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Comparison of Swine Performance When Fed Diets Containing Corn Root Worm Protected Corn, Parental Line Corn, or Conventional Corn Grown During 2000 in Nebraska

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Summary and Implications

This experiment was conducted to evaluate growth performance and carcass quality measurements in growing-finishing pigs fed diets containing either Corn Root Worm Protected Corn (CRW0586), the parental control corn (RX670), or two commercial sources of non-genetically modified corn (DK647 and RX740). The experiment used 72 barrows and 72 gilts with an average initial body weight of 50 lb. The pigs were allotted to a randomized complete block design with a 2 × 4 factorial arrangement of treatments (two sexes × four corn hybrids). The experiment continued until the average body weight was 260 lb, at which time all pigs were slaughtered. Real-time ultrasound measurements were taken on the final day of the experiment. Carcass quality measurements were made 24 hours postmortem. Corn hybrid did not affect average daily gain (ADG) or average daily feed intake (ADFI), but there was an effect of sex, with barrows having greater ($P < 0.01$) ADG and ADFI than gilts. Feed efficiency was not affected by the different corn hybrids, but gilts had improved ($P < 0.01$) feed efficiency compared to barrows during Finisher 1 (0.37 versus 0.35) and Finisher 2 (0.32 versus 0.30). Real-time ultrasound measurements were similar among corns; however, a sex effect was detected for backfat (BF) depth, with gilts having less ($P < 0.01$) BF than barrows (0.78 versus 0.98 in). There were no differences in carcass midline BF measurements among corns, but there was a significant difference between barrows and gilts, with gilts having less ($P < 0.05$) BF than barrows. Hot carcass weight was greater ($P < 0.01$) in barrows than gilts (210 versus 190 lb). Also, the percent carcass lean was greater ($P < 0.01$) in gilts than barrows (51.7 versus 49.5%). Longissimus muscle quality scores were similar among corns and between barrows and gilts. Analysis of longissimus muscle composition revealed no main effect of corn ($P > 0.20$) or sex ($P > 0.30$) for protein, fat, and water percentages. However, Corn Root Worm Protected Corn (73.1%) differed ($P < 0.04$) from parental control corn (73.6%) but not commercial corns (73.3 and 73.3%) in longissimus water content. In summary, there were no differences in growth performance or carcass measurements in growing-finishing pigs fed diets containing either Corn Root Worm Protected Corn, the parental control corn, or two commercial sources of non-genetically modified corn. Thus, the replacement of non-transgenic corn with Corn Root Worm Protected Corn in growing-finishing diets will result in similar growth performance and(or) carcass measurements.

Introduction

Transgenic crops offer producers a wide variety of agronomic benefits. Crops with microbial Bt formulations contain the Cry (crystalline protein inclusions) insect control proteins. Following a single acute exposure, Cry proteins bind to specific receptors in the midgut cells of susceptible insects and form ion-selective channels in the cell membrane. The cells swell due to an influx of water which leads to cell lysis, the insect stops eating and dies. The test event, MON 863, produces a variant of the wild type Cry3Bb1 protein, which protects against Corn Root Worm (CRW, *Diabrotica*).

The objective of this study was to compare growth performance and carcass quality measurements in growing-finishing pigs fed diets containing either Corn Root Worm Protected Corn (CRW0586), the parental control corn (RX670), or two commercial sources of non-genetically modified corn (DK647 and RX740).

Procedures

Animals and Treatment

A total of 144 crossbred [Danbred × (Danbred × NE White Line)] barrows and gilts with an average initial body weight (BW) of 50 lb were used. The pigs were allotted to a randomized complete block experiment with a 2 × 4 factorial arrangement of treatments. Blocks were based on initial weight and pen location within the building. There were two sexes (barrows and gilts) and four genetic corn lines (CRW0586, RX670, DK647, and RX740). Diets (Table 1) contained corn and soybean meal and were fortified with vitamins and minerals to meet or exceed the NRC (1998) requirements for 44- to 264-lb pigs. There were four

(Continued on next page)

diet phases during the experiment (Grower 1, Grower 2, Finisher 1, and Finisher 2). Each diet phase was 28 days, except Finisher 2 which was 20 days, this resulted in a total experimental period of 104 days.

The pigs were housed in a modified-open-front building with 24 pens (pen dimensions 4.9 × 15.7 ft), and each pen contained six pigs. Pigs had ad libitum access to feed and water throughout the experimental period. Pigs remained on the experiment until the average BW of the pigs reached approximately 260 lb (d 104), at which time all pigs were removed from the experiment.

Data and Sample Collection

Pigs were weighed and feed intakes were measured biweekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency. Real-time ultrasound measurements were taken at the end of the experiment by a certified technician, and tenth-rib backfat (BF) depth and longissimus muscle area (LMA)

Table 1. Ingredient and calculated composition of diets, as-fed basis.

	Dietary Phases[a]			
Ingredients, %	Grower 1	Grower 2	Finisher 1	Finisher 2
Corn	68.65	74.79	78.66	82.47
Soybean meal (46.5% CP)	26.00	20.25	16.25	12.75
Tallow	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.25	0.85	0.93	0.75
Limestone	0.40	0.40	0.40	0.40
Salt	0.30	0.30	0.30	0.30
Vitamin premix [b c]	0.20	0.20	0.15	0.15
Trace mineral premix [d e]	0.15	0.15	0.10	0.10
Tylosin, 40 g/lb	---	---	0.13	---
L-Lysine•HCl	0.05	0.06	0.08	0.08
Calculated nutrient content				
Crude protein, %	18.10	15.80	14.30	12.10
Lysine, %	1.00	0.85	0.75	0.65
ME [f], Mcal/lb	1.56	1.57	1.57	1.57
Calcium, %	0.70	0.60	0.60	0.55
Phosphorus, %	0.60	0.50	0.50	0.45

[a]The only difference in the four diets within each dietary phase was the addition of the different genetic corn lines.
[b]Supplied per pound of complete feed in grower diets: retinyl acetate, 1,995 IU; cholecalciferol, 200 IU; α-tocopherol acetate, 11 IU; menadione sodium bisulfite, 1.6 mg; riboflavin, 4.0 mg; d-pantothenic acid, 8.0 mg; niacin, 12.0 mg; vitamin B_{12}, 12.0 µg.
[c]Supplied per pound of complete feed in finisher diets: retinyl acetate, 1,500 IU; cholecalciferol, 150 IU; α-tocopherol acetate, 8.2 IU; menadione sodium bisulfite, 1.2 mg; riboflavin, 3.0 mg; d-pantothenic acid, 6.0 mg; niacin, 9.0 mg; vitamin B_{12}, 9.0 µg.
[d]Supplied per pound of complete feed in grower diets: Zn (as ZnO), 58 mg; Fe (as $FeSO_4 \cdot H_2O$),58 mg; Mn (as MnO), 13.6 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 5 mg; I (as $Ca(IO_3) \cdot H_2O$), 0.12 mg; Se (as Na_2SeO_3), 0.14 mg.
[e]Supplied per pound of complete feed in finisher diets: Zn (as ZnO), 38.5 mg; Fe (as $FeSO_4 \cdot H_2O$), 38.5 mg; Mn (as MnO), 9.1 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 3.2 mg; I (as $Ca(IO_3) \cdot H_2O$), 0.08 mg; Se (as Na_2SeO_3), 0.09 mg.
[f]Metabolizable energy.

Table 2. Growth performance of barrows and gilts.

	Genetic Line				Sex			P-Value [a]		
Item	CRW0586	RX670	DK647	RX740	Barrows	Gilts	Pooled SEM	Trt	Sex	Trt x Sex
No. Pens	6	6	6	6	12	12				
Initial Wt., lb	50.12	50.08	50.12	49.94	50.10	50.05	0.236	NS	NS	NS
Final Wt., lb	260.48	258.67	255.43	259.66	270.66	246.45	4.941	NS	< 0.01	NS
Grower 1										
ADG, lb [b]	1.63	1.68	1.63	1.61	1.72	1.57	0.037	NS	< 0.01	NS
ADFI, lb [c]	3.22	3.29	3.20	3.22	3.35	3.09	0.064	NS	< 0.01	NS
ADG/ADFI	0.51	0.51	0.51	0.50	0.51	0.50	0.007	NS	NS	NS
Grower 2										
ADG, lb	2.07	2.03	2.01	2.06	2.18	1.87	0.064	NS	< 0.01	NS
ADFI, lb	5.01	4.87	4.81	4.83	5.27	4.50	0.150	NS	< 0.01	NS
ADG/ADFI	0.42	0.41	0.42	0.42	0.42	0.42	0.011	NS	NS	NS
Finisher 1										
ADG, lb	2.29	2.27	2.23	2.25	2.40	2.12	0.073	NS	< 0.01	NS
ADFI, lb	6.48	6.22	6.24	6.33	6.87	5.76	0.205	NS	< 0.01	NS
ADG/ADFI	0.36	0.37	0.36	0.36	0.35	0.37	0.011	NS	< 0.01	NS
Finisher 2										
ADG, lb	2.12	2.09	2.05	2.21	2.21	2.03	0.079	NS	< 0.01	NS
ADFI, lb	6.90	6.77	6.59	6.88	7.30	6.28	0.236	NS	< 0.01	NS
ADG/ADFI	0.31	0.31	0.31	0.32	0.30	0.32	0.009	NS	< 0.01	NS
Overall										
ADG, lb	2.07	2.07	1.98	2.07	2.12	1.90	0.046	NS	< 0.01	NS
ADFI, lb	5.27	5.18	5.09	5.18	5.56	4.81	0.135	NS	< 0.01	NS
ADG/ADFI	0.38	0.39	0.39	0.39	0.38	0.39	0.007	NS	< 0.01	NS

[a]Trt = treatment; and NS = nonsignificant effect , P > 0.10.
[b]ADG = average daily gain.
[c]ADFI = average daily feed intake.

Table 3. Ultrasound and carcass measurements .

	Genetic Line				Sex			P-Value[a]				
Item	CRW0586	RX670	DK647	RX740	Barrows	Gilts	Pooled SEM	Trt	Sex	Trt x Sex	GMO vs P[b]	GMO vs Conv.[c]
No. pens	6	6	6	6	12	12						
Ultrasound measurements												
Backfat, in	0.87	0.88	0.85	0.91	0.98	0.78	0.051	NS	< 0.01	NS	NS	NS
LMA[d], in^2	7.26	7.27	7.08	7.09	7.24	7.12	0.188	NS	NS	NS	NS	NS
Ultrasound lean measurements[e i]												
Total lean, lb[f]	101.45	100.86	99.38	99.82	102.18	98.59	1.603	NS	< 0.01	NS	NS	NS
Percent lean[f]	50.40	50.36	50.61	49.96	48.76	51.90	0.821	NS	< 0.01	NS	NS	NS
Lean gain, lb/d	0.82	0.81	0.80	0.81	0.83	0.79	0.015	NS	< 0.01	NS	NS	NS
Carcass measurements[g]												
Hot carcass weight, lb	202.09	200.70	196.91	200.52	209.89	190.23	4.101	NS	< 0.01	NS	NS	NS
First rib BF, in	1.64	1.65	1.62	1.66	1.76	1.53	0.059	NS	< 0.01	NS	NS	NS
Tenth rib BF, in	1.06	1.08	1.06	1.08	1.16	0.98	0.044	NS	< 0.01	NS	NS	NS
Last rib BF, in	1.07	1.09	1.12	1.07	1.19	0.98	0.035	NS	< 0.01	NS	NS	NS
Last lumbar BF, in	0.88	0.88	0.89	0.96	1.00	0.81	0.032	0.08	< 0.01	< 0.05	NS	NS
LMA, in^2	10.06	9.64	9.49	9.57	9.78	9.60	0.260	NS	NS	NS	NS	< 0.05
Carcass lean measurements[h i]												
Total lean, lb[f]	102.47	101.21	98.65	101.61	103.77	98.19	1.985	NS	< 0.01	NS	NS	NS
Percent lean[f]	50.83	50.50	50.25	50.85	49.50	51.72	0.358	NS	< 0.01	NS	NS	NS
Lean gain, lb/d	0.83	0.82	0.79	0.82	0.84	0.79	0.019	NS	< 0.01	NS	NS	NS

[a]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv = conventional lines; and NS = nonsignificant effect , P > 0.10.
[b]Transgenic line (CRW0586) comparison with parental control line (RX670).
[c]Transgenic line (CRW0586) comparison with conventional lines (DK647 and RX740).
[d]Longissimus muscle area.
[e]National Pork Producers Council 2000 fat-free lean equation using ultrasound data: (0.833 × sex (barrow=1 and gilt=2) - (16.498 × ultrasound 10th rib BF (in)) + (5.424 × ultrasound 10th rib LMA (in^2)) + (0.291 × live wt. (lb)) - 0.534.
[f]Figured on a fat-free lean basis.
[g]Backfat measurements were taken at the midline.
[h]National Pork Producers Council 2000 fat-free lean equation using carcass data: 23.568 - (21.348 × last rib BF (in)) + (0.503 × warm carcass wt. (lb)).
[i]Lean gain calculation: $\dfrac{\text{Final fat-free lean} - \text{Initial fat-free lean}^{j}}{104}$
[j]Initial fat-free equation: .95 * [-3.95 + (.418 × live weight, lb)]

were recorded. At the termination of the experiment, the pigs were shipped to SiouxPreme Packing Co. in Sioux Center, Iowa, where carcass characteristics were measured on individually identified pigs. At 24 hours postmortem, midline BF measurements (first rib, tenth rib, last rib, and last lumbar) and LMA traces at the tenth rib were collected on all the carcasses. Carcass quality tests were also performed at 24 hours postmortem. These tests were on the longissimus muscle at the tenth rib and included pH; firmness and marbling scores; and Minolta L*, a*, and b* values. A longissimus muscle sample was collected from each carcass at the tenth rib and loin samples from three pigs per pen were used to determine longissimus muscle composition.

Statistical Analysis

Data were analyzed as a randomized complete block design using PROC MIXED of SAS (1999). The main effects in the statistical model were sex (barrows and gilts) and genetic corn line (CRW0586, RX670, DK647, and RX740). Also, the sex x corn line interaction was included in the model. Contrasts were performed to compare the transgenic line with its parental control and with the two commercial reference lines. In all analyses, pen was the experimental unit.

Results

Growth Performance

Average daily gain, ADFI, and ADG/ADFI for the four diet phases and the entire experimental period are shown in Table 2. During the four diet phases, ADG, ADFI, and feed efficiency were not affected ($P > 0.10$) by corn. Average daily gain was greater (1.72, 2.18, 2.40, and 2.21 lb versus 1.57, 1.87, 2.12, and 2.03 lb; $P < 0.01$) in barrows than gilts, respectively, during the four diet phases. Also, ADFI was greater (3.35, 5.27, 6.88, and 7.30 lb versus 3.09, 4.50, 5.76, and 6.28 lb; $P < 0.01$) in barrows than gilts during the four diet phases. During the Finisher 1 and 2 periods, gilts had improved (0.37 and 0.35 versus 0.32 and 0.30; $P < 0.01$) feed efficiency compared to barrows, with no differences ($P \geq 0.10$) between barrows and gilts during the Grower 1 and 2 periods. Results of the overall experimental period indicate no differences

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Table 4. Longissimus muscle quality scores and composition.

	Genetic Line				Sex			P-Value[a]				
Item	CRW0586	RX670	DK647	RX740	Barrows	Gilts	Pooled SEM	Trt	Sex	Trt x Sex	GMO vs P[b]	GMO vs Conv.[c]
Longissimus muscle quality scores												
Marbling[d]	2.67	2.44	2.28	2.28	2.48	2.36	0.193	NS	NS	NS	NS	< 0.05
Firmness[e]	2.94	3.08	2.86	3.08	2.91	3.07	0.147	NS	NS	NS	NS	NS
pH	5.58	5.57	5.57	5.56	5.58	5.55	0.039	NS	NS	NS	NS	NS
Minolta L*	47.20	46.65	46.53	46.62	46.86	46.64	0.712	NS	NS	NS	NS	NS
Minolta a*	6.99	7.21	6.72	6.84	6.96	6.93	0.210	NS	NS	NS	NS	NS
Minolta b*	2.27	2.19	1.76	1.85	2.09	1.94	0.227	NS	NS	NS	NS	< 0.05
Longissimus muscle composition, %												
Protein	23.43	22.94	23.20	23.02	23.15	23.15	0.324	NS	NS	NS	NS	NS
Fat	2.30	2.22	2.03	2.27	2.28	2.13	0.204	NS	NS	NS	NS	NS
Water	73.11	73.62	73.34	73.37	73.31	73.41	0.236	NS	NS	< 0.05	<0.05	NS

[a]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv = conventional lines; and NS = nonsignificant effect , P > 0.10.
[b]Transgenic line (CRW0586) comparison with parental control line (RX670).
[c]Transgenic line (CRW0586) comparison with conventional lines (DK647 and RX740).
[d]Scored on a scale of 1 to 4, where 1 = practically devoid of marbling and 4 = moderate to slightly abundant marbling.
[e]Scored on a scale of 1 to 4, where 1 = very soft and 4 = very firm.

($P > 0.10$) among corn varieties for ADG, ADFI, and feed efficiency. However, overall ADG (2.12 versus 1.90 lb) and ADFI (5.56 versus 4.81 lb) were greater ($P < 0.01$) in barrows than gilts, and overall feed efficiency was improved (0.39 versus 0.38; $P < 0.01$) in gilts than barrows.

Carcass Characteristics

Real-time ultrasound and carcass measurements are summarized in Table 3. Ultrasound measurements of tenth-rib BF and LMA did not differ ($P > 0.10$) among corns, but tenth-rib BF was greater ($P < 0.01$) in barrows (0.98 in) than gilts (0.78 in). Carcass BF (first rib, tenth rib, and last rib) measurements were similar ($P > 0.10$) among corns, but differences (1.76, 1.16, and 1.19 in versus 1.53, 0.98, and 0.98 in; $P < 0.01$) between barrows and gilts for carcass first, tenth, and last rib BF measurements, respectively were detected with no differences ($P > 0.10$) in LMA. Last lumbar BF depth was influenced by corn hybrid ($P = 0.08$). Pigs fed the commercial line RX740 (0.96 in) had a greater amount of last lumbar BF compared to pigs fed CRW0586 (0.88 in), RX670 (0.88 in), and DK647 (0.89 in). Also, a treatment × sex interaction ($P < 0.05$) was detected for last lumbar backfat depth. Hot carcass weight was not affected by corn hybrid, but was greater for barrows than gilts (210 lb versus 190 lb; $P < 0.01$). However, gilts had a greater (51.72% versus 49.50%; $P < 0.01$) percentage of carcass fat-free lean compared to barrows.

Longissimus Muscle Quality Scores and Composition

Longissimus muscle quality scores for pH; marbling and firmness; Minolta L*, a*, and b* values, and longissimus muscle composition are summarized in Table 4. Longissimus muscle quality scores were not affected ($P \geq 0.10$) by sex or corn hybrid. However, the Corn Root Worm Protected Corn (CRW0586) had a greater marbling score (2.67 versus 2.28; $P < 0.05$) and Minolta b* color score (2.27 versus 1.81; $P < 0.05$) compared the two commercial corn varieties (DK647 and RX740). Protein, fat, and water percentage of the longissimus muscle were similar ($P \geq 0.10$) between barrows and gilts and among corns. However, a treatment x sex interaction ($P < 0.05$) was detected for longissimus muscle water percentage. Also, the transgenic corn (CRW0586) versus parental (RX670) comparison resulted in a difference ($P < 0.05$) in longissimus muscle water percentage with pigs fed the transgenic corn (73.11%) having less water than pigs fed the parental corn (73.62%).

Discussion

The results indicate no significant differences among the corn treatments for ADG, ADFI, or feed efficiency. However, in the present study, expected sex differences between gilts and barrows were observed in growth performance. Recent experiments using barrows and gilts during the finishing period have shown that barrows have greater ADG and ADFI than gilts. However, in these same experiments, gilts had superior feed efficiency compared to barrows. Results of the current experiment support the results of previous experiments and indicate the same differences in ADG, ADFI, and feed efficiency between barrows and gilts.

Dietary treatment did not affect ultrasound and carcass measurements, however a difference in backfat depth between barrows and gilts was detected, with no difference in longissimus muscle area. The difference in backfat depth between barrows and gilts is supported by the results of other researchers, however in those experiments gilts had greater longissimus muscle area than barrows, which is in contrast to the results of the present experiment. The similar longissimus muscle area between barrows and gilts may be a result of feeding the barrows and gilts the same lysine concentration throughout the four-phase growing-finishing experiment. Previous research has shown that gilts require higher dietary concentrations of lysine compared to barrows to maximize growth performance and carcass leanness. The significant effect of sex on hot carcass weight is a result of terminating the experiment on a constant time basis resulting in a significant difference in final weight between barrows and gilts.

Longissimus muscle pH is related to pork quality. The pH value is correlated to the quality traits of color and water holding capacity as well as various eating quality traits, such as tenderness. In the present study, corn and (or) sex did not affect pH. Most previous studies have indicated that 24-h postmortem pH measurements are similar between barrows and gilts. The pH values were similar to previous experiments and the pH values were within the normal range for measurements taken 24 h postmortem. The subjective measurements of marbling and firmness of the longissimus muscle were similar among corns and between barrows and gilts. The marbling and firmness values in the present study were numerically similar to those of previous experiments where pigs were fed a corn-soybean meal diet.

Corn line and sex had minimal influence on longissimus muscle color scores (Minolta L*, a*, and b*). The Minolta L* values, which measure the lightness (0-100) of the sample, were within a normal range of 42 to 50 and were in agreement with other data. Although, Minolta a* and b* values, which measure the amount of red (+a*) or green (-a*) and the amount of yellow (+b*) or blue (-b*) in a meat sample, were not affected by corn or sex, the numerical values of the present study were lower than those of previously reported experiments.

The percentages of protein, fat, and water in longissimus muscle in the present experiment were not affected by corn or sex. This finding is similar to that of previous researchers, who reported no treatment effects on chemical composition of muscle. Although the main effect of corn on longissimus muscle water was not significant at the $P < 0.05$ level, individual contrasts indicated less water ($P < 0.05$) in the Corn Root Worm Protected Corn group (73.11%) than the parental control group (73.62%). However, Corn Root Worm Protected Corn group did not differ ($P > 0.20$) from the two commercial varieties (73.34% and 73.37%).

Conclusion

This experiment demonstrates that the feeding value of Corn Root Worm Protected Corn (CRW0586) is similar to that of conventional corns (DK647 and RX740). Therefore, the replacement of non-transgenic corn with Corn Root Worm Protected Corn in swine diets will result in similar growth performance and(or) carcass measurements.

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[1]Robert L. Fischer is a research technologist and graduate student, Phillip S. Miller is an associate professor, Sara S. Blodgett is a graduate student, and Steven J. Kitt is a graduate student in the Department of Animal Science. References are available from the authors upon request.