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Soybean meal from Roundup Ready or conventional soybeans in diets for growing-finishing swine[1,2,3]

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ABSTRACT: Dehulled soybean meal prepared from genetically modified, herbicide (glyphosate)-tolerant Roundup Ready soybeans containing the CP4 EPSPS protein and near-isogenic conventional soybeans were assessed in an experiment with growing-finishing pigs. The soybeans were grown in the yr 2000 under similar agronomic conditions except that the Roundup Ready soybeans were sprayed with Roundup herbicide. Both were processed at the same plant. The composition of the two types of soybeans and the processed soybean meal were similar. Corn-soybean meal diets containing conventional or Roundup Ready soybean meal and fortified with minerals and vitamins were fed to 100 crossbred pigs from 24 to 111 kg BW. Diets contained approximately 0.95% lysine initially and were reduced to 0.80 and 0.65% lysine when pigs reached 55 and 87 kg BW, respectively. There were 10 pens (five pens of barrows and five pens of gilts) per treatment with five pigs per pen. All pigs were scanned at 107 kg mean BW and all barrows were killed at the end of the test for carcass measurements and tissue collection. Rate and efficiency of weight gain, scanned backfat and longissimus area, and calculated carcass lean percentage were not different ($P > 0.05$) for pigs fed diets containing conventional or Roundup Ready soybean meal. Gilts gained slower, but they were more efficient and leaner ($P < 0.05$) than barrows. Responses to the type of soybean meal were similar for the two sexes with no evidence of a diet × sex interaction for any of the traits. In most instances, carcass traits of barrows were similar for the two types of soybean meal. Longissimus muscle samples from barrows fed conventional soybean meal tended ($P = 0.06$) to have less fat than those fed Roundup Ready soybean meal, but water, protein, and ash were similar. Sensory scores of cooked longissimus muscles were not influenced ($P > 0.05$) by diet. The results indicate that Roundup Ready soybean meal is essentially equivalent in composition and nutritional value to conventional soybean meal for growing-finishing pigs.

Key Words: Biotechnology, Pigs, Soybeans

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Introduction

Genetically modified crops offer a variety of benefits to growers (James, 1999). An example is insect-protected (Bt) corn, released in the mid-1990s, which is resistant to the European corn borer (Betz et al., 2000). In addition, several crops—including soybeans—have been developed that include a single gene that confers tolerance to glyphosate, the active ingredient in a commonly used herbicide (Roundup; Padgette et al., 1995). This gene encodes a glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthase from *Agrobacterium* sp. Strain CP4 (CP4 EPSPS). Since 1996, glyphosate-tolerant crop varieties have been commercialized for soybeans, canola, cotton, and corn.

Research has been conducted showing that genetically modified corn (e.g., Bt and Roundup Ready corn) and soybean meal produced from genetically modified soybeans (e.g., Roundup Ready soybeans) are comparable in chemical composition to their near-isogenic, conventional counterparts (Padgette et al., 1996; Sidhu et al., 2000). Studies showing the nutritional equivalency of Bt or herbicide-tolerant corn and conventional corn have been conducted with dairy cattle (Faust and Miller, 1997; Faust and Spangler, 2000; Folmer et al., 2000b), beef cattle (Russell and Peterson, 1999; Folmer et al., 2000a; Hendrix et al., 2000), sheep (Daenicke et

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al., 1999), and poultry (Aulrich et al., 1998; Brake and Vlachos, 1998; Halle et al., 1998); however, until recently (Stanisiewski et al., 2001; Weber and Richert, 2001), no studies have been reported with swine. One study (Hammond et al., 1996) examined the nutritional bioequivalency of soybean meal prepared from normal and glyphosate-tolerant soybeans on a short-term basis in several species, but a complete growth study in pigs has not been reported.

The objectives of the present study were to assess the nutritional bioequivalency of soybean meal prepared from herbicide-tolerant or conventional soybeans in corn-soybean meal diets for growing-finishing swine.

Experimental Procedures

Soybeans and Dehulled Soybean Meal. Two sources of dehulled soybean meal from either genetically modified soybeans or from near-isogenic conventional soybeans were evaluated in this study. The genetically modified soybeans, Roundup Ready (cultivar H4994RR; Monsanto Co., St. Louis, MO) contained the CP4 EPSPS protein, making them tolerant to the glyphosate herbicide Roundup (Monsanto Co.). The conventional soybeans (cultivar H4994; Monsanto Co.) were nearly isogenic to the Roundup Ready soybeans. Both soybeans were grown in the yr 2000 under similar agronomic conditions, except that the Roundup Ready soybeans were sprayed with Roundup. Both types of soybeans were processed at the same pilot plant (POS Pilot Plant Corp., Saskatoon, Saskatchewan, Canada).

Animals and Diets. The experiment was conducted from May to August, 2000, at the swine research unit at the University of Kentucky Research and Education Center, Princeton, KY. One hundred crossbred (Landrace × Yorkshire) specific-pathogen-free pigs inititally averaging 23.7 kg BW were used in the study. They were grouped by sex (barrows and gilts), and then pigs within each group were allotted at random to two dietary treatments from outcome groups of initial weight. Each pen consisted of five pigs, and there were five pens of barrows and five pens of gilts in the study for a total of 10 replications per dietary treatment.

Corn-soybean meal diets fortified with minerals and vitamins to meet or exceed NRC (1998) standards were fed in meal form during the experimental period (Table 1). During each of three phases, the same amount of dehulled soybean meal and the same amount of corn were used in the two diets. A common source of commercial corn was used during the experiment. Diets were formulated to contain approximately 0.95, 0.80, and 0.65% total lysine during the growing, early finishing, and late finishing phases of the experiment, with diet changes made at mean BW of 54.5 and 86.6 kg BW, respectively. Changes in lysine concentration were made by adjusting the amounts of corn and soybean meal in the diets. Dietary lysine levels were the same for both barrows and gilts and were sufficient to meet the NRC (1998) estimated requirements for gilts with medium-high rates of fat-free carcass lean gain (i.e., 325 g/d). Other minor adjustments were made in the diets for the three phases. Antimicrobial agents were not included in the diets.

Pigs were housed in an open-front building in 1.2- × 6.7-m concrete-floored pens with approximately half of the pen covered. Pigs were allowed to consume feed and water on an ad libitum basis from wooden, two-hole self-feeders and automatic watering fountains. The pens were cleaned two or three times per week. The pigs were individually weighed and feed consumption was determined on a pen basis at weekly or biweekly intervals during the experiment.

Carcass Evaluation. At a mean BW of 107 kg, all pigs were scanned with real-time ultrasound (Animal Ultrasound Services, Ithaca, NY) by an experienced technician. A longitudinal transducer was used to estimate the mean backfat and longissimus muscle depth at five locations between the 10th and 15th ribs, 5 cm off the midline, of each animal. From longissimus depth, cross-sectional area of the longissimus area was estimated. From backfat depth and longissimus depth, the percentage carcass lean was estimated. Equations were as provided by the user's manual for AUSKey System (Animal Ultrasound Services), adapted to metric units. The carcass percentage lean is assumed to contain between 5 and 10% fat (i.e., not fat-free), although this is not specifically identified in the manual. Equations were as follows:

$$\text{Longissimus muscle area, cm}^2 = 4.174 + (5.987 \times \text{longissimus muscle depth, cm})$$

$$\text{Carcass lean, \%} = 58.46 - (6.00 \times \text{backfat, cm}) + (1.181 \times \text{longissimus muscle depth, cm})$$

Carcass lean gain was estimated by subtracting the kilograms of initial lean for each pig from the kilograms of final lean and dividing by the number of days. The initial lean was from the NPPC (2000) equation (adapted to metric units), as follows:

$$\text{Initial lean, kg} = (0.418 \times \text{initial BW, kg}) - 1.66$$

The experiment was terminated on a pen basis when the mean weight of the pen reached 109 kg BW. The overall final weight averaged 110.8 kg. The barrows were transported from Princeton, KY, to the University of Kentucky Meats Laboratory, Lexington, KY (approximately 330 km), on the following morning and were humanely killed (electrically stunned followed by exsanguination), dehaired, and eviscerated. The head was removed and the carcass was split longitudinally. Hot carcass weight was then determined. Following a 24-h chill at 1°C, backfat thickness was measured at the carcass midline at the first rib, last rib, and the last lumbar vertebrae. The carcasses were split between the 10th and 11th rib, and backfat depth (three-fourths of the distance from the midline to the end of the longissimus muscle) and longissimus muscle area were mea-

Table 1. Composition (as fed basis) of diets

Item	Grower[a]	Early finisher[a]	Late finisher[a]
	%		
Ground corn	73.125	78.50	83.75
Dehulled soybean meal[b]	24.30	19.10	14.00
Dicalcium phosphate	1.25	1.10	0.95
Ground limestone	0.80	0.80	0.80
Iodized salt	0.35	0.35	0.35
Vitamin premix[c]	0.10	0.075	0.075
Trace mineral premix[d]	0.075	0.075	0.075
Calculated analysis[e]			
Crude protein, %	18.7	16.5	14.3
Lysine, %[f]	0.96	0.81	0.66
Calcium, %	0.67	0.62	0.58
Phosphorus, %	0.61	0.56	0.51
Available phosphorus, %	0.30	0.27	0.23
ME, kcal/kg	3,322	3,330	3,337

[a]The three diets were fed from approximately 24 to 55 kg, 55 to 87 kg, and 87 to 111 kg BW, respectively.
[b]Soybean meal from Roundup Ready or near-isogenic conventional soybeans (H4994RR and H4994, respectively; Monsanto Co., St. Louis, MO).
[c]At 0.10% of the diet, provided the following per kilogram of diet: vitamin A, 6,600 IU; vitamin D_3, 880 IU; vitamin E, 22 IU; vitamin K (as menadione sodium bisulfite complex), 6.4 mg; riboflavin, 8.8 mg; pantothenic acid, 22 mg; niacin, 44 mg; vitamin B_{12}, 0.022 mg; D-biotin, 0.22 mg; folic acid, 1.1 mg.
[d]Provided per kilogram of diet: Zn, 135 mg; Fe, 135 mg, Mn, 45 mg; Cu, 13 mg; I, 1.5 mg; Se, 0.3 mg.
[e]Based on calculated analysis of corn and actual analysis of the conventional soybean meal.
[f]The diets containing Roundup Ready soybean meal contained approximately 0.01 of a percentage point less lysine and calcium, and 0.02 of a percentage point more phosphorus, based on the calculated analysis of corn and actual analysis of the soybean meal.

sured. A sample of the longissimus muscle was removed and kept on ice until analyzed for DM, CP, fat, and ash. From the carcass data, the percentage fat-free lean in the carcass was determined using the NPPC (2000) equation (adapted to metric units) as follows:

$$\text{Carcass fat-free lean, \%} = 100 \times [3.899 + (0.465 \times \text{hot carcass weight, kg}) - (3.914 \times \text{10th-rib backfat, cm}) + (0.21146 \times \text{longissimus muscle area, cm}^2)] \div \text{hot carcass weight, kg}$$

Carcass fat-free lean gain was estimated by subtracting the kilograms of initial fat-free lean for each pig from the kilograms of final fat-free lean and dividing by the number of days on test. The initial lean was from the NPPC (2000) equation, adapted to a fat-free basis, as follows:

$$\text{Initial fat-free lean, kg} = 0.95 \times [(0.418 \times \text{initial BW, kg}) - 1.66]$$

Sensory Evaluation. A section of the longissimus muscle from the 10th to 12th rib was removed from all barrows in three replications and frozen. After thawing, three chops (2.54 cm thick) were cooked on an open-hearth grill (Farberware; Kidde Co., Bronx, NY) to an internal temperature of 71°C. An experienced sensory panel evaluated one chop from each loin for juiciness, tenderness, off flavor, flavor intensity, connective tissue, and overall acceptance on a scale from 1 to 8 with 8 being the most desirable (AMSA, 1995). Weights were recorded before and after cooking to determine cook loss. Three 1.26-cm cores were taken from each of the two remaining cooked chops for Warner-Bratzler shear force determination (AMSA, 1995) with an Instron machine (Model 4301, Instron Corp., Canton, MA).

Composition of Soybeans, Soybean Meals, Diets, and Muscle. The soybeans were screened for a number of mycotoxins (aflatoxin B1, B2, G1, G2; ochratoxin A; T-2 toxin; HT-2 toxin; diacetoxyscirpenol; neosolaniol; fusarenon X; deoxynivalenol [DON]; 15 acetyl-DON; 3-acetyl-DON; nivalenol; zearalenone; and fumonisin B1, B2, and B3) by a commercial laboratory (Romer Labs, Union, MO). Representative samples of the soybeans and the soybean meals were analyzed in duplicate or triplicate for dry matter after oven drying to a constant weight, for crude protein by a N analyzer (N × 6.25), for crude fat based on ether extraction, and for crude fiber; all methods were based on standard procedures (AOAC, 1995). Neutral detergent fiber was analyzed by methods described by Robertson and Van Soest (1981) and modified by Jeraci et al. (1988). Calcium was analyzed with atomic absorption spectrophotometry after wet-ashing procedures. Phosphorus was determined by a gravimetric procedure (AOAC, 1995). Amino acids were analyzed in triplicate with ion exchange chromatography after acid hydrolysis. Methionine and cystine were oxidized to methionine sulfone and cysteic acid by treatment with performic acid before hydrolysis. Tryptophan was analyzed after alkaline hydrolysis. Samples of the unfrozen longissimus muscle from all barrows were analyzed for water, crude protein (Kjeldahl N ×

6.25), crude fat (ether extraction), and ash using standard procedures (AOAC, 1995). Assays were conducted at the DHI Forage Analysis Laboratory (Ithaca, NY), University of Missouri Experiment Station Chemical Laboratories (Columbia, MO), or at the University of Kentucky.

Statistical Analyses. The data were analyzed as a randomized complete block design (Steele and Torrie, 1980) using the GLM procedure of SAS (SAS Institute, Inc., Cary, NC). The statistical model for the performance and scan data included the effects of block, sex, diet, sex × diet, and residual (error), and the model for the carcass, loin tissue composition, and sensory data included the effects of block, diet, and residual (error). In addition, BW at the time the pigs were ultrasonically scanned was included in the model as a covariate in the analysis of the scan data, and final BW was used as a covariate in the analysis of the carcass and loin tissue composition data. In all instances, pen was considered the experimental unit.

Results

Composition of Soybeans, Soybean Meals, and Diets. A mycotoxin screen indicated that all mycotoxins were below detectable limits in both types of soybeans (data not shown). The proximate components of the two dehulled soybean meals were similar, as shown in Table 2. Both were slightly higher in CP than listed by NRC (1998) for dehulled soybean meal, probably due to the slightly higher DM content. The conventional soybean meal had slightly more crude fat, apparently due to the processing of the soybeans. Fiber components were essentially equal for the two soybean meals. Calcium concentrations were similar for the two soybean meals, and both were slightly less than the 0.30% listed by NRC (1998). Phosphorus concentration was approximately 14% higher in the Roundup Ready vs the conventional soybean meal, and both were slightly higher than as listed by NRC (1998) for dehulled soybean meal.

The lysine concentrations in the conventional and Roundup Ready soybean meals were 3.16 and 3.09% (Table 2). This difference of 0.07 of a percentage point is quite small and similar to the range of 3.02 to 3.12% lysine that was reported for various sources of dehulled soybean meal obtained from various locations in the United States over a 2-yr period (Cromwell et al., 1999). All of the amino acids were essentially equivalent for the two soybean meal types and were within a reasonable range of the amino acid concentrations reported for dehulled soybean meal (Cromwell et al., 1999) and close to those listed by NRC (1998).

The calculated lysine levels of the diets (Table 1) were close to the targeted levels, based on the lysine analyses of the two soybean meals and a calculated lysine level of 0.26% for corn (NRC, 1998). Because of this small difference in lysine levels for the two soybean meals, the diets containing Roundup Ready soybean meal contained approximately 0.01 of a percentage point less lysine than the diets containing conventional soybean meal. Similarly, the dietary Ca and P levels of the two diets differed slightly, based on the Ca and P analysis of the soybean meals and assumed levels of 0.03 and 0.28%, respectively, in corn (NRC, 1998), but they were above the estimated NRC (1998) requirements during the three phases.

Performance Data. Body weight gain, feed intake, and efficiency of feed utilization of pigs fed diets containing the two types of soybean meal were not different ($P > 0.05$) during any of the three phases or over the entire test period (Table 3). Barrows consumed more feed and gained faster than gilts during the growing and early finishing phase and over the entire experiment ($P < 0.05$), but neither group was affected by type of diet, as evidenced by nonsignificant ($P > 0.05$) sex × diet interactions.

Carcass Data. Carcass leanness, based on ultrasonic scan, was similar ($P > 0.05$) for pigs fed the two sources of soybean meal (Table 4). As expected, gilts had less scanned backfat depth and greater scanned longissimus muscle depth, calculated longissimus muscle area, estimated carcass lean, and lean growth rate than barrows ($P < 0.05$). There was no evidence of a sex × diet interaction for any of the traits based on the scan data.

Indices of carcass leanness of barrows (Table 5) indicated no consistent trends for those fed the two sources

Table 2. Composition (as fed basis) of dehulled soybean meals[a]

Item	Dehulled soybean meal[bc] Conventional	Roundup Ready
	%	
Dry matter	90.3	91.0
Crude protein	51.5	51.2
Crude fat	1.59	0.89
Crude fiber	3.41	3.12
NDF	4.95	4.85
ADF	3.50	3.94
Hemicellulose	1.45	0.91
Calcium	0.24	0.20
Phosphorus	0.73	0.83
Amino acids		
Arginine	3.74	3.66
Histidine	1.44	1.40
Isoleucine	2.32	2.27
Leucine	3.96	3.89
Lysine	3.16	3.09
Methionine	0.70	0.71
Cystine	0.76	0.80
Phenylalanine	2.58	2.51
Tyrosine	1.80	1.76
Threonine	1.95	1.94
Tryptophan	0.77	0.75
Valine	2.44	2.43

[a]Means based on triplicate analyses except for fat and fiber.
[b]Soybean meal from Roundup Ready or near-isogenic conventional soybeans (H4994RR and H4994, respectively; Monsanto Co., St. Louis, MO).
[c]Urease activity was <0.04 pH rise, indicating that the meals were sufficiently heated to destroy the trypsin inhibitors.

Table 3. Performance of pigs fed corn-dehulled soybean meal diets containing conventional or Roundup Ready dehulled soybean meal[ab]

	Sex						
	Barrows		Gilts		Mean		
Item Soybean meal:	C[c]	RR[c]	C	RR	C	RR	CV
Initial weight, kg[d]	24.1	24.2	23.3	23.4	23.7	23.8	0.95
Final weight, kg	110.8	113.7	108.6	110.2	109.7	112.0	3.34
Growing phase (23.7 to 54.5 kg)							
ADG, kg[e]	0.83	0.85	0.80	0.80	0.82	0.82	4.77
ADFI, kg[e]	2.02	2.13	1.94	1.96	1.98	2.04	6.71
Feed/gain	2.43	2.51	2.42	2.45	2.42	2.48	3.84
Early finishing phase (54.5 to 86.6 kg)							
ADG, kg[e]	0.93	0.99	0.89	0.89	0.91	0.94	7.07
ADFI, kg[d]	2.90	3.12	2.64	2.71	2.77	2.92	7.31
Feed/gain	3.13	3.17	2.97	3.06	3.05	3.11	6.04
Late finishing phase (86.6 to 110.8 kg)							
ADG, kg	0.78	0.80	0.75	0.82	0.77	0.81	10.13
ADFI, kg	3.04	3.08	2.81	3.06	2.93	3.07	8.65
Feed/gain	3.91	3.87	3.74	3.78	3.83	3.83	5.39
Entire test (23.7 to 110.8 kg)							
ADG, kg[e]	0.85	0.88	0.82	0.83	0.83	0.85	4.96
ADFI, kg[d]	2.64	2.76	2.43	2.52	2.53	2.64	6.11
Feed/gain	3.10	3.14	2.98	3.04	3.04	3.09	3.80

[a]Based on 10 replications of five pigs per pen (five replications of barrows and five replications of gilts).
[b]No effect of diet or sex × diet interaction for any of the traits ($P > 0.05$).
[c]C = conventional, RR = Roundup Ready.
[d]Effects of sex ($P < 0.01$).
[e]Effects of sex ($P < 0.05$).

of soybean meal. Last-rib and mean backfat thicknesses were greater for pigs fed the conventional vs Roundup Ready soybean meal diets ($P < 0.05$), but the pattern was the reverse for backfat depth measured at the 10th rib. Estimated carcass lean was not different ($P > 0.05$) for pigs fed the two diets. The lower values, compared with the values calculated from the scan data, are due to the availability of recent equations (NPPC, 2000) that calculate carcass lean percentages and lean gain on a fat-free basis. The fat-free lean gains of 302 and 292 g/d for the two treatments indicate that the barrows were of medium lean growth capacity (NRC, 1998).

Chemical Composition. Chemically determined fat in the longissimus muscle tended ($P = 0.06$) to be slightly higher in barrows fed the genetically modified soybean meal, but water, protein, and ash concentrations were not different ($P > 0.10$) for the two treatments (Table 6).

Physical and Sensory Scores. Cook loss, Warner-Bratzler shear force values, and sensory scores were not different ($P > 0.05$) between longissimus muscles from

Table 4. Ultrasound scan data of pigs fed corn-dehulled soybean meal diets containing conventional or Roundup Ready soybean meal[abc]

	Sex						
	Barrows		Gilts		Mean		
Item Soybean meal:	C[d]	RR[d]	C	RR	C	RR	CV
Weight at scan, kg[e]	108.6	111.6	104.1	105.5	106.3	108.5	3.98
Backfat, cm[e]	2.03	2.08	1.73	1.73	1.88	1.91	7.66
Loin depth, cm[e]	4.95	4.73	5.33	5.17	5.14	4.95	3.94
Longissimus muscle, cm^2 [e]	33.8	32.5	36.1	35.1	34.9	33.8	3.46
Carcass lean, %[e]	51.7	51.2	54.1	53.8	52.9	52.5	2.08
Lean gain, g/d[e]	330	324	351	350	341	337	2.81

[a]Based on 10 replications of five pigs per pen (five replications of barrows and five replications of gilts) initially averaging 23.7 kg BW.
[b]All data are adjusted by covariance for body weight at time of scanning.
[c]No effects of diet or sex × diet interaction for any of the traits ($P > 0.05$).
[d]C = conventional, RR = Roundup Ready.
[e]Effects of sex ($P < 0.01$).

Table 5. Carcass data of barrows fed corn-dehulled soybean meal diets containing conventional or Roundup Ready soybean meal[ab]

	Dehulled soybean meal in diet		
Item	Conventional	Roundup Ready	CV
Final body weight, kg	110.8	113.7	3.30
Hot carcass weight, kg	79.4	81.2	4.10
Hot carcass yield, %	71.6	71.4	1.22
Backfat, cm			
First rib	4.43	4.07	4.62
Last rib[c]	2.45	2.20	2.51
Last lumbar	2.94	2.69	7.65
Avg[c]	3.27	2.98	3.59
10th rib backfat, cm	2.68	2.74	4.37
Longissimus muscle area, cm^2	37.8	35.5	5.62
Carcass fat-free lean, %[d]	48.1	47.3	2.21
Carcass fat-free lean, g/d[d]	302	292	3.81

[a]Five replications of five barrows per pen.
[b]Carcass backfat, longissimus muscle area, and fat-free lean are adjusted by covariance for final body weight.
[c]Effect of diet ($P < 0.05$).
[d]Based on NPPC (2000) equations for carcass fat-free lean.

pigs fed the conventional and Roundup Ready soybean meal diets (Table 7). The trends in lower shear force and higher sensory scores were, in general, associated with the slightly higher fat content of the longissimus muscle from pigs fed the diet containing Roundup Ready soybean meal.

Discussion

Soybean cultivars have been developed that include a single gene that confers tolerance to glyphosate, the active ingredient in Roundup herbicide (Padgette et al., 1995). With the exception of glyphosate tolerance, the composition of the modified cultivar has been demonstrated to be equivalent to the unmodified parental control (Padgette et al., 1996). Our results agree in that we observed no difference in the composition of soybean meal prepared from glyphosate-tolerant and conventional soybeans. Similar results of no substantial compositional effects have been reported for other genetically modified and unmodified seeds, such as insect-resistant (Bt) and conventional corn (Padgette et al., 1996; Sidhu et al., 2000).

Table 6. Chemical composition of loin tissue of barrows fed corn-dehulled soybean meal diets containing conventional or Roundup Ready soybean meal[a]

	Dehulled soybean meal in diet		
Item	Conventional	Roundup Ready	CV
Water, %	72.83	72.50	0.30
Protein, %	23.43	23.31	2.18
Fat, %[c]	3.01	3.40	5.58
Ash, %	1.05	1.05	3.40

[a]Five replications of five barrows per pen.
[b]All data adjusted by covariance for final body weight.
[c]A tendency of a dietary effect ($P = 0.06$).

Recent studies with Bt and non-Bt corn have clearly shown that they are comparable in their nutritional value for dairy cattle (Faust and Miller, 1997; Faust and Spangler, 2000; Folmer et al, 2000b), beef cattle (Russell and Peterson, 1999; Folmer et al., 2000a; Hendrix et al., 2000), sheep (Daenicke et al., 1999), and poultry (Aulrich et al., 1998; Brake and Vlachos, 1998; Halle et al., 1998). It was only recently that similarity in feeding value of the Bt and non-Bt corn types for swine was reported (Stanisiewski et al., 2001; Weber and Richert, 2001). Similarity in the feeding value of glyphosate-tolerant and normal corn for dairy cattle (Donkin et al., 2000; S. S. Donkin, personal communication) and poultry (Sidhu et al., 2000) also have been recently reported.

Short-term studies by Hammond et al. (1996) showed that the feeding value of soybeans for rats, catfish, chickens, and dairy cattle was not altered by genetic incorporation of glyphosate tolerance into the soybeans. Our study now clearly demonstrates that soybean meal prepared from glyphosate-tolerant soybeans (Roundup Ready) is nutritionally equivalent to soybean meal prepared from near-isogenic conventional soybeans for growing-finishing swine and results in a similar eating quality of pork. This is the first study to demonstrate the nutritional bioequivalence of herbicide-tolerant soybeans in this species and to show that the sensory characteristics of pork are unaffected by feeding genetically modified soybean meal.

Ash et al. (2000) were unable to detect the CP4 EPSPS protein in liver, eggs, or feces of hens fed soybean meal from herbicide-tolerant soybeans. Studies are in progress to determine whether the CP4 EPSPS protein or the transgenetic DNA is detectable in tissues

Table 7. Physical and sensory characteristics of pork chops from barrows fed corn-dehulled soybean meal diets containing conventional or Roundup Ready soybean meal[ab]

	Dehulled soybean meal in diet		
Item	Conventional	Roundup Ready	CV
Warner-Bratzler shear force, kg	3.95	3.58	18.80
Cook loss, %	31.97	30.28	14.92
Sensory scores[c]			
Juiciness	5.52	5.58	13.58
Tenderness	5.91	6.10	13.57
Off-Flavor	7.08	7.18	4.58
Flavor intensity	5.74	5.95	6.24
Connective tissue	6.54	6.53	7.18
Overall acceptance	5.80	6.05	10.50

[a]Three replications of five barrows per pen.
[b]None of the differences were significant ($P > 0.05$).
[c]Based on scores of 1 to 8, with 8 being the most desirable.

of the pigs fed the herbicide-tolerant soybeans in our study.

Implications

The results of this study clearly indicated that dehulled soybean meal prepared from genetically modified herbicide-tolerant (Roundup Ready) soybeans is essentially equivalent in composition and nutritional value to dehulled soybean meal prepared from nearly isogenic soybeans for growing-finishing swine. In addition, the eating quality of pork is similar for pigs fed the two types of soybean meal. This study clearly demonstrates that genetic modification of soybeans to make them tolerant to glyphosate herbicide does not affect their nutritional composition or the performance of swine when fed the soybean meal derived from the soybeans.

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