2 animals affected, as might be expected with both monensin and tylosin being included in the diet; no effect of treatment on incidence or severity of liver abscesses was de-

Table 5. Carcass characteristics of heifers fed test diets[1]

Item	TC1507	Control	33J56	33R77	SEM
Number of animals	19	20	20	19	—
Standard carcass measures[2]					
Hot carcass weight, kg	342	340	343	346	11
Dressing percent	66.07	65.57	65.58	65.15	0.42
KPH fat, %	2.31	2.38	2.33	2.45	0.12
12th rib fat, mm	15.0	16.7	13.0	15.7	1.6
Ribeye area, sq cm	82.2	81.9	82.7	83.6	2.4
Marbling[3]	522	588	554	535	26
Yield grade[4]	3.3	3.5	3.1	3.4	0.3
USDA yield grade, % of carcasses/treatment[5,6]					
YG 1	11	0	5	5	—
YG 2	21	5	25	21	—
YG 3	37	50	40	42	—
YG 4	21	40	20	21	—
YG 5	11	5	10	11	—
Liver abscess incidence, % of carcasses/treatment[5]					
Absent	95	95	100	100	—
Present[6]	5	5	0	0	—
Quality grade, % of carcasses/treatment[5]					
Prime	0	15	5	5	—
Choice+	0	5	15	0	—
Choice	21	15	10	26	—
Choice–	47	45	30	21	—
Select+	11	15	10	21	—
Select	16	5	25	21	—
Select–	5	0	5	5	—
Choice– and above	68	80	60	53	—
Select+ and below	32	20	40	47	—

[1]TC1507 = grain from a hybrid containing the TC1507 event; control = the nontransgenic control corn with comparable genetic background (Pioneer hybrid 33P66); 33J56 and 33R77 = nontransgenic commercial corn hybrid grains.

[2]Treatment means not different ($P > 0.05$).

[3]Marbling scores between 500 and 599 fall into the Choice-quality grade category.

[4]Yield grade calculated based upon cutability.

[5]Treatments not different (Mantel-Haenszel χ^2 $P > 0.05$).

[6]Liver abscess severity score for one heifer fed TC1507 was classified as Moderate; one heifer fed the control diet had a liver abscess severity score of Severe.

tected. The number of carcasses assigned to specific quality grades did not differ ($P > 0.05$) among diet groups. The majority of carcasses (65%) in this trial graded Choice- or above.

IMPLICATIONS

Beef heifers fed diets containing grain from an event TC1507 hybrid (Herculex I) had similar growth performance and carcass traits to those of heifers fed diets containing grain from its near-isoline and 2 other nontransgenic commercial corn hybrids.

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