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Comparison of Swine Performance When Fed Diets Containing Roundup Ready® Corn, Parental Line Corn, or Two Commercial Corns

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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 Roundup Ready® corn expressing the CP4 EPSPS protein, the parental control corn, or two commercial sources of non-genetically modified corn. The experiment used 72 barrows and 72 gilts with an 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 x four corn hybrids). The experiment continued until the average body weight was 255 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. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI) were not affected by corn variety, but there was an effect of sex for all growth performance traits, with barrows having greater ($P < 0.001$) ADG and ADFI than gilts and gilts having better ($P < 0.001$) feed efficiency than barrows. Real-time ultrasound measurements were similar among corns, however a sex effect was detected for backfat (BF) depth, with gilts having less ($P < 0.001$) BF than barrows. 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. Total body electrical conductivity measurements were not affected by corn, but hot carcass weight was greater ($P < 0.001$) in barrows than gilts. Also, primal percentage and percent carcass lean were greater ($P < 0.01$) in gilts than barrows. Longissimus muscle quality scores were similar among corns and between barrows and gilts, except for pH, which was greater ($P < 0.05$) in barrows than gilts. Analysis of longissimus muscle composition revealed no main effect of corn variety ($P > 0.05$) or effect of sex ($P > 0.05$) for protein, fat, and water percentages. Roundup Ready® corn (2.99%) differed ($P < 0.04$) from parental control corn (2.20%) but not commercial corns (3.08 and 3.06%) in longissimus fat content. In summary, there were no differences in growth performance or carcass measurements in growing-finishing pigs fed diets containing either Roundup Ready® corn, the parental control corn, or two commercial sources of non-genetically modified corn. Roundup Ready® corn can replace traditional corn in diets for growing-finishing pigs.

Introduction

Genetically modified crops offer producers a wide variety of agronomic benefits. The use of Roundup Ready® corn provides flexible and broad-spectrum, post-emergent weed control. Glyphosate, which is the active ingredient in the herbicide Roundup, is one of the most widely used herbicides in the world. Therefore, Roundup Ready® corn was developed to be tolerant to glyphosate. Previous experiments conducted with pigs and chickens have demonstrated that genetically modified corns are substantially equivalent to nontransgenic corn. Therefore, the objective of this study was to compare growth performance and carcass quality measurements in growing-finishing pigs fed diets containing either Roundup Ready® corn (CRR 0633), the parental control corn (RX 670), or two commercial sources of non-genetically modified corn (RX 760 and DK 647).

Procedures

Animals and Treatments

A total of 144 crossbred (PIC × Duroc× Hampshire) barrows and gilts with an initial 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 (RX 740, DK 647, RX 670, and CRR 0633). 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 265-lb pigs. There were four diet phases during the experiment (Grower 1, Grower 2, Finisher 1, and Finisher 2).

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

Ingredients, %	Dietary Phases			
	Grower 1	Grower 2	Finisher 1	Finisher 2
Corn[a]	68.07	74.21	78.11	81.79
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]	0.70	0.70	0.70	0.70
Trace mineral premix[c]	0.10	0.10	0.10	0.10
Antibiotic	0.13	0.13	0.13	0.13
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[d], 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 kilogram of diet: retinyl acetate, 3,088 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23.2 mg; choline, 77.2 mg; vitamin B_{12}, 15.4 µg.
[c]Supplied per kilogram of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4$•H_2O), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4$•5 H_2O), 11 mg; I (as $Ca(IO_3)$•H_2O), .22 mg; Se (as Na_2SeO_3), .3 mg.
[d]Metabolizable energy.

Each diet phase was 28 days, except Finisher 2, which was 19 days. This resulted in a total experimental period of 103 days.

The pigs were housed in a modified-open-front building with 24 pens (pen dimensions 4.95 ft × 15.84 ft), and each pen contained six barrows or gilts. Pigs had ad libitum access to feed and water throughout the experimental period. Pigs remained on the experiment until the average body weight of the pigs reached approximately 255 lb, 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 ADG, ADFI, and feed efficiency (ADG/ADFI). 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) were recorded. At the termination of the experiment, pigs were shipped to SiouxPreme Packing Co. in Sioux Center, Iowa, where carcass characteristics were measured on individually identified pigs using total body electrical conductivity (TOBEC). 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 loin sample was collected from each carcass at the tenth rib and ten loin samples per treatment (five barrows and five gilts) were used to determine longissimus muscle chemical composition (protein, fat, and water).

Statistical Analysis

Data were analyzed as a randomized complete block design using PROC MIXED of SAS. The main effects in the statistical model were sex (barrows and gilts) and genetic corn line (RX 740, DK 647, RX 670, and CRR 0633). Also, the sex × corn line interaction was included in the statistical analysis. Contrasts were performed to compare the transgenic line with its parental control (CRR 0633 vs RX 670) and with the two commercial reference lines (CRR 0633 vs RX 740 and DK 647). In all analyses pen was the experimental unit.

Results

Growth Performance

Average daily gain, ADFI, and feed efficiency (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 ($P \geq 0.30$) by corn variety. Average daily gain was greater (1.65, 2.27, 2.34, and 2.23 lb versus 1.57, 1.94, 2.12, and 2.07 lb; $P < 0.05$) in barrows than gilts during the four diet phases. Also, ADFI was greater (3.26, 5.42, 6.86, and 7.32 lb versus 3.09, 4.65, 5.84, and 6.42 lb; $P < 0.05$) in barrows than gilts during the four diet phases, respectively. During the Finisher 1 and 2 periods, gilts had better (0.36 and 0.32 versus 0.34 and 0.30; $P < 0.01$) feed efficiency than barrows, with no differences ($P \geq 0.53$) between barrows and gilts during the Grower 1 and 2 periods. Results of the overall experimental period indicate no differences ($P \geq 0.54$) among corn varieties for ADG, ADFI, and feed efficiency. However, overall ADG (2.12 versus 1.92 lb) and ADFI (5.58 versus 4.87 lb) were greater ($P > 0.001$) in barrows than gilts, and overall feed efficiency was better (0.39 versus 0.38; $P < 0.001$) in gilts than barrows.

Carcass Characteristics

Real-time ultrasound, carcass, and TOBEC measurements are summarized in Table 3. Ultrasound measurements of tenth-rib BF and LMA did not differ ($P \geq 0.38$) among corns, but tenth-rib BF was greater ($P < 0.001$) in barrows (0.91 in) than gilts (0.72 in). Carcass BF (first rib, tenth rib, last rib, and last lumbar) measurements were similar ($P \geq 0.43$)

Table 2. Growth performance of barrows and gilts.[a]

Item	Genetic Line				SEM	P-Value [b]				
	RX 740	DK 647	RX 670	CRR 0663		Trt	Sex	Trt × Sex	GMO vs P[c]	GMO vs Conv[d]
No. pens	6	6	6	6						
Initial wt., lb	49.79	49.79	49.74	49.70	0.075	NS	<0.001	NS	NS	NS
Final wt., lb	256.24	257.21	256.88	256.57	3.274	NS	<0.001	NS	NS	NS
Grower 1										
ADG, lb	1.58	1.65	1.58	1.60	0.029	NS	0.008	NS	NS	NS
ADFI, lb	3.14	3.24	3.14	3.20	0.051	NS	0.007	NS	NS	NS
ADG/ADFI	0.50	0.51	0.50	0.50	0.009	NS	NS	NS	NS	NS
Grower 2										
ADG, lb	2.11	2.11	2.11	2.08	0.031	NS	<0.001	NS	NS	NS
ADFI, lb	5.02	5.04	5.09	5.01	0.093	NS	<0.001	NS	NS	NS
ADG/ADFI	0.42	0.42	0.41	0.42	0.007	NS	NS	NS	NS	NS
Finisher 1										
ADG, lb	2.24	2.20	2.25	2.23	0.047	NS	0.001	NS	NS	NS
ADFI, lb	6.31	6.27	6.43	6.39	0.146	NS	<0.001	NS	NS	NS
ADG/ADFI	0.36	0.35	0.35	0.35	0.010	NS	<0.001	NS	NS	NS
Finisher 2										
ADG, lb	2.13	2.15	2.15	2.17	0.053	NS	0.012	NS	NS	NS
ADFI, lb	6.75	6.86	6.82	7.03	0.147	NS	<0.001	NS	NS	NS
ADG/ADFI	0.32	0.31	0.32	0.31	0.010	NS	0.001	NS	NS	NS
Overall										
ADG, lb	2.00	2.01	2.01	2.01	0.030	NS	<0.001	NS	NS	NS
ADFI, lb	5.18	5.22	5.24	5.27	0.094	NS	<0.001	NS	NS	NS
ADG/ADFI	0.39	0.39	0.38	0.38	0.006	NS	0.001	NS	NS	NS

[a]Two pigs removed from the data set.
[b]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv = conventional lines; and NS = nonsignificant effect, $P > 0.10$.
[c]Transgenic line (CRR 0633) comparison with parental control line (RX 670).
[d]Transgenic line (CRR 0633) comparison with conventional lines (RX 740 and DK 647).

among corns, but differences (1.80, 1.29, 1.44, and .99 in versus 1.81, 1.09, 1.30, and .83 in; $P < 0.05$) between barrows and gilts for all carcass BF measurements were detected with no differences ($P \geq 0.14$) in LMA. Total body electrical conductivity measurements for hot carcass weight (203 lb versus 188 lb; $P < 0.001$), shoulder weight (27.52 lb versus 26.81 lb; $P < 0.08$), and total lean (99.36 lb versus 96.98 lb; $P < 0.10$) were greater for barrows than gilts. However, gilts had a greater (39.97% versus 37.77%; $P < 0.0001$) percentage of primal weight in relation to hot carcass weight and a greater (51.50% versus 49.02%; $P < 0.01$) percentage of fat-free lean compared to barrows. The TOBEC measurements did not differ among corns ($P \geq 0.30$). Carcass fat-free lean gain calculated from TOBEC measurements was not affected by either sex or corn variety ($P \geq 0.14$).

Longissimus Muscle Quality Scores and Composition

Longissimus muscle quality scores for pH; marbling and firmness; and Minolta L*, a*, and b* values were not affected ($P \geq 0.32$) by sex or corn line, except for pH which was greater ($P < 0.05$) in barrows (5.65) than gilts (5.60) (Table 4). Protein and water percentage of the longissimus muscle were similar ($P > 0.21$) between barrows and gilts and among corns. The longissimus muscle fat percentage was influenced by sex ($P = 0.07$) and corn variety ($P = 0.07$). The genetically modified corn (CRR 0633) vs parental (RX 670) comparison resulted in a difference ($P < 0.04$) in longissimus muscle fat percentage with pigs fed the parental corn (2.20%) having less fat than pigs fed the genetically modified corn (2.99%).

Discussion

The results indicate no significant differences among the corns for ADG, ADFI, or feed efficiency. However, in the present study, traditional 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

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Table 3. Ultrasound and carcass measurements.[a]

	Genetic Line					P-Value[b]				
Item	RX 740	DK 647	RX 670	CRR 0663	SEM	Trt	Sex	Trt × Sex	GMO vs P[c]	GMO vs Conv[d]
Ultrasound measurements										
Backfat, in	0.82	0.81	0.82	0.83	0.031	NS	<0.001	NS	NS	NS
LMA[e], in^2	7.25	7.43	7.58	7.51	0.136	NS	NS	NS	NS	NS
Carcass measurements[f]										
First rib, in	1.88	1.89	1.87	1.87	0.060	NS	0.037	NS	NS	NS
Tenth rib, in	1.18	1.17	1.17	1.21	0.029	NS	<0.001	NS	NS	NS
Last rib, in	1.42	1.35	1.33	1.38	0.041	NS	0.006	NS	NS	NS
Last lumbar, in	0.91	0.89	0.91	0.93	0.030	NS	<0.001	NS	NS	NS
LMA, in^2	8.57	8.77	9.08	8.77	0.313	NS	NS	NS	NS	NS
TOBEC measurements										
Hot carcass wt., lb	194.86	196.28	195.64	195.72	1.400	NS	0.001	NS	NS	NS
Ham wt., lb[h]	22.48	22.61	22.33	22.40	0.266	NS	NS	NS	NS	NS
Loin wt., lb[h]	25.87	26.76	26.18	26.35	0.322	NS	NS	NS	NS	NS
Shoulder wt., lb[h]	26.93	27.39	27.21	27.10	0.365	NS	0.077	NS	NS	NS
Primal percentage[hi]	38.68	39.04	38.87	38.88	0.372	NS	<0.001	NS	NS	NS
Total lean, lb[g]	93.85	93.41	93.02	92.77	1.315	NS	0.092	NS	NS	NS
Percent lean[g]	48.22	47.51	47.67	47.59	0.570	NS	0.001	NS	NS	NS
Lean gain, lb/d[j]	0.76	0.75	0.75	0.75	0.013	NS	NS	NS	NS	NS

[a]Ultrasound data set contains 142 pigs and the carcass data set contains 141 pigs.
[b]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv = conventional lines; and NS = nonsignificant effect, P > 0.10.
[c]Transgenic line (CRR 0633) comparison with parental control line (RX 670).
[d]Transgenic line (CRR 0633) comparison with conventional lines (RX 740 and DK 647).
[e]Longissimus muscle area.
[f]Backfat measurements were taken at the midline.
[g]Figured on a fat-free lean basis.
[h]Contains 5% fat.
[i]Primal percentage was calculated by taking the total weight of the primals (ham, loin, and shoulder) divided by the hot carcass weight.
[j]Lean gain calculation: Final fat-free lean – Initial fat-free lean[k]

[k]Initial fat-free equation: $\frac{.95 * [-3.95 + (.418 * \text{live weight, lb})]}{103\ \text{d}}$

Table 4. Longissimus muscle quality scores and composition.[a]

	Genetic Line					P-Value[b]				
Item	RX 740	DK 647	RX 670	CRR 0663	SEM	Trt	Sex	Trt × Sex	GMO vs P[c]	GMO vs Conv[d]
Longissimus muscle quality scores										
Marbling	2.00	2.00	2.03	2.00	0.014	NS	NS	NS	NS	NS
Firmness	2.08	1.93	2.22	2.08	0.096	NS	NS	NS	NS	NS
pH	5.63	5.63	5.60	5.64	0.016	NS	0.015	NS	NS	NS
Minolta L*	49.75	50.78	50.59	50.69	0.623	NS	NS	NS	NS	NS
Minolta a*	7.20	6.71	7.17	7.40	0.262	NS	NS	NS	NS	NS
Minolta b*	2.11	2.39	2.51	2.58	0.294	NS	NS	NS	NS	NS
Longissimus muscle composition, %										
Protein	23.74	23.48	23.78	23.51	0.216	NS	NS	NS	NS	NS
Fat	3.08	3.06	2.20	2.99	0.247	0.070	0.071	NS	0.039	NS
Water	72.31	72.40	72.71	72.53	0.262	NS	NS	NS	NS	NS

[a]Data set includes 141 pigs, two pigs were not slaughtered and one loin was lost at the slaughter facility.
[b]Trt = treatment; GMO = genetically modified organism; P = parental control line; Conv. = conventional lines; and NS = nonsignificant effect, P > 0.10.
[c]Transgenic line (CRR 0633) comparison with parental control line (RX 670).
[d]Transgenic line (CRR 0633) comparison with conventional lines (RX 740 and DK 647).

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 previous experiments, however in these 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 estimate for 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.

Total body electrical conductivity measurements of the ham, loin, and shoulder weights were similar among corns, but the weight of the shoulder was significantly different between barrows and gilts. This increase in shoulder weight of the barrows is a result of the greater slaughter weight of barrows (267 lb) versus gilts (247 lb). However, the TOBEC estimation of primal weights is similar to the wholesale primal weights reported in previous experiments. In the present experiment, the combined weight of the primals (ham, loin, and shoulder) as a percentage of the hot carcass weight was greater in gilts than barrows. Similarly, researchers have reported that when barrows and gilts are fed to a similar end weight, the primal percentage is greater in gilts than in barrows. Previous studies have shown that gilts produce carcasses with a greater percentage of lean compared to barrows at similar end weights. The percentage of fat-free lean was greater in gilts than barrows in the present experiment. This observation is supported by the decrease in backfat measurements and a greater primal percentage in gilts than barrows.

Longissimus muscle pH is strongly related to pork quality. The pH value is highly 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 variety did not affect pH, but there was a significant effect of sex on the pH value with longissimus muscles from barrows having a greater pH value than those from gilts. Most previous studies have indicated that 24-hours postmortem pH measurements are similar between barrows and gilts. Although, a significant effect of sex on pH was detected, the pH values were similar to previous experiments and the pH is within the normal range for measurements taken 24 hours 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.

The different corns and sexes resulted in 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 experiments. 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 and water in longissimus muscle in the present experiment were not affected by corn variety or sex ($P > 0.05$). Also, the percentages of protein, fat, and water in longissimus muscle are similar to the percentages reported in other experiments. There was a trend toward differences in longissimus muscle fat percentage due to sex ($P = 0.07$) and corn variety ($P = 0.07$). Barrows (3.08%) had a greater fat percentage than gilts (2.59%). This observation is consistent with the greater backfat measurements and lesser fat-free lean percentage in barrows than gilts. Although the main effect of corn on longissimus muscle fat was not significant at the $P < 0.05$ level, individual contrasts indicated less fat ($P < 0.04$) in the parental control group (2.20%) than the Roundup Ready® group (2.99%). However, the Roundup Ready® group did not differ ($P < 0.80$) from the two commercial varieties (3.08% and 3.06%).

Compositional analyses have been conducted to measure proximate (protein, fat, ash, carbohydrate, and moisture), acid detergent fiber, neutral detergent fiber, amino acid, fatty acid, calcium, and phosphorus contents of Roundup Ready® corn line.

Results from the compositional analyses showed that the amounts of proximate components, fiber, phosphorus, amino acids, and fatty acids in the Roundup Ready® corn were comparable to those in the grain of the control line and were within published literature ranges. Because Roundup Ready® corn has been shown to be similar in composition to that of traditional corn, it is not surprising that in the present experiment no differences were detected among corns for growth performance; ultrasound and carcass measurements; and longissimus muscle quality measurements.

Conclusion

This experiment demonstrates that the feeding value of Roundup Ready® corn (CRR 0633) is equivalent to that of conventional corns (RX 740 and DK 647). Therefore, Roundup Ready® corn can be used in swine diets with no detrimental effects on growth performance or carcass characteristics.

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[1]Robert L. Fischer is a research technologist and graduate student, Austin J. Lewis is a professor, and Phillip S. Miller is an associate professor in the Department of Animal Science.