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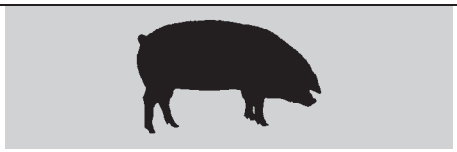

Growth Performance and Carcass Composition of Pigs Fed Corn Grain from DAS-Ø15Ø7-1 (Herculex I) Hybrids[1]

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ABSTRACT

The objective of this experiment was to evaluate a transgenic source of corn grain containing the event DAS-Ø15Ø7-1 (TC1507) when included in diets fed to growing and finishing pigs. The commercial product trait name of TC1507 corn is Herculex I; this corn grain contains the cry1F gene from Bacillus thuringiensis var. aizawai and the phosphinothricin acetyltransferase (pat) gene from Streptomyces viridochromogenes. These 2 genes confer in planta insecticidal activity toward several corn pests and tolerance to herbicides containing the active ingredient glufosinate-ammonium. Ninety-six pigs were allotted to 4 dietary treatments with 3 pigs/pen and 8 pen replicates/treatment. The 4 dietary treatments consisted of corn-soybean meal diets formulated with a commercial source of corn, a standard corn, a control corn, or TC1507. Pigs were fed the experimental diets from 23.5 to approximately 120 kg BW, and the ADG, ADFI, and G:F were calculated. Hot carcass weights, back fat thickness, loin eye area, and loin eye depth were measured at slaughter, and dressing percentage and average lean meat percentage were calculated. Results of the experiment showed that pig performance was not affected by dietary treatments (P = 0.27 to 0.97) and there were no effects of dietary treatment on any carcass measurement (P = 0.13 to 0.95). Based on the results of this experiment, it was concluded that performance and carcass quality of pigs fed diets containing corn produced from seeds containing TC1507 were not different from those of pigs fed other corn hybrids.

Key words: carcass measurement, growth performance, Herculex I transgenic corn, pig, TC1507 corn

INTRODUCTION

Biotechnology has been used to produce genetically modified field crops with input traits including herbicide tolerance and insect resistance. These crops have improved yields, reduced pest management costs and pesticide use, and increased conservation tillage practices (Sankula, 2006). Genetically modified corn varieties have been widely adopted for commercial use in the United States since 1996. Insect-protected, herbicide-tolerant, and stacked gene varieties accounted for 73% of all corn planted in the United States in the 2007 growing season (USDA Economic Research Service, 2007). The US hectares planted to herbicide-tolerant and insect-resistant crops in 2006 accounted for 53% of the total global area planted with genetically modified crops, and approximately 28% of those hectares were 2- and 3-stacked-trait products (James, 2006).

The corn grain containing the event DAS-Ø15Ø7-1 (**TC1507**) is a genetically modified corn containing the *cry*1F gene from *Bacillus thuringiensis* var. *aizawai* and the phosphinothricin acetyltransferase (*pat*) gene from *Streptomyces viridochromogenes* that was developed through collaboration between Pioneer Hi-Bred International Inc. (Johnston, IA) and Dow AgroSciences LLC (Indianapolis, IN). The *cry*1F gene encodes the Cry1F protein, which has insecticidal activity toward European corn borer, southwestern corn borer, fall armyworm, black cutworm, corn earworm, and western bean cutworm (Williams et

[1] Herculex I Insect Protection by Dow AgroSciences and Pioneer Hi-Bred. Herculex is a registered trademark of Dow AgroSciences LLC.

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al., 1998; Vilella et al., 2002; Catangui and Berg, 2006). The expressed PAT protein confers in planta tolerance to herbicides that contain the active ingredient glufosinate-ammonium, such as Liberty (Bayer AG, Leverkusen, Germany). The commercial product trait name of TC1507 corn is Herculex I. In contrast, YieldGard (MON 810, Monsanto, St. Louis, MO) corn trait uses the *cry1Ab* gene from *Bacillus thuringienisis* ssp. *kurstaki* strain HD1 and confers insect protection against the European corn borer, southwestern corn borer, southern cornstalk borer, corn earworm, fall armyworm, and stalk borer (US Environmental Protection Agency, 2001).

Herculex I is approved for use in animal feeding in the United States. It was not expected that the expression of the Cry1F protein and PAT protein would change the nutritional value of the corn when fed to pigs, but there were no published data to verify this assumption. It was therefore the objective of this experiment to test the hypothesis that pigs fed diets containing TC1507 corn grain would have performance that was not different from that of pigs fed diets containing 3 other corn hybrids.

MATERIALS AND METHODS

Animals, Experimental Design, and Housing

Animals used in this experiment were managed according to guidelines recommended by FASS (1999). The protocol for the experiment was reviewed and approved by the Institutional Animal Care and Use Committee at South Dakota State University (Brookings, SD), where the animal portion of the experiment was conducted.

Ninety-six growing pigs were allotted to 4 experimental diets based on BW, ancestry, and sex (gilts or barrows) in a randomized complete block design. The initial average BW was 23.5 ± 3.42 kg. Pigs were the offspring of Duroc × Large White sires mated to Yorkshire × Duroc × Landrace dams. There were 3 pigs/pen and 8 replicate pens/treatment group, and 4 pens with gilts and 4 pens with barrows. The number of

Table 1. Analyzed nutrient composition of corn grains and soybean meal used in experimental diets (as-is basis)[1]

	Source of corn[2]				
Item	Commercial	Standard	Control	TC1507	Soybean meal
GE, kcal/kg	3,909	3,869	3,854	3,896	4,182
DM, %	86.74	82.92	86.04	86.89	88.68
CP, %	8.24	7.80	8.26	8.39	47.27
Ether extract, %	—	3.10	2.80	3.10	0.52
Crude fiber, %	—	1.40	1.40	1.40	3.00
Ash, %	1.16	1.06	1.15	1.02	5.35
Ca, %	—	0.005	0.007	0.008	0.35
P, %	—	0.22	0.23	0.22	0.65
Indispensable amino acids, %					
Arg	0.33	0.25	0.30	0.28	3.12
His	0.21	0.19	0.20	0.20	3.18
Ile	0.25	0.22	0.23	0.23	1.96
Leu	0.87	0.81	0.83	0.87	3.27
Lys	0.25	0.22	0.24	0.23	2.68
Met	0.16	0.17	0.16	0.15	0.64
Phe	0.35	0.31	0.33	0.33	2.18
Thr	0.28	0.18	0.18	0.20	1.81
Trp	0.06	0.05	0.06	0.06	0.66
Val	0.35	0.31	0.33	0.33	2.04
Dispensable amino acids, %					
Ala	0.54	0.52	0.52	0.55	1.88
Asp	0.57	0.28	0.31	0.34	5.34
Cys	0.15	0.16	0.18	0.17	0.68
Glu	1.37	1.15	1.21	1.25	8.35
Gly	0.29	0.25	0.26	0.26	1.89
Pro	0.64	0.57	0.60	0.60	2.22
Ser	0.39	0.26	0.27	0.29	2.32
Tyr	0.19	0.08	0.12	0.12	1.46

[1]The commercial corn sample was not analyzed for ether extract, crude fiber, Ca, and P.

[2]Commercial = bin run corn; standard = Pioneer hybrid 33J56; control = near-isoline Pioneer hybrid 33P66; TC1507 = transgenic corn 33P66 plus event TC1507.

replicates per treatment was selected based on the ability of the statistical analysis to detect a 10% difference between treatments at $P < 0.05$ and a minimum power of 80% (International Life Sciences Institute, 2003). Pens (1.2 × 2.4 m) were equipped with a 1-hole feeder and a nipple drinker and had a fully slatted concrete floor. The ambient temperature was maintained at approximately 20°C throughout the experiment.

Diets, Feeding, and Diet Analyses

Dietary treatments consisted of corn-soybean meal diets formulated with the following 4 corn hybrids: bin run corn provided by South Dakota State University (designated "commercial"), check corn Pioneer brand hybrid 33J56 (designated "standard"), near-isoline Pioneer hybrid 33P66 (designated "control"), and the transgenic corn 33P66 plus TC1507 (Table 1). The latter 3 corn hybrids were provided by Pioneer Hi-Bred International Inc. and were all grown in a field production trial located in Richland, Iowa. The control plot was located under isolation distances (201-m border) from the TC1507 corn plot to minimize the risk of cross-pollination. The same source of soybean meal was used in all diets during the growing and finishing periods.

A 3-phase feeding program was designed to meet the changing nutrient needs of the pigs during the growing period. Grower diets were fed from the beginning of the experiment until pigs reached a BW of approximately 60 kg; early finisher diets were fed from approximately 60 to 90 kg, and late finisher diets were fed from 90 to approximately 120 kg. All corn hybrids were included in the diets for the entire feeding period. Diets were formulated by mixing corn, soybean meal, soybean oil (1%), vitamins, and minerals (Table 2). No crystalline amino acids were used. Within each phase, all diets were formulated to meet or exceed current estimates for nutrient requirements (NRC, 1998). Grower, early finisher, and late finisher diets were formulated to contain 1.00, 0.80, and 0.63% total Lys, respectively. The inclusion of corn was approximately 65, 73, and 81% in the grower, early finisher, and late finisher diets, respectively. All corn hybrids and soybean meal were analyzed for GE, DM, CP, ether extract, crude fiber, ash, Ca, P, and amino acids, and diets were formulated based on the results of these analyses. All diets were analyzed for GE, DM, CP, ash, Ca, and amino acids. These analyses confirmed that diets contained the desired quantities of Lys and other amino acids within a 10% margin of error. Gross energy was determined via bomb calorimetry (model 1271, Parr Instruments, Moline, IL), and all other analyses were performed according to AOAC (2000). Feed and water were provided to the pigs on an ad libitum basis throughout the experiment.

Table 2. Composition of experimental diets (as-is basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Ground corn grain	65.10	73.5	80.6
Soybean meal	31.75	23.6	16.6
Soybean oil	1.0	1.0	1.0
Ground limestone	0.8	0.65	0.65
Dicalcium phosphate	0.85	0.75	0.65
Salt	0.35	0.35	0.35
Vitamin premix[2]	0.05	0.05	0.05
Trace mineral premix[3]	0.10	0.10	0.10
Analyzed composition			
GE, kcal/kg	4,325	3,984	4,016
DM, %	95.81	88.80	90.06
CP, %	22.80	19.00	14.45
Ash, %	4.67	4.14	3.35
Ca, %	0.61	0.54	0.43
Indispensable amino acids, %			
Arg	1.27	0.89	0.61
His	0.53	0.46	0.35
Ile	0.87	0.69	0.52
Leu	1.71	1.44	1.19
Lys	1.09	0.87	0.60
Met	0.37	0.27	0.22
Phe	1.04	0.81	0.61
Thr	0.81	0.84	0.66
Trp	0.23	0.25	0.18
Val	0.97	0.77	0.61

[1]The composition shown is for the diets containing the TC1507 grain. Because of small differences in the chemical composition among the 4 corn grains, the diets containing the commercial, standard, and control corn grains varied slightly from the composition of the diets containing the TC1507 corn grain.

[2]Provided the following quantities of vitamins per kilogram of complete diet: vitamin A, 5,016 IU as vitamin A acetate; vitamin D_3, 496 IU as D-activated animal sterol; vitamin E, 44 IU as DL-α-tocopheryl acetate; vitamin K_3, 0.76 mg as menadione dimethylpyrimidinol bisulfite; thiamine, 0.75 mg as thiamine mononitrate; riboflavin, 5 mg; pyridoxine, 2.0 mg as pyridoxine hydrochloride; vitamin B_{12}, 0.025 mg; D-pantothenic acid, 12.5 mg as calcium pantothenate; niacin, 30 mg; folic acid, 0.75 mg; and biotin, 0.2 mg.

[3]Provided the following quantities of minerals per kilogram of complete diet: Cu, 25 mg as copper sulfate; Fe, 120 mg as iron sulfate; I, 0.30 mg as potassium iodate; Mn, 25 mg as manganese sulfate; Se, 0.30 mg as sodium selenite; and Zn, 125 mg as zinc oxide.

Table 3. Growth performance and carcass measurements of pigs fed experimental diets[1]

	Source of corn[2]					
Item	Commercial	Standard	Control	TC1507	SEM	*P*-value
Pig performance						
Initial weight,[3] kg						
Gilts	23.7	23.6	23.7	23.6	1.05	0.91
Barrows	23.2	23.9	23.2	23.1	1.05	0.01
Final weight, kg	116.7	120.5	121.2	119.5	2.4	0.47
ADG, kg/d	0.82	0.86	0.86	0.85	0.02	0.39
ADFI, kg/d	2.55	2.73	2.69	2.63	0.07	0.27
G:F, kg/kg	0.323	0.319	0.323	0.325	0.012	0.97
Carcass data						
Slaughter weight, kg	115.40	118.80	118.90	117.60	2.50	0.61
Hot carcass weight, kg	84.90	86.50	87.10	85.30	1.90	0.68
Dressing percentage	73.56	72.62	73.23	72.51	0.47	0.13
10th-rib backfat, mm	19.40	19.80	19.50	20.30	1.50	0.95
Loin eye area, cm^2	47.42	48.44	48.55	45.84	1.18	0.22
Loin depth, mm	6.40	6.48	6.58	6.37	0.13	0.52
Fat-free lean, kg	45.80	46.50	47.00	45.30	0.90	0.42
Lean meat, %	54.05	54.00	54.10	53.20	0.87	0.76

[1]There were 8 pens/treatment, 4 pens with barrows and 4 pens with gilts, and 3 pigs per pen.

[2]Commercial = bin run corn; standard = Pioneer hybrid 33J56; control = near-isoline Pioneer hybrid 33P66; TC1507 = transgenic corn 33P66 plus event TC1507.

[3]Treatment × sex interaction ($P < 0.05$).

Data Recording, Calculations, and Statistical Analysis

Individual pig weights were recorded at the beginning and at the conclusion of each phase. Daily feed allocations were recorded and the weight of feed in the feeders was recorded at the end of each phase. Pigs were slaughtered at a BW of approximately 120 kg. Live weights at slaughter and standard carcass measurements (hot carcass weight, 10th-rib backfat thickness, loin eye area, and loin eye depth) were collected, and dressing percentage and lean meat percentage were calculated (National Pork Board, 2000). Performance was evaluated by calculating ADG, ADFI, and G:F for the entire experiment.

Data were analyzed using the MIXED procedure (SAS Institute Inc., Cary, NC). The model consisted of treatment, sex, and the treatment × sex interaction. Block (defined as replicate × sex) was included as a random effect for all analyses; block × treatment was also included as a random effect for the analysis of carcass data. Pen was the experimental unit for all analyses.

There was an unintended treatment × sex interaction ($P < 0.05$) in the initial BW of the pigs, in which barrows allotted to the standard corn were heavier (23.9 kg) than barrows allotted to the other treatments (23.2, 23.2, and 23.1 kg for pigs allotted to commercial, control, and TC1507 corn, respectively). However, for gilts there were no differences in initial BW among treatments. Likewise, for all other analyzed data, no interactions were observed.

RESULTS AND DISCUSSION

The current experiment was conducted to evaluate TC1507 corn grain by comparing the performance of pigs fed diets containing TC1507 corn with the performance of pigs fed diets containing nontransgenic, near-isogenic corn grain (control) and 2 additional reference corn grains (commercial and standard). There were no differences among treatment groups for ADG, ADFI, or G:F, which was true for each of the 3 phases and for the overall experimental period (Table 3). Thus, the type of corn used in the diets did not influence pig performance. Likewise, there were no differences among treatments in hot carcass weight, dressing percentage, 10th-rib backfat, loin eye area, or carcass leanness. These observations indicate that the inclusion of TC1507 corn in diets fed to growing-finishing pigs would not influence growth performance or standard carcass measurements.

Performance and standard carcass measurements of pigs fed transgenic corn containing the genes expressing the Cry protein were similar to the performance and standard carcass measurements of pigs fed the control and commercial hybrids (Hyun et al., 2004, 2005). Reuter et al. (2002) also demonstrated that there were no differences in nutrient and energy digestibility between pigs fed diets containing transgenic corn and pigs fed diets containing control hybrids.

Table 4. Growth performance by sex of pigs fed experimental diets[1]

	Sex			
Item	Gilts	Barrows	SEM	*P*-value
Pig performance				
Initial weight, kg	23.7	23.3	1.0	0.81
Final weight, kg	119.4	119.5	1.6	0.96
ADG, kg/d	0.82	0.88	0.02	0.15
ADFI, kg/d	2.62	2.68	0.06	0.50
G:F, kg/kg	0.316	0.329	0.011	0.40
Carcass data				
Slaughter weight, kg	117.2	118.3	2.2	0.64
Hot carcass weight, kg	85.5	86.6	1.9	0.54
Dressing, %	72.96	73.20	0.47	0.58
10th-rib backfat, mm	16.4	23.0	1.1	0.004
Loin eye area, cm^2	49.35	45.33	1.05	0.013
Loin depth, cm	6.64	6.24	0.12	0.019
Fat-free lean, kg	47.8	44.5	0.7	0.009
Lean meat, %	55.79	51.86	0.75	0.006

[1]There were 8 pens/treatment, 4 pens with barrows and 4 pens with gilts, and 3 pigs per pen.

Inclusion of corn grain containing TC1507 has no influence on performance and carcass yield in broilers (McNaughton and Zeph, 2004), egg production in laying hens (Scheideler et al., 2008), performance and carcass quality in growing and finishing steers (Sindt et al., 2007), and performance in lactating dairy cows (Faust et al., 2007). The results from the present experiment showing that there was no influence of corn grain containing the TC1507 event on performance and carcass measurements of growing-finishing pigs is, therefore, in agreement with data obtained in other species. Likewise, results from the present experiment agree with recent data showing that inclusion of a corn grain containing event DAS 59122-7 in diets fed to pigs did not affect the performance or carcass composition of growing-finishing pigs (Stein et al., 2009). To our knowledge, the experiment by Stein et al. (2009) is the only other publication reporting data for pigs fed a transgenic corn hybrid with combined insect resistance and herbicide tolerance; data from the present experiment are in agreement with the conclusions from the experiment by Stein et al. (2009).

There were no differences in ADG, ADFI, or G:F between gilts and barrows (Table 4). The differences in carcass measurements between sexes were expected, with barrows having more backfat ($P < 0.01$) than gilts, and gilts having greater ($P < 0.05$) loins, more fat-free lean ($P < 0.01$), and a greater ($P < 0.01$) lean meat percentage than barrows. These differences between sexes concurred with previous reports on carcass composition of gilts and barrows (Stein et al., 2006).

IMPLICATIONS

Results from this experiment demonstrate that the feeding value for growing-finishing pigs of a transgenic corn hybrid containing event TC1507 is not different from that of other corn hybrids. Neither pig performance nor carcass measurements are influenced by the presence or absence of TC1507 corn in the diets.

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