Comparison of Broiler Performance When Fed Diets Containing Grain from YieldGard (MON810), YieldGard × Roundup Ready (GA21), Nontransgenic Control, or Commercial Corn[1]

M. L. Taylor,*[,2] G. F. Hartnell,* S. G. Riordan,* M. A. Nemeth,* K. Karunanandaa,* B. George,† and J. D. Astwood*

*Monsanto Company, 800 N. Lindbergh Blvd., St. Louis, Missouri 63167; and †Colorado Quality Research, 400 East County Road 72, Wellington, Colorado 80549

ABSTRACT This 42-day experiment was undertaken to compare the nutritional value of insect-protected corn event MON810 (YieldGard) and YieldGard × herbicide-tolerant corn event GA21 (Roundup Ready) to their nontransgenic controls as well as four different commercial reference corns, when fed to growing Cobb × Cobb broilers. A randomized complete block design was used, and each treatment was replicated with five pens of males and five pens of females with 10 broilers per pen. Broilers were fed approximately 55% wt/wt corn during the first 20 d and approximately 60% wt/wt corn thereafter. The corn component of diets fed to broilers was supplied entirely with grain from the eight hybrids included in the experiment. Final live weights averaged 2.09 kg/bird fed YieldGard corn and 2.15 kg/bird fed YieldGard × Roundup Ready corn and were not different ($P > 0.05$) from final weights for birds fed control or commercial corn. Feed conversion was not affected ($P > 0.05$) by YieldGard (1.72) or YieldGard × Roundup Ready (1.77) corn feeding when compared with the feeding of other corn diets. Chill weights, fat pad, thigh weights, and wing weights were not affected by diets ($P > 0.05$). Differences ($P < 0.05$) were noted for breast and drum weights across treatments. Broilers overall performed consistently and had similar carcass yield and meat composition when fed diets containing YieldGard (event MON810) or YieldGard (event MON810) × Roundup Ready (event GA21) as compared with their nontransgenic controls and commercial diets.

(*Key words*: broiler performance, carcass yield, *Bacillus thuringiensis*, Cry1A(b), maize 5-enolpyruvylshikimate-3-phosphate synthase)

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INTRODUCTION

YieldGard corn (event MON810) and YieldGard (event MON810) × Roundup Ready (event GA21) corn produce the Cry1A(b) protein that confers insect protection against the European corn borer (*Ostrinia numbilalis*). YieldGard × Roundup Ready corn also expresses the maize protein, 5-enolpyruvylshikimate-3-phosphate synthase (mEPSPS), that confers tolerance to glyphosate, the active ingredient in Roundup herbicide. The combined trait corn was produced by conventional breeding of two transgenically derived single-trait products, YieldGard corn and Roundup Ready (event GA21) corn. YieldGard corn event MON810 was modified to produce the Cry1A(b) protein from *Bacillus thuringienisis* (Bt) subsp. *kurstaki* strain HD-1 (Sanders et al., 1998). Roundup Ready corn event GA21 was produced by the insertion of the gene that expresses the mEPSPS protein, which is 99.3% identical in its amino acid sequence to the wild-type corn 5-enolpyruvylshikimate-3-phosphate synthase enzyme (LeBrun et al., 1997).

The benefits of biotech crops has been reviewed, and the value of biotech crops to farmers is evidenced by the rapid adoption rate with a cumulatiave total of more than 175 million ha planted between 1996 and 2001 (James, 2001). However, concerns have arisen about potential unintended effects of the introduction of the transgenes into crops. Multiple studies have concluded that YieldGard corn and Roundup Ready corn (event GA21) are substantially equivalent in composition to conventional corn (Sanders et al., 1998; Sidhu et al., 2000). Broiler studies may detect potential effects resulting from the transformation event or from the expression of the new trait or traits by examining performance characteristics during a rapid

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[1]YieldGard, Roundup, and Roundup Ready are registered trademarks of Monsanto Technology LLC.

[2]To whom correspondence should be addressed: Mary.L.Taylor@monsanto.com.

Abbreviation Key: Bt = *Bacillus thuringiensis*; Cry1A(b) = insecticidal crystalline protein from Bt; mEPSPS = modified maize 5-enolpyruvylshikimate-3-phosphate synthase protein.

growth period. In this experiment, as in that of Sidhu et al. (2000), rapidly growing broilers were chosen as a useful model to demonstrate the equivalence in wholesomeness of transgenic corn to conventional corn because of their sensitivity to changes in nutrient quality and because corn is a major ingredient in their diet. This experiment assessed the nutritional value of YieldGard corn and YieldGard × event GA21 Roundup Ready corn to conventional corn by measuring performance, carcass yield, and meat quality response variables in broilers.

MATERIALS AND METHODS

Birds and Housing

This experiment was conducted in accordance with the principles and guidelines for the care and use of agricultural animals in research (Federation of Animal Science Societies, 1999). In addition, it was conducted in compliance with the Food and Drug Administration's "Good Laboratory Practice Regulations for Nonclinical Laboratory Studies" (21CFR, Part 58). Day old Cobb × Cobb broiler chickens were purchased[3] for the study. Broilers were vaccinated for Marek's disease at the hatchery and for Newcastle disease and infectious bronchitis at the test site at 7 d of age. The broilers were randomly assigned by gender to pens under simulated commercial conditions for raising broilers. Broilers were housed in concrete floor pens (1.5 m × 0.9 m) providing approximately 0.3 m^2 per bird. All birds were placed in clean pens containing 10 to 13 cm deep clean wood shavings. The poultry room was environmentally controlled for incandescent lighting and temperature. Incandescent lighting was provided for 23 h the first 6 d and ranged from 10 to 16 h for the remainder of the study. Target room temperature was approximately 34°C at study start and minimally decreased each day to a target room temperature of approximately 23°C at d 30 through the remainder of the study. Water and feed were available ad libitum throughout the experiment. Water was provided via a hanging automatic bell drinker (36-cm diameter) per pen, and feed was provided via a hanging tube feeder (43-cm diameter) per pen. A chick feeder tray was also placed in each pen for the first 6 d. Environmental conditions (floor space, temperature, lighting, bird density, and feeder and water space) were similar for all treatments.

Experimental Design

A randomized complete block design was used with eight treatments (two test, two nontransgenic controls, and four commercial reference diets). For each of the treatment groups, there were 100 broilers in 10 pens: five pens of males (10 broilers per pen) and five pens of females (10 broilers per pen) for a total of 800 birds. Initially, there were an additional two broilers in each pen to compensate for early chick mortality, which occur normally during the first few days posthatch. On d 7, the group size was culled to a maximum of 10 broilers per pen. The primary criterion for the removal was slower-growing birds, which was followed by random selection.

Grains

Grain of the YieldGard corn hybrid, DK551 BtY, produced in Yuma County, CO, and YieldGard × event GA21 Roundup Ready corn hybrid, DK493 RR/BtY, produced in Humboldt County, IA, was grown during 1999. Grain from the nontransgenic control hybrids (DK551 and DK 493 AF) was produced in Yuma County, CO, and St. Joseph County, MI, respectively, in 1999. Grain from four commercial hybrids grown during 1999 was included in the experiment for reference purposes. The commercial hybrids purchased from United States' growers in 1999 were DK539, DK521, DK537 (all grown in Yuma County, CO) and BX86 (grown in Clinton County, IL).

Mycotoxin[4] and pesticide[5] screens of the corn grain used for this experiment were conducted prior to experiment initiation to verify levels were below the limits of concern for broiler performance. Proximate and amino acid analyses[5] were performed on the grain according to the Association of Official Analytical Chemists (1998) and an additional Kjeldahl method (Bradstreet, 1965) for the crude protein analyses. Carbohydrate values were calculated. Diets were formulated based on the individual nutrient analyses (Table 1) for the grain from each test, control, and commercial hybrid.

Diets

Dietary protein was provided by the corn supplemented with commercial dehulled soybean meal. Synthetic methionine and lysine were added to the diets as needed to conform to industry standards. A coccidiostat, salinomycin (Sacox)[6] was mixed into test diets at a level of 60 g/ton. All diets were formulated such that the critical amino acid levels met nutritional recommendations of NRC (1994) for poultry. From d 1 to d 20, chickens were fed a starter diet containing approximately 55% wt/wt corn. From d 20 to d 42, chickens were fed a grower/finisher diet containing approximately 60% wt/wt corn (Table 2). Analyses of formulated poultry diets[7] are summarized in Table 3. Calcium and phosphorus were analyzed using inductively coupled plasma radial spectrometry.

Measurements

During the course of the experiment, broiler flocks were examined twice daily for general health. All mortalities and unhealthy birds killed were weighed and necropsied. Probable cause of death or reason for removal was documented. Broilers in each pen were weighed by group at d

[3]Hoover's Hatchery, Rudd, IA.
[4]Romer Laboratories, Union, MO.
[5]Covance Laboratories, Madison, WI.
[6]Intervet, Inc., Millsboro, DE.
[7]Covance Laboratories, Madison, WI; Dairy One Laboratories, Ithaca, NY.

TABLE 1. Proximate (%) and amino acid (mg/g) composition[1] of corn YieldGard (DK551 BtY), YieldGard × Roundup Ready (DK493RR/BtY), controls DK551 and DK493 AF, and commercial lines BX86, DK521, DK537, and DK539)

Analyzed composition (as-is basis)	BX86	DK521	DK537	DK539	Control DK551	Control DK493 AF	YieldGard	YieldGard × Roundup Ready
Crude protein	8.18	6.99	7.63	7.02	7.25	7.50	6.90	10.1
Crude Fat	3.23	2.98	2.37	2.74	3.34	3.76	2.54	3.41
Moisture	14.8	11.6	12.4	11.4	14.9	9.59	14.0	12.3
Carbohydrates	72.6	77.5	76.8	77.7	73.4	78.0	75.4	73.0
Crude fiber	1.57	1.60	2.36	1.78	1.58	1.48	1.96	1.36
Aspartic acid	5.46	5.02	5.68	4.91	5.01	5.16	4.83	6.42
Threonine	2.76	2.44	2.79	2.51	2.51	2.66	2.42	3.35
Serine	3.92	3.40	3.70	3.49	3.63	3.60	3.26	4.93
Glutamic acid	15.9	12.8	14.4	12.7	13.9	14.0	13.1	20.2
Proline	7.58	5.91	7.19	6.35	6.94	6.87	6.54	9.47
Glycine	3.06	2.94	3.19	2.85	2.92	3.21	2.81	3.71
Alanine	6.42	5.15	5.90	5.11	5.62	5.61	5.30	7.91
Cystine	1.72	1.65	1.53	1.46	1.68	1.94	1.62	2.10
Valine	4.08	3.56	4.04	3.38	3.66	3.88	3.51	4.99
Methionine	1.79	1.44	1.29	1.23	1.60	1.99	1.43	2.17
Isoleucine	3.10	2.43	2.87	2.33	2.64	2.67	2.53	3.67
Leucine	11.0	8.27	9.69	8.28	9.39	8.98	8.70	13.6
Tyrosine	2.80	2.29	2.49	2.39	2.68	2.64	2.44	3.39
Phenylalanine	4.20	3.32	3.89	3.31	3.63	3.54	3.38	5.09
Histidine	2.33	2.09	2.29	2.06	2.16	2.31	2.06	2.85
Lysine	2.48	2.42	2.73	2.38	2.28	2.66	2.22	2.88
Arginine	3.74	3.59	3.65	3.34	3.41	3.75	3.41	4.55
Tryptophan	0.54	0.47	0.50	0.48	0.49	0.53	0.45	0.73

[1]Analyses conducted at Covance Laboratories, Madison, WI.

TABLE 2. Ingredient composition of diets (YieldGard (DK551 BtY), YieldGard × Roundup Ready (DK493RR/BtY), controls DK551 and DK493 AF, and commercial lines BX86, DK521, DK537, and DK539)

	Treatment							
Ingredient (%)	BX86	DK521	DK537	DK539	Control DK493 AF	Control DK551	YieldGard	YieldGard × Roundup Ready
Starter diet formulation								
Corn	57.29	54.89	56.06	54.87	55.37	55.70	54.99	60.49
Dehulled soybean meal	35.85	37.95	36.95	37.95	37.55	37.25	37.85	33.25
Soy oil	3.35	3.75	3.55	3.75	3.70	3.60	3.75	2.80
Defluorinated phosphate	1.85	1.85	1.80	1.85	1.80	1.90	1.85	1.80
Limestone	0.75	0.65	0.70	0.65	0.70	0.65	0.65	0.75
Salt	0.28	0.27	0.28	0.27	0.28	0.27	0.27	0.28
DL-Methionine	0.23	0.24	0.26	0.26	0.21	0.23	0.24	0.22
Choline chloride-60%	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Trace minerals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamins	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Lysine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sacox (coccidiostat)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Grower/finisher diet formulation								
Corn	62.85	60.20	61.52	60.23	60.68	61.11	60.31	66.47
Dehulled soybean meal	30.60	32.95	31.85	32.90	32.50	32.15	32.80	27.60
Soy oil	3.25	3.65	3.40	3.65	3.60	3.50	3.65	2.60
Defluorinated phosphate	1.75	1.75	1.70	1.75	1.70	1.80	1.75	1.70
Limestone	0.65	0.55	0.60	0.55	0.65	0.55	0.60	0.65
Salt	0.29	0.29	0.30	0.29	0.30	0.29	0.29	0.30
DL-Methionine	0.25	0.26	0.28	0.28	0.22	0.25	0.25	0.24
Choline chloride-60%	0.11	0.10	0.11	0.10	0.10	0.11	0.10	0.13
Trace minerals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamins	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Lysine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Sacox (coccidiostat)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

[1]Trace mineral premix (SEM Minerals, Quincy, IL) contained 0.003% calcium and provided following in milligrams per kilogram of diet: Mn, 120; Zn, 100; Fe, 40; Cu, 10; I, 1.4; Se, 0.3, and Mg, 26.

[2]Vitamin premix (Roche Vitamins, Inc., Parsippany, NJ) provided the following per kilogram of diet: vitamin A, 9,350 IU from all *trans*-retinyl acetate; cholecalciferol D3, 3,025 IU; vitamin E, 27.5 IU from dl-α-tocopherol; vitamin B12, 13.75 μg; riboflavin, 7.7 mg; niacin, 49.5 mg; pantothenic acid, 12.1 mg; menadione, 1.925 mg; folic acid, 0.99 mg; ethoxyquin, 77 mg; biotin, 0.088 mg; thiamine, 1.925 mg, and pyridoxine, 3.08 mg.

TABLE 3. Nutrient composition[1] of diets (YieldGard (DK551 BtY), YieldGard × Roundup Ready (DK493RR/BtY), controls DK551 and DK493 AF, and commercial lines BX86, DK521, DK537, and DK539)

Analyzed composition (as is basis)	BX86	DK521	DK537	DK539	Control DK493 AF	Control DK551	YieldGard	YieldGard × Roundup Ready
Starter diets								
ME[2] (kcal/kg)	3,079	3,081	3,081	3,081	3,082	3,079	3,082	3,080
Crude protein (%)	21.1	20.5	21.8	20.1	21.1	21.8	21.3	21.2
Crude fat (%)	5.9	6.4	6.2	6.4	6.6	6.7	6.6	5.9
Moisture (%)	10.4	11.3	11.1	10.6	10.0	9.9	10.6	10.1
Arginine (%)	1.26	1.22	1.18	1.14	1.34	1.28	1.32	1.31
Lysine (%)	1.19	1.06	1.07	1.15	1.25	1.11	1.15	1.11
Methionine (%)	0.51	0.54	0.53	0.54	0.51	0.50	0.52	0.49
Cystine (%)	0.33	0.30	0.31	0.29	0.33	0.33	0.32	0.30
Tryptophan (%)	0.20	0.21	0.20	0.19	0.22	0.24	0.19	0.21
Threonine (%)	0.74	0.72	0.69	0.67	0.75	0.73	0.79	0.75
Valine (%)	0.99	0.88	0.91	0.96	1.01	0.97	0.95	1.01
Calcium (%)	1.01	1.08	0.97	1.17	1.03	1.14	1.04	1.12
Phosphorus (%)	0.83	0.83	0.79	0.88	0.82	0.86	0.83	0.88
Grower/finisher diets								
ME[2] (kcal/kg)	3,135	3,135	3,134	3,136	3,135	3,134	3,135	3,135
Crude protein (%)	21.1	20.5	21.8	20.1	21.1	21.8	21.3	21.2
Crude fat (%)	5.9	6.4	6.2	6.4	6.6	6.7	6.6	5.9
Moisture (%)	10.4	11.3	11.1	10.6	10.0	9.9	10.6	10.1
Arginine (%)	1.26	1.22	1.18	1.14	1.34	1.28	1.32	1.31
Lysine (%)	1.19	1.06	1.07	1.15	1.25	1.11	1.15	1.11
Methionine (%)	0.51	0.54	0.53	0.54	0.51	0.50	0.52	0.49
Cystine (%)	0.33	0.30	0.31	0.29	0.33	0.33	0.32	0.30
Tryptophan (%)	0.20	0.21	0.20	0.19	0.22	0.24	0.19	0.21
Threonine (%)	0.74	0.72	0.69	0.67	0.75	0.73	0.79	0.75
Valine (%)	0.99	0.88	0.91	0.96	1.01	0.97	0.95	1.01
Calcium (%)	1.01	1.08	0.97	1.17	1.03	1.14	1.04	1.12
Phosphorus (%)	0.83	0.83	0.79	0.88	0.82	0.86	0.83	0.88

[1]Amino acid analysis conducted at Covance Laboratories, Madison, WI, and remaining analyses at Dairy One Laboratories, Ithaca, NY.

[2]Calculated value.

1 and d 42 and individually at experiment termination (d 43 for males and d 44 for females). Average BW per pen and BW per bird values within each treatment group were calculated for each gender. The average feed conversion per pen was calculated for the entire duration of the experiment by using the total feed consumption during the experiment divided by the total BW of the surviving broilers in the pen. This was averaged for each treatment group by gender. Adjusted feed conversion was calculated by using the total feed consumption per pen divided by the total BW of the surviving broilers and BW of broilers that died or were removed from the pen. At experiment termination, carcass measurements (chill weight and breast, thigh, wing, and drum weights, kg) for all birds were taken, and fat pads were collected from each bird and weighed. The first male or female bird processed from each pen for all treatments was selected for breast and thigh tissue collection for subsequent analyses. Breast muscle samples from 10 broilers fed YieldGard corn and 10 broilers fed conventional corn grain were analyzed for transgenic DNA and detection of the Cry1A(b) protein in tissues (Jennings et al., 2003). In addition, moisture, protein, and fat analyses were conducted[8] on breast and thigh meat samples.

[8]University of Missouri, Experiment Stations Chemical Laboratories, Columbia, MO.

Statistical Analysis

ANOVA using a randomized complete block design were performed on starting and final live weights, feed consumption, feed conversion, adjusted feed conversion, chill weight, percent chill weight (chill weight/live weight), breast weight, percent breast weight (breast weight/chill weight), wing weight, percent wing weight (wing weight/chill weight), thigh weight, percent thigh weight (thigh weight/chill weight), drum weight, percent drum weight (drum weight/chill weight), fat pad weight, percent fat pad (fat pad/live weight), and moisture, protein, and fat values for breast and thigh meat. All percentage values were calculated by dividing the response variable by chill or live weight, as appropriate. Statistical analysis was carried out using a linear mixed model procedure of SAS software (SAS Institute, Inc.)

Mean values obtained for the YieldGard and YieldGard × Roundup Ready diet groups were compared with those for the nontransgenic controls and commercial diet groups at the 5% level of significance using a protected Fisher's least significant difference test (Fisher, 1949). The statistical model (ANOVA) included effects of treatments, gender, block, and gender by treatment interactions, with the experimental unit being the pen. Additional statistical analyses individually compared the fit of YieldGard corn or YieldGard × Roundup Ready diets to the population of

TABLE 4. Summary of broiler mortality by gender[1]

Treatment	Percent mortality d 0 to 7		Percent mortality d 7 to 42	
	Males	Females	Males	Females
BX86	3.3	1.7	6.0	2.0
DK521	3.3	3.3	8.0	2.0
DK537	10.0	3.3	18.0	4.0
DK539	10.0	0.0	12.0	0.0
DK493 AF control	3.3	1.7	12.0	6.0
DK551 control	6.7	6.7	4.0	2.0
YieldGard	8.3	5.0	4.0	0.0
YieldGard × Roundup Ready	1.7	5.0	8.0	8.0

[1]A total of 60 males and 60 females per treatment for d 0 to 7; a total of remaining 50 males and remaining 50 females per treatment for d 7 to 42.

responses from control and commercial corn diets to determine if the values of the test response variables were consistent across treatments. These analyses defined two catagories, transgenic and nontransgenic. The transgenic catagory contained one diet with either YieldGard corn or YieldGard × Roundup Ready corn, and the nontransgenic catagory contained control and commercial diets. Comparisons for YieldGard corn included the nontransgenic control (DK493 AF) for the YieldGard × Roundup Ready corn, and comparisons for YieldGard × Roundup Ready corn included the nontransgenic control (DK551) for the YieldGard corn. When a statistically significant gender by treatment interaction was noted for any of the response variables, the means were also broken out by gender.

RESULTS

General Observations

Mycotoxin and pesticide levels in corn grain mixed into the diets were below the limits of concern for broiler performance. Levels of mycotoxins in the grain ranged from nondetectable to less than 2 ppm for fumonisins and trichothecenes. All values for the pesticide screen were below the assay limits of detection: organophosphates (0.050 ppm), organonitrogens (0.500 ppm), organochlorinates (0.200 ppm), and N-methylcarbamates (0.100 ppm). Diets were formulated based on the individual nutrient analyses of the grain to meet NRC (1994) recommendations. A total of 44 broilers (4.6% of total) died during the first 7 d with mortality spread out across treatments. Mortality during d 7 to d 42 was slightly higher than normal in this experiment at 6% with the highest mortality occurring in males (Table 4). The distribution of the broilers that died from d 7 to experiment termination was random across treatments, ranging from 2% (for test corn, DK551 BtY) to 11% (for commercial corn, DK537). Most of the apparent causes of death between d 7 and d 42 were attributed to sudden death and ascites. Remaining broilers in all treatments were in good health.

Performance Response Variables for YieldGard Corn

All performance response variables measured were not different ($P > 0.05$) across the broilers fed diets of YieldGard corn, its nontransgenic control corn, and commercial corn (Table 5). Live weight at d 1, live weight at d 42, total feed intake, feed conversion, and adjusted feed conversion were not different ($P > 0.05$) across all treatments. Broilers fed diets containing YieldGard corn had similar adjusted feed conversion as those fed all other diets.

Carcass Measurements for YieldGard Corn

Carcass measurements of chill weight, fat pad, thighs, drums, and wings were not different ($P > 0.05$) across the broilers fed diets of YieldGard corn, the nontransgenic control, and commercial corn (Table 5). Broilers fed diets containing YieldGard corn had significantly ($P < 0.05$) greater breast meat yield compared with nontransgenic control DK551 but similar yield to four commercial corn diets. Drum yield from broilers fed diets containing YieldGard corn was not different ($P > 0.05$) than broilers fed diets containing the nontransgenic control and three commercial diets. Drum yield from broilers fed diets containing DK539 and DK493 AF was slightly higher ($P < 0.05$) than drum yield from broilers fed diets containing YieldGard corn. For meat composition, no differences ($P > 0.05$) were observed in the percentage of moisture, protein, or fat in breast meat or in thigh meat across YieldGard corn, control corn, and commercial corn diets (Table 5).

Performance Response Variables for YieldGard × Roundup Ready Corn

All performance response variables measured were not different ($P > 0.05$) across the broilers fed diets of YieldGard × Roundup Ready corn and all other diets (Table 5). Live weight at d 1, live weight at d 42, total feed intake, feed conversion, and adjusted feed conversion were not different ($P > 0.05$) across treatments. Comparison of adjusted feed conversion demonstrated similar performance between diets containing YieldGard × Roundup Ready corn and the population of other diets.

Carcass Measurements for YieldGard × Roundup Ready Corn

Carcass measurements of chill weight, fat pad, thighs, drums, and wings were not different ($P > 0.05$) among the

TABLE 5. Performance and carcass yield comparison of broilers fed YieldGard corn DK551 BtY, nontransgenic control corn (DK551), YieldGard × Roundup Ready (RR) corn DK493 RR/BtY, nontransgenic control corn (DK493 AF), and commercial corn (mean values of combined males and females)

	Treatment									
	7	6	8	5	1	2	3	4		
	Yield Gard	Control DK 551	YieldGard × RR	Control DK 493 AF	Commercial BX 86	Commercial DK 521	Commercial DK 537	Commercial DK 539	Treatments SSD[1]	LSD[2] 5.0%
Performance										
Live weight (g/bird) d 1	35.67	35.30	35.87	35.37	35.58	35.25	35.48	35.58	NS	0.63
Live weight (kg/bird) d 42	2.09	2.07	2.15	2.11	2.13	2.11	2.12	2.14	NS	0.06
Feed intake (kg/bird)	3.59	3.55	3.80	3.74	3.65	3.74	3.93	3.84	NS	0.32
Feed conversion	1.72	1.72	1.77	1.77	1.71	1.77	1.84	1.79	NS	0.12
Adjusted feed conversion	1.68	1.67	1.66	1.64	1.67	1.69	1.68	1.68	NS	0.04
Carcass yield										
Chill weight (kg)	1.44	1.44	1.49	1.46	1.48	1.46	1.49	1.47	NS	0.05
Chill weight (% of live wt)	68.42	68.74	69.18	68.71	69.16	69.08	69.31	68.68	NS	0.82
Fat pad weight (% of live wt)	1.43	1.57	1.55	1.42	1.45	1.50	1.46	1.46	NS	0.12
Breast meat weight (% of chill wt)	24.12[ab]	23.42[c]	23.93[bc]	23.44[c]	24.37[ab]	24.18[ab]	24.46[a]	23.94[abc]	**	0.53
Thigh weight (% of chill wt)	17.54	17.49	17.50	17.50	17.39	17.27	17.28	17.34	NS	0.28
Drum weight (% of chill wt)	13.94[c]	14.02[bc]	14.08[abc]	14.31[a]	14.04[bc]	13.95[c]	13.97[c]	14.22[ab]	*	0.24
Wing weight (% of chill wt)	11.91	11.95	11.89	11.98	11.89	11.89	11.84	11.93	NS	0.18
Breast meat analysis										
Moisture (%)	74.81	74.73	74.62	74.55	74.85	75.09	74.94	74.73	NS	0.56
Protein (%, as-is basis)	22.77	22.52	22.89	23.00	23.19	22.35	22.72	22.73	NS	0.61
Fat (%, as-is basis)	1.126	1.092	1.080	1.139	1.186	1.045	1.130	1.038	NS	0.12
Thigh meat analysis										
Moisture (%)	76.37	75.93	76.06	75.90	76.44	76.18	76.70	76.46	NS	0.58
Protein (%, as-is basis)	20.23	20.31	20.47	20.44	20.11	20.29	19.89	20.03	NS	0.72
Fat (%, as-is basis)	2.70	2.67	2.38	2.59	2.60	2.72	2.49	2.52	NS	0.35

[a–d]Individual treatment means with the same superscript letter in the same row were not statistically different ($P > 0.05$).

[1]Statistical significance of overall F-test: NS = not significant ($P > 0.05$); *$P < 0.05$; **$P < 0.01$.

[2]Least significant difference between two means ($P < 0.05$).

TABLE 6. Performance, carcass yield of the broilers and compositional analysis in breast and thigh meat. Comparison of the transgenic corn DK551 BtY with the nontransgenic population

	Males				Females			
	Transgenic	Nontransgenic	SSD[1]	LSD[2] 5.0%	Transgenic	Nontransgenic	SSD[1]	LSD[2] 5.0%
Performance								
Live weight (g/bird) d 1	35.77	35.30	NS	0.75	35.57	35.56	NS	0.67
Live weight (kg/bird) d 42	2.22	2.26	NS	0.12	1.96	1.97	NS	0.05
Feed intake (kg/bird)	3.83	4.08	NS	0.68	3.35	3.40	NS	0.15
Feed conversion	1.72	1.81	NS	0.25	1.71	1.73	NS	0.06
Adjusted feed conversion	1.66	1.65	NS	0.05	1.70	1.69	NS	0.05
Carcass yield								
Chill weight (kg)	1.48	1.54	NS	0.06	1.40	1.40	NS	0.04
Chill weight (% of live wt)	67.51	68.48	NS	1.04	69.33	69.42	NS	0.76
Fat pad weight (% of live wt)	1.26	1.32	NS	0.23	1.60	1.64	NS	0.12
Breast meat weight (% of chill wt)	23.61	23.86	NS	1.42	24.62	24.07	NS	1.30
Thigh weight (% of chill wt)	17.48	17.39	NS	0.36	17.61	17.36	NS	0.54
Drum weight (% of chill wt)	14.24	14.33	NS	0.54	13.65	13.84	NS	0.45
Wing weight (% of chill wt)	12.02	11.93	NS	0.20	11.80	11.90	NS	0.19
Breast meat analysis								
Moisture (%)	74.85	74.72	NS	0.75	74.78	74.91	NS	0.67
Protein (%, as-is basis)	22.92	22.91	NS	0.86	22.62	22.59	NS	1.03
Fat (%, as-is basis)	1.21	1.16	NS	0.22	1.04	1.05	NS	0.15
Thigh meat analysis								
Moisture (%)	75.93	76.24	NS	1.12	76.80	76.30	NS	1.16
Protein (%, as-is basis)	20.36	20.29	NS	0.85	20.09	20.07	NS	1.22
Fat (%, as-is basis)	2.87	2.68	NS	0.36	2.52	2.51	NS	0.42

[1]SSD = statistical significance of differences: NS = not significant ($P > 0.05$); *$P < 0.05$.

[2]Least significant difference between two means ($P < 0.05$).

broilers fed diets of YieldGard × Roundup Ready corn, its nontransgenic control, and commercial corn (Table 5). Breast meat from broilers fed diets containing YieldGard × Roundup Ready corn was similar to broilers fed diets of its non-transgenic control and all but one commercial corn line. Drum yield from broilers fed diets containing YieldGard × Roundup Ready corn was not different ($P > 0.05$) than broilers fed diets containing the nontransgenic control and all commercial corn lines. Differences ($P < 0.05$) in drum yield on a percent chill weight basis only were observed between the nontransgenic control and all but one commercial corn line. For meat composition, no differences ($P > 0.05$) were observed in the percentage of moisture, protein, and fat in breast meat or in thigh meat across treatments (Table 5).

Population Statistical Analysis

Comparison of the YieldGard corn to the population of control and commercial corn showed no differences ($P > 0.05$) in all growth performance, carcass yield, and meat quality response variables measured in both males and females (Table 6). Comparison of the YieldGard × Roundup Ready corn to the population of control and commercial corn for males and females showed no differences in most performance response variables and in all carcass yield and meat quality response variables measured (Table 7). At the experiment start, there was a difference ($P < 0.05$) in the initial weight of males to be fed YieldGard × Roundup Ready corn compared with the population. These minor differences in the males at the experiment start did not impact the final weight comparisons at d 42.

DISCUSSION

Multiple studies have been conducted to assess the impact of diets containing transgenic corn on broiler growth and performance (Clark and Ipharraguerre, 2001). In all studies, the conclusions were in agreement that the genetically enhanced corn provided equivalent growth, performance, and carcass yields in all response variables measured when compared with conventional corn. One of these experiments included Roundup Ready corn event GA21, and it was concluded that final BW and fat pad weights were within the expected range for broilers while feed conversion was similar to the U.S. industry average (Sidhu et al., 2000). Results of the current broiler feeding experiment are in agreement with those of Sidhu et al. (2000) and demonstrated no differences in nutritional value among diets containing YieldGard corn or YieldGard × event GA21 Roundup Ready corn when compared with their respective control or to commercial corn in terms of broiler performance, meat composition, and health. In addition, ranges observed in this experiment for drum yield on a percent chill weight basis (Table 5) were within reported literature values (10.5 to 14.6%) for broiler studies using the Cobb × Cobb strain (Kidd et al., 1996; Peak et al., 2000).

When individual treatment comparisons were made, broilers overall performed and had similar carcass yield and meat composition with diets containing YieldGard and YieldGard × event GA21 Roundup Ready corn, the nontransgenic control, or commercially available corn. As a result, it was concluded that the transgenic corn containing the insect-protected or combined insect-protected

TABLE 7. Performance, carcass yield of the broilers and compositional analysis in breast and thigh meat. Comparison of the transgenic corn DK493RR/BtY with the nontransgenic population

	Males				Females			
	Transgenic	Nontransgenic	SSD[1]	LSD[2] 5.0%	Transgenic	Nontransgenic	SSD[1]	LSD[2] 5.0%
Performance								
Live weight (g/bird) d 1	36.33	35.30	*	0.82	35.40	35.56	NS	0.63
Live weight (kg/bird) d 42	2.31	2.26	NS	0.12	1.98	1.97	NS	0.05
Feed intake (kg/bird)	4.05	4.08	NS	0.68	3.56	3.40	NS	0.21
Feed conversion	1.75	1.81	NS	0.25	1.80	1.73	NS	0.08
Adjusted feed conversion	1.65	1.65	NS	0.47	1.67	1.69	NS	0.05
Carcass yield								
Chill weight (kg)	1.57	1.54	NS	0.06	1.41	1.40	NS	0.04
Chill weight (% of live wt)	68.71	68.48	NS	0.95	69.64	69.42	NS	0.73
Fat pad weight (% of live wt)	1.44	1.32	NS	0.23	1.66	1.64	NS	0.13
Breast meat weight (% of chill wt)	23.55	23.86	NS	1.42	24.31	24.07	NS	1.30
Thigh weight (% of chill wt)	17.52	17.39	NS	0.40	17.48	17.36	NS	0.54
Drum weight (% of chill wt)	14.42	14.33	NS	0.54	13.75	13.84	NS	0.45
Wing weight (% of chill wt)	11.95	11.93	NS	0.19	11.84	11.90	NS	0.18
Breast meat analysis								
Moisture (%)	74.58	74.72	NS	0.94	74.66	74.91	NS	0.67
Protein (%, as-is basis)	23.09	22.91	NS	0.81	22.68	22.59	NS	1.03
Fat (%, as-is basis)	1.07	1.16	NS	0.22	1.09	1.05	NS	0.15
Thigh meat analysis								
Moisture (%)	75.97	76.24	NS	1.12	76.15	76.30	NS	1.16
Protein (%, as-is basis)	20.50	20.29	NS	0.86	20.44	20.07	NS	1.22
Fat (%, as-is basis)	2.55	2.68	NS	0.38	2.20	2.51	NS	0.39

[1]SSD, statistical significance of differences: NS = not significant ($P > 0.05$); *$P < 0.05$.

[2]Least significant difference between two means ($P < 0.05$).

and glyphosate-tolerant traits were nutritionally equivalent in broiler diets as those containing their corresponding nontransgenic control and commercially available corn. This conclusion is consistent with those addressing the composition of the Roundup Ready corn event GA21, which showed that there were no relevant differences in nutritional and compositional properties relative to control and reference corn (Sidhu et al., 2000). These data confirm and support the conclusion that the genetically modified corn events evaluated are as nutritious as traditional corn.

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