Comparison of yellow dent and NutriDense corn hybrids in swine diets[1,2]

C. W. Hastad*, M. D. Tokach*, R. D. Goodband*[3], J. L. Nelssen*, S. S. Dritz†, J. M. DeRouchey*, and C. L. Jones*

*Department of Animal Sciences and Industry, and †Food Animal Health and Management Center, College of Veterinary Medicine, Kansas State University, Manhattan 66506-0201

ABSTRACT: Two experiments were conducted to verify the feeding value of NutriDense (ND) and NutriDense Low-Phytate (NDLP) corn (Exseed Genetics LLC, BASF Plant Science, Research Triangle Park, NC) relative to that of yellow dent (YD) corn in swine diets. NutriDense corn is a high-protein, high-oil variety, and NDLP is a high-protein, high-oil, low-phytate variety. In Exp. 1, 315 nursery pigs that initially weighed 15.2 kg were used in a 21-d growth assay. Dietary treatments were arranged in a 3 × 3 factorial; main effects were corn source (YD, ND, and NDLP) and added fat (0, 3, or 6%, as-fed basis). Diets were formulated to contain 3.83 g of lysine/Mcal using calculated nutrient values. There were no corn source × fat interactions observed. Pigs fed YD, ND, and NDLP had ADG of 750, 734, and 738 g/d and G:F of 0.64, 0.66, and 0.65, respectively. No differences ($P > 0.10$) in ADG were observed among the three corn sources; however, pigs fed diets containing either ND or NDLP corn had decreased ADFI ($P < 0.02$) and improved G:F ($P < 0.05$) compared with pigs fed diets containing YD corn. Increasing dietary fat increased ADG (727, 746, and 748 g/d; linear, $P < 0.04$) and G:F (0.62, 0.66, and 0.68; linear, $P < 0.01$) and decreased ADFI (linear, $P < 0.01$). Using the NRC (1998) value for ME in YD corn, we calculated the energy value for ND and NDLP based on G:F differences compared with pigs fed YD corn. These data indicated the ME values for ND and NDLP corn are 4.5 and 2.5% greater (3,575 and 3,505 Kcal/kg), respectively, than for YD corn (3,420 Kcal/kg). In Exp. 2, 1,144 gilts (initial BW = 50.1 kg) were used in a commercial research facility to evaluate the effects of corn source (ND and YD) and added fat (0, 3, or 6%, as-fed basis) in a 2 × 3 factorial on pig performance and carcass traits. There was a corn source × fat interaction for ADFI and G:F. Increasing added fat resulted in greater changes in ADFI and G:F in pigs fed YD corn diets compared with those fed ND corn. Feeding ND corn increased ADG (main effect, $P < 0.04$), and greater percentages of added fat increased ADG (main effect; linear, $P < 0.01$). Results of Exp. 2 suggest that ND corn has 5.3% more ME than YD corn. The additional energy provided by ND corn improves G:F in both nursery and grow-finish pigs, and ND corn offers a means of formulating diets more concentrated in energy than YD corn.

Key Words: Corn, Energy, Fat, Nursery Pigs, Pigs

 J. Anim. Sci. 2005. 83:2624–2631

Introduction

Genetic selection and modification have provided new varieties of cereal grains that have enhanced nutrient profiles for use in livestock diets. These improvements have resulted in corn varieties with higher concentrations of nutrients such as oil and AA. Previous studies in pigs have demonstrated effective utilization of these corn varieties (Adams and Jensen, 1987; Han et al., 1987; Adeola and Bajjalieh, 1997). Diets using corn with enhanced nutritional traits can improve feed efficiency, decrease nutrient waste, and potentially be cost-effective to swine producers.

NutriDense (**ND**) corn (Exseed Genetics LLC, BASF Plant Science, Research Triangle Park, NC) is nutritionally enhanced to provide greater nutrient density than conventional yellow dent (**YD**) corn. Specifically, it contains approximately 30% more lysine, 50% more total sulfur-containing AA, 18% more threonine, and 6% more ME than normal corn. A second genetically modified low-phytate corn (NutriDense Low-Phytate; **NDLP**) contains approximately 75% available P (Ex-

[1]Contribution No. 04-248-J from the Kansas Agric. Exp. Stn., Manhattan.

[2]Appreciation is expressed to Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC, for providing the corn and partial financial support and to New Horizons Farms, Pipestone, MN, for providing the animals and facilities used in Exp. 2.

[3]Correspondence: 242 Weber Hall (phone: 785-532-1228; fax: 785-532-7059; e-mail: Goodband@ksu.edu).

Received September 22, 2004.

Accepted July 14, 2005.

Table 1. Analyzed chemical composition of corn sources and values (in parentheses) used for diet formulation with NutriDense and NutriDense Low-Phytate (LP) corns [a,b]

Item	Yellow dent corn	NutriDense	NutriDense LP
DM, %	85.21	(88.0) 87.39	(88.0) 85.38
Fat, %	3.48	(4.8) 4.56	(4.8) 4.41
CP, %	7.39	(10.0) 9.33	(10.0) 7.71
GE, kcal/kg	3,919	4,051	4,125
Crude fiber, %	2.38	(2.0) 2.26	(2.0) 2.17
Ca, %	0.02	(0.01) 0.06	(0.01) 0.04
Total P, %	0.24	(0.32) 0.28	(0.32) 0.28
Mg, %	0.10	(0.13) 0.11	(0.13) 0.10
K, %	0.32	(0.35) 0.32	(0.35) 0.28
AA, %			
Arginine	0.36	(0.52) 0.46	(0.52) 0.42
Cysteine	0.19	(0.23) 0.24	(0.25) 0.20
Histidine	0.22	(—) 0.28	(—) 0.25
Isoleucine	0.26	(0.41) 0.35	(0.41) 0.28
Leucine	0.92	(1.35) 1.25	(1.35) 0.89
Lysine	0.23	(0.31) 0.28	(0.31) 0.27
Methionine	0.16	(0.21) 0.22	(0.24) 0.19
Threonine	0.27	(0.34) 0.33	(0.38) 0.29
Tryptophan	0.06	(0.07) 0.07	(0.07) 0.06
Valine	0.38	(0.55) 0.47	(0.56) 0.41

[a]Nutrient values are reported on an as-fed basis and represent the mean of two samples of yellow dent and NutriDense corn and one sample of NutriDense LP corn (Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC).
[b]Values used in diet formulation using yellow dent corn were from NRC (1998).

Table 2. Diet composition for Exp. 1 (as-fed basis)[a]

	Corn source								
	Yellow dent			NutriDense			NutriDense Low-Phytate		
Item	0%[b]	3%	6%	0%	3%	6%	0%	3%	6%
Ingredient, %									
Corn source	62.79	57.61	52.46	62.17	57.04	52.02	61.64	56.57	51.55
Soybean meal, 46.5% CP	33.38	35.55	37.68	34.13	36.24	38.25	35.11	37.12	39.13
Choice white grease	—	3.00	6.00	—	3.00	6.00	—	3.00	6.00
Monocalcium phosphate, 21% P	1.50	1.50	1.50	1.30	1.30	1.30	0.90	0.95	0.95
Limestone	0.95	0.95	0.95	1.05	1.05	1.05	1.00	1.00	1.00
Antibiotic[c]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[d]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[e]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-Lysine HCl	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-Methionine	0.03	0.04	0.06	—	0.02	0.03	—	0.02	0.03
Calculated analysis									
Lysine, %	1.25	1.30	1.35	1.30	1.35	1.40	1.33	1.38	1.42
ME, kcal/kg	3,276	3,410	3,545	3,408	3,532	3,655	3,485	3,602	3,721
CP, %	20.9	21.4	22.0	22.1	22.6	23.0	22.5	22.9	23.3
Ca, %	0.77	0.78	0.78	0.76	0.77	0.77	0.67	0.69	0.69
P, %	0.72	0.72	0.72	0.71	0.71	0.70	0.63	0.64	0.63
Available P, %	0.39	0.39	0.40	0.39	0.39	0.39	0.39	0.39	0.39
Lysine:calorie, g/Mcal	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82

[a]Diet composition was calculated using NRC (1998) values for all ingredients, except NutriDense corn sources, for which data were provided by the supplier (Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC).
[b]Percentages represent added fat.
[c]Provided 55 mg of Carbadox/kg.
[d]Vitamin premix provided per kilogram of diet: 11,023 IU of vitamin A, 1,653.45 IU of vitamin D_3, 44.09 IU of vitamin E, 4.41 mg of vitamin K (MPB 100%), 0.04 mg of B_{12}, 9.92 mg of riboflavin, 33.07 mg of pantothenic acid, and 55.12 mg of niacin.
[e]Trace mineral premix provided per kilogram of diet: 165 ppm of Zn from Zn oxide, 165 ppm of Fe from Fe sulfate, 40 ppm of Mn from Mn oxide, 16.5 ppm of Cu from Cu sulfate, 0.30 ppm of I from Ca iodate, and 0.30 ppm of Se from Na selenite.

Table 3. Composition of diet fed from d 0 to 14 of Exp. 2 (as-fed basis)[a]

	Corn source					
	Yellow dent[b]			NutriDense		
Item	0%	3%	6%	0%	3%	6%
Ingredient, %						
Corn source	76.01	71.32	66.91	76.12	71.40	66.94
Soybean meal, 46.5% CP	21.51	23.20	24.77	21.42	23.20	24.82
Choice white grease	—	2.95	5.75	—	2.95	5.75
Monocalcium phosphate, 21% P	0.91	0.96	1.01	0.73	0.78	0.84
Limestone	0.90	0.90	0.89	1.02	1.00	0.98
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix[c]	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix[d]	0.08	0.08	0.08	0.08	0.08	0.08
Calculated analysis						
Lysine, %	1.16	1.20	1.24	1.20	1.24	1.28
Lysine:calorie, g/Mcal	3.50	3.50	3.50	3.50	3.50	3.49
ME, kcal/kg	3,316	3,435	3,547	3,435	3,547	3,651
CP, %	19.13	19.59	19.97	20.28	20.65	20.95
Ca, %	0.69	0.70	0.71	0.68	0.69	0.70
P, %	0.63	0.64	0.64	0.62	0.63	0.64
Ca:P	1.10	1.10	1.10	1.10	1.10	1.10

[a]Diet composition was calculated using NRC (1998) values for all ingredients, except NutriDense corn sources, for which data were provided by the supplier (Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC).

[b]The added fat designations of 0, 3, and 6% represented an average inclusion of the diets used in the phase-feeding program.

[c]Trace mineral premix provided per kilogram of diet: 110 ppm of Zn from Zn oxide, 110 ppm of Fe from Fe sulfate, 26 ppm of Mn from Mn oxide, 11 ppm of Cu from Cu sulfate, 0.20 ppm of I from Ca iodate, and 0.20 ppm of Se from Na selenite.

[d]Vitamin premix provided per kilogram of diet: 7,056 IU of vitamin A, 1,058 IU of vitamin D_3, 28 IU of vitamin E, 2.8 mg of vitamin K (MPB 100%), 0.03 mg of B_{12}, 6.3 mg of riboflavin, 21 mg of pantothenic acid, and 35 mg of niacin.

seed Genetics LLC, personal communication) compared with YD corn, which has 14% available P (NRC, 1998).

Peter et al. (2001) determined the available P content of ND and NDLP corn and the energy value of these hybrids compared with normal corn. They confirmed the predicted value of most nutrients, with the exception of the energy value for the low-phytate corn. NutriDense and NDLP were expected to contain approximately 6 and 9% more energy than normal YD corn, respectively; however, the experimental results indicated that the advantages were approximately 6.5 and 4%, respectively.

Although ND and NDLP corns should have greater nutritional value than YD corn, this has not been verified in large-scale growth experiments. Therefore, the primary purpose of these experiments was to determine whether ND and NDLP have greater feeding value than YD corn as assessed by large-scale growth experiments. A second objective was to determine whether diets with higher energy density (ND corn and fat compared with YD corn plus fat) could be efficiently used to improve finishing pig growth performance.

Materials and Methods

All experimental procedures used in these studies were approved by the Kansas State University Animal Care and Use Committee.

In Exp. 1, a total of 315 barrows (Line 327 sire × C22 dams; PIC, Franklin, KY), initially 15.2 kg and 36 ± 2 d of age, were used in a 21-d growth assay. Pigs were blocked by BW and allotted to one of nine treatments. There were five pigs per pen and seven pens per treatment. Pigs were housed in the Kansas State University Segregated Early Weaning facility. Each pen was 1.2 m × 1.2 m and contained one stainless steel self-feeder and one nipple water unit to provide ad libitum access to feed and water. Temperature initially was maintained at 23 ± 3°C and was decreased to maintain comfort as the pigs grew.

The nine diets included three corn sources: YD, ND, and NDLP, each with increasing added fat (0, 3, and 6% choice white grease, as-fed basis). Nutrient values for ND and NDLP corn were provided by the supplier and used in diet formulation (Table 1). The energy values for ND and NDLP corn were assumed to be 6 and 9% greater than the value of YD corn in diet formulation (Peter et al., 2001). Samples of each corn source also were analyzed for chemical and AA composition (Table 1). Nutrient values from NRC (1998) were used for YD corn. Based on the calculated chemical compositions, all experimental diets were balanced to maintain a constant lysine-to-calorie ratio and available P level (Table 2). Pigs and feeders were weighed every 7 d to determine ADG, ADFI, and G:F.

Table 4. Composition of diet fed from d 14 to 42 of Exp. 2 (as-fed basis)[a]

	Corn source					
	Yellow dent[b]			NutriDense		
Item	0%	3%	6%	0%	3%	6%
Ingredient, %						
Corn source	68.65	64.09	59.98	68.41	63.92	59.87
Soybean meal, 46.5% CP	28.60	30.41	31.99	28.91	30.66	32.17
Choice white grease	—	2.70	5.20	—	2.70	5.20
Monocalcium phosphate, 21% P	1.13	1.18	1.21	0.96	1.01	1.07
Limestone	0.95	0.95	0.95	1.05	1.04	1.03
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix[c]	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix[d]	0.08	0.08	0.08	0.08	0.08	0.08
Calculated analyses						
Lysine, %	0.97	1.00	1.04	1.00	1.04	1.08
Lysine:calorie, g/Mcal	2.90	2.90	2.90	2.90	2.90	2.91
Valine:lysine, %	0.81	0.80	0.79	0.90	0.88	0.87
ME, kcal/kg	3,327	3,459	3,582	3,459	3,582	3,702
CP, %	16.46	16.85	17.21	17.59	17.93	18.24
Ca, %	0.61	0.62	0.63	0.60	0.61	0.62
P, %	0.55	0.56	0.57	0.54	0.55	0.56
Ca:P	1.10	1.10	1.10	1.10	1.10	1.10

[a]Diet composition was calculated using NRC (1998) values for all ingredients, except NutriDense corn sources, for which data were provided by the supplier (Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC).

[b]The added fat designations of 0, 3, and 6% represented an average inclusion of the diets used in the phase-feeding program.

[c]Trace mineral premix provided per kilogram of diet: 110 ppm of Zn from Zn oxide, 110 ppm of Fe from Fe sulfate, 26 ppm of Mn from Mn oxide, 11 ppm of Cu from Cu sulfate, 0.20 ppm of I from Ca iodate, and 0.20 ppm of Se from Na selenite.

[d]Vitamin premix provided per kilogram of diet: 7,056 IU of vitamin A, 1,058 IU of vitamin D_3, 28 IU of vitamin E, 2.8 mg of vitamin K (MPB 100%), 0.03 mg of B_{12}, 6.3 mg of riboflavin, 21 mg of pantothenic acid, and 35 mg of niacin.

Experiment 2 was conducted at a commercial research facility in Southwestern Minnesota. The facility is made up of four individual barns, each 12.5 m × 76.2 m, with forty-eight 3.05-m × 5.49-m pens. Each pen contained one 4-hole dry feeder and a one-cup water unit. Each curtain-sided barn had a deep pit with completely slatted floors and operated on natural ventilation during the summer and mechanically assisted ventilation during the winter. Forty-two pens of gilts (Line 327 sire × C22 dams; PIC) were blocked by BW (initially 50.1 kg) and allotted to one of six dietary treatments. There were 27 or 28 pigs per pen and seven pens per treatment.

Two corn sources (YD or ND), each with increasing added fat (choice white grease), were used in Exp. 2. The same nutrient values for Exp. 1 were used for ND, except for the energy content, which was based on the calculated value from the results of Exp. 1. The NRC (1998) nutrient values were used for YD corn. A treatment structure similar to that described by Webster et al. (2002) was used. The first treatment diet contained YD corn and no added fat (Tables 3, 4, and 5). The second dietary treatment contained ND corn. Based on the calculated added energy provided by the ND corn, fat (2.7 to 3.2%, based on phase) was added to a YD corn-based diet to equal the energy content of the ND corn diet. This percentage of added fat (2.7 to 3.2%, based on phase) was then added to a ND corn-based diet to provide the fourth dietary treatment. Fat (5.2 to 6.2%, based on phase) was then added to a YD corn-based diet to equal the energy content of the second ND corn diet. In the sixth diet, this percentage of fat (5.2 to 6.2%, based on phase) was then added a ND corn-based diet to complete the treatment structure.

All treatments were formulated to maintain equal lysine:calorie and Ca:total P within each phase. Diet phase changes occurred on d 14 and 42. Pig and feeder weights were measured every 14 d to calculate ADG, ADFI, and G:F. At the end of the experiment, pigs from each pen were individually tattooed and shipped to a commercial processing plant (Swift, Inc., Worthington, MN), where standard carcass criteria (loin and fat depth, HCW, dressing percentage, lean percentage, and fat-free-lean index) were measured.

Statistical Analyses. In both experiments, treatments were arranged in a randomized complete block design. Analysis of variance was conducted on all data using the MIXED procedure of SAS (Version 8.01), with a Kenward and Roger error correction for df (SAS Inst., Inc., Cary, NC). Pen was the experimental unit. The

Table 5. Composition of diet fed from d 42 to 78 for Exp. 2 (as-fed basis)[a]

	Corn source					
	Yellow dent[b]			NutriDense		
Item	0%	3%	6%	0%	3%	6%
Ingredient, %						
Corn source	80.99	76.16	71.69	81.28	76.49	72.01
Soybean meal, 46.5% CP	16.98	18.59	20.03	16.80	18.35	19.81
Choice white grease	—	3.20	6.20	—	3.20	6.20
Monocalcium phosphate, 21% P	0.59	0.63	0.67	0.37	0.43	0.47
Limestone	0.85	0.84	0.82	0.96	0.94	0.93
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine HCl	0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix[c]	0.08	0.08	0.08	0.08	0.08	0.08
Vitamin premix[d]	0.06	0.06	0.06	0.06	0.06	0.06
Calculated analyses						
Lysine, %	0.80	0.84	0.87	0.84	0.87	0.90
Lysine:calorie, g/Mcal	2.40	2.40	2.40	2.40	2.40	2.40
ME, kcal/kg	3,344	3,488	3,622	3,488	3,622	3,750
Protein, %	14.78	15.12	15.41	15.94	16.18	16.41
Ca, %	0.51	0.52	0.52	0.50	0.51	0.51
P, %	0.47	0.47	0.48	0.45	0.46	0.47
Ca:P	1.10	1.10	1.10	1.10	1.10	1.10

[a]Diet composition was calculated using NRC (1998) values for all ingredients, except NutriDense corn sources, for which data were provided by the supplier (Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC).
[b]The added fat designations of 0, 3, and 6% represented an average inclusion of the diets used in the phase-feeding program.
[c]Trace mineral premix provided per kilogram of diet: 88 ppm of Zn from Zn oxide, 88 ppm of Fe from Fe sulfate, 21 ppm of Mn from Mn oxide, 8.8 ppm of Cu from Cu sulfate, 0.15 ppm of I from Ca iodate, and 0.15 ppm of Se from Na selenite.
[d]Vitamin premix provided per kilogram of diet: 5,292 IU of vitamin A, 794 IU of vitamin D_3, 21 IU of vitamin E, 2.1 mg of vitamin K (MPB 100%), 0.02 mg of B_{12}, 4.3 mg of riboflavin, 16 mg of pantothenic acid, and 26 mg of niacin.

statistical model included treatment as a fixed effect and block as a random effect. After testing for interactions between corn source and fat level, linear and quadratic polynomial contrasts were used to determine the effects of increasing fat. Single df contrasts were used to determine differences among corn sources.

Table 6. Effect of corn source and added fat on growth performance of nursery pigs (Exp. 1)[a]

	Corn source								
	Yellow dent			NutriDense[b]			NutriDense Low-Phytate (LP)[b]		
Item	0%[c]	3%	6%	0%	3%	6%	0%	3%	6%
ADG, g	731	760	759	714	747	741	737	733	743
ADFI (as-fed basis), g	1,199	1,169	1,130	1,135	1,121	1,081	1,167	1,127	1,086
G:F	0.61	0.65	0.67	0.63	0.67	0.69	0.63	0.65	0.68
Energy efficiency[d]	5,373	5,250	5,273	5,411	5,299	5,332	5,513	5,537	5,439

				Corn source			Added fat		
	Added fat	Corn source	Added fat × Corn source	Yellow dent vs. NutriDense	Yellow dent vs. NutriDense LP	NutriDense vs. NutriDense LP	Linear	Quadratic	SE
	P-value								
ADG, g	0.07	0.24	0.55	0.10	0.22	0.69	0.04	0.28	15.1
ADFI (as-fed basis), g	<0.01	0.01	0.97	<0.01	0.02	0.39	<0.01	0.67	29.8
G:F	<0.01	0.02	0.59	0.01	0.05	0.43	<0.01	0.50	0.01
Energy efficiency	0.19	<0.01	0.70	0.32	<0.01	<0.01	0.09	0.51	71.0

[a]315 pigs (five pigs per pen and seven pens per treatment) with an average initial BW of 15.2 kg.
[b]Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC.
[c]Percentages represent added fat.
[d]Calculated as energy required (kcal) per kilogram of gain.

Results

In Exp. 1, there were no differences ($P > 0.10$) in ADG among corn sources (Table 6); however, ADFI decreased ($P < 0.02$) and G:F increased ($P < 0.05$) for pigs fed ND or NDLP corn compared with pigs fed YD corn. There were no differences among pigs fed either ND or NDLP corn varieties for any of the response criteria. Increasing dietary fat increased (linear, $P < 0.04$) ADG, decreased (linear, $P < 0.01$) ADFI, and improved (linear, $P < 0.001$) G:F. Data from the experiment were then used to calculate the relative energy value for ND and NDLP corn compared with YD corn. Based on the average corn content of the YD diets and their respective G:F, the quantity of corn required for 1 kg of gain was calculated. Kilocalories per kilogram of gain were then calculated by multiplying the quantity of corn per kilogram of gain by 3,420 Kcal (NRC, 1998). By using this measure for the YD corn diets, the ME values of the ND and NDLP corn were calculated to be 4.5 and 2.5% greater than those for the YD diets.

In Exp. 2, pigs fed ND corn had increased ($P < 0.04$) ADG compared with those fed YD corn (Table 7). Greater percentages of added fat also increased ADG ($P < 0.01$); however, a corn source × added fat interaction was observed for ADFI and G:F. This interaction was the result of increasing added fat, resulting in a greater decrease in ADFI and improvement in G:F for pigs fed YD corn than for those fed ND corn.

There were no corn source × added fat interactions observed for carcass criteria (Table 8). Corn source had no effect on most carcass criteria, with the exception of carcass dressing percentage. Pigs fed YD corn had greater ($P < 0.05$) dressing percentage (75.33 vs. 74.87) than those fed ND corn. Greater percentages of added fat increased (quadratic, $P < 0.04$) final weight and carcass weight, and it tended (linear, $P = 0.09$) to decrease dressing percentage. Increasing added fat had no effect on backfat, fat-free lean index, loin depth, and percentage lean.

Similar to Exp. 1, using NRC (1998) values for ME of YD corn, we calculated an energetic efficiency of gain (9,568, 9,033, and 9,190 Kcal of ME/kg of gain) for YD corn diets with 0, 3, and 6% added fat, respectively. We then calculated what the energy content of the ND corn would need to be to provide an identical energetic efficiency. Based on these calculations, the ME value of ND corn is 5.3% greater than that of YD corn.

Discussion

Analysis of our data indicated that ME was approximately 4.5 and 2.5% greater for ND and NDLP corn varieties, respectively, than for YD corn. These results agree with those of Peter et al. (2001), indicating that ND and NDLP corn varieties have a greater ME concentration than YD corn. Peter et al. (2001) determined that ME was increased by 6.5 and 4% for ND and NDLP corn, respectively, compared with YD corn. The differ-

Table 7. Effects of corn source and added fat on growth performance of growing-finishing pigs (Exp. 2)[a]

	Corn source						*P*-value				Added fat *P*-value	
	Yellow dent			NutriDense[b]								
Item	0%[c]	3%	6%	0%	3%	6%	Added fat	Corn source	Added fat × corn source	SE	Linear	Quadratic
ADG, g	815	849	829	829	846	862	0.01	0.04	0.13	9.7	0.01	0.08
ADFI (as-fed basis), g	2,336	2,210	2,119	2,214	2,172	2,135	<0.01	0.004	0.004	25.0	<0.01	0.55
G:F	0.35	0.38	0.39	0.37	0.39	0.40	<0.01	<0.01	0.04	0.004	<0.01	0.03
Energy efficiency[d]	9,558	9,033	9,190	9,273	9,230	9,211	<0.01	0.75	0.03	104.5	<0.02	0.03

[a]1,144 pigs (27 pigs per pen and seven pens per treatment) with an average initial BW of 50.1 kg.
[b]Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC.
[c]Percentages represent added fat. Because the amount of corn varied in the three dietary phases fed throughout the study, the percentage of fat added to achieve the desired energy concentrations varied but averaged 3 and 6% for the entire study.
[d]Calculated as energy required (kcal) per kilogram of gain.

Table 8. Effects of corn source and added fat on carcass traits of growing-finishing pigs (Exp. 2)[a]

	Corn source						P-value				Added fat P-value	
	Yellow dent			NutriDense[b]								
Item	0%[c]	3%	6%	0%	3%	6%	Added fat	Corn source	Added fat × corn source	SE	Linear	Quadratic
Final BW, kg	113.87	116.31	115.65	114.55	116.83	116.98	0.003	0.140	0.82	1.045	0.004	0.03
Backfat, mm	14.7	15.3	15.3	14.6	15.4	15.1	0.08	0.77	0.84	0.332	0.11	0.13
FFLI[d]	51.04	50.92	50.83	51.11	50.83	51.06	0.36	0.54	0.57	0.149	0.39	0.28
Loin depth, mm	55.6	56.4	55.7	54.8	55.0	55.6	0.69	0.18	0.68	0.753	0.53	0.61
Lean, %	56.58	56.31	56.19	56.53	56.06	56.34	0.18	0.77	0.66	0.221	0.19	0.23
Yield, %	75.52	75.61	74.85	75.03	74.85	74.73	0.19	0.05	0.51	0.003	0.09	0.39
Carcass wt, kg	86.24	88.00	86.72	86.07	87.43	88.25	0.01	0.51	0.11	0.791	0.01	0.04

[a]1,144 pigs (27 pigs per pen and seven pens per treatment) with an average initial BW of 50.1 kg.
[b]Exseed Genetics, LLC, BASF Plant Science, Research Triangle Park, NC.
[c]Percentages represent added fat. Because the amount of corn varied in the three dietary phases fed throughout the study, the percentage of fat added to achieve the desired energy concentrations varied but averaged 3 and 6% for the entire study.
[d]Fat-free lean index.

ences between our results and theirs may be because the YD corn used in our experiment had greater energy and, thus, a relatively smaller difference was calculated. This idea is supported by the results of Fent et al. (2000), who showed that ME content of corn varies. Another explanation may be differences in the fat content among the ND corn used in the different experiments, which is generally 1 to 2 percentage units greater than in YD corn. In addition, we used the NRC (1998) value for YD corn rather than the analyzed value used by Peter et al. (2001).

Another factor to consider in interpreting our results is the fact that in diet formulation, we increased other nutrients, in particular lysine and other AA to maintain a calorie to lysine ratio. It could be that if the pigs were above their energy requirement, improvements in growth could have been due to increased AA or other nutrient intake. It has been shown, however, that young growing pigs are generally in an energy-dependent phase of growth and that appetite limits energy intake for maximum protein deposition (Campbell and Taverner, 1988). Recent studies also have shown that finishing pigs reared in commercial environments such as those used in this experiment will have lower feed intake (30%) and show a greater response to dietary energy than pigs housed in a university research environment (De La Llata et al., 2001; Hastad et al., 2004).

Spencer et al. (2000) and Veum et al. (2001) reported that low-phytic acid corn increased the availability of P and other nutrients. Corn with this trait would be predicted to have a greater concentration of energy because of changes in the chemical composition of the kernel (C. M. Peter, Exseed Genetics LLC, personal communication). Results of this experiment agree with those of Peter et al. (2001), who demonstrated that NDLP corn has more energy than YD corn.

A second goal of our study was to evaluate the ability to achieve higher energy diets with ND corn varieties compared with YD corn plus added fat. In both nursery and finishing studies, we observed linear increases in ADG through the highest levels of added fat with all corn varieties. This finding indicates that higher dietary energy density and further improvements in ADG can be achieved with ND corn and added fat compared with YD corn plus added fat. Nursery trials conducted with high-oil corn by Bergstrom et al. (1997) and DeCamp et al. (1998) also showed improvements in feed conversion. In growing-finishing pigs, Kendall et al. (1999) showed a similar improvement in feed efficiency when YD corn was replaced with a high-oil corn hybrid. In a corn and soybean meal-based diet, 5 to 6% fat is commonly the maximum added. Fat additions >5 to 6% typically result in bridging and other feed-handling problems. Thus, the ND corn may provide an option to feed an even higher energy density diet than can be achieved with YD corn plus added fat.

Implications

Genetic selection and modification have provided new varieties of cereal grains that have enhanced nutrient profiles for use in livestock diets. NutriDense corn is a high-protein, high-oil variety, and NutriDense-Low Phytate is a high-protein, high-oil, low-phytate variety. By conducting nursery trials and then using energetic efficiency of gain of pigs fed yellow dent corn diets, the metabolizable energy values of the NutriDense and NutriDense-Low Phytate corn were calculated to be 4.5 and 2.5% greater than those of yellow dent corn. In finishing pigs, the metabolizable energy content was calculated to be 5.3% greater than that of yellow dent corn. The greater energy content of NutriDense corns resulted in improved feed efficiency and offers a means of formulating diets more concentrated in energy than diets based on yellow dent corn.

Literature Cited

Adams, K. L., and A. H. Jensen. 1987. High fat maize in diets for pigs and sows. Anim. Feed Sci. Technol. 17:201–208.

Adeola, O., and N. L. Bajjalieh. 1997. Energy concentration of high oil corn varies for pigs. J. Anim. Sci. 75:430–436.

Bergstrom, J. R., C. J. Samland, J. L. Nelssen, M. D. Tokach, and R. D. Goodband. 1997. The effects of high oil corn and fat level on nursery pig growth performance. J. Anim. Sci. 75:(Suppl. 1):164. (Abstr.)

Campbell, R. G., and M. R. Taverner. 1988. Genotype and sex effects on the relationship between energy intake and protein deposition in growing pigs. J. Anim. Sci. 66:676–686.

DeCamp, S. A., B. T. Richert, T. R. Cline, and J. W. Frank. 1998. Evaluating high oil corn and normal corn as energy sources in nursery pig diets. J. Anim. Sci. 76:(Suppl. 1):632. (Abstr.)

De La Llata, M., S. S. Dritz, M. D. Tokach, R. D. Goodband, J. L. Nelssen, and T. M. Loughin. 2001. Effects of dietary fat on growth performance and carcass characteristics of growing-finishing pigs reared in a commercial environment. J. Anim. Sci. 79:2643–2650.

Fent, R. W., S. D. Carter, B. W. Senne, and M. J. Rincker. 2000. Determination of the metabolizable energy concentrations of three corn hybrids fed to growing pigs. 2000 OSU Animal Science Research Report. Available: http://www.ansi.okstate.edu/research/2000rr/23.htm. Accessed Jan. 14, 2004.

Han, Y., C. M. Parsons, and D. E. Alexander. 1987. Nutritive value of high oil corn for poultry. Poult. Sci. 66:678–685.

Hastad, C. W., S. S. Dritz, M. D. Tokach, R. D. Goodband, J. L. Nelssen, J. M. DeRouchey, R. D. Boyd, and M. E. Johnston. 2004. Phosphorus requirements of grow-finish pigs reared in a commercial environment. J. Anim. Sci. 82:2945–2952.

Kendall, D. C., K. A. Bowers, B. T. Richert, and T. R. Cline. 1999. Evaluation of high-oil corn feeding strategies for grow-finish pigs. J. Anim. Sci. 77:(Suppl. 1):169. (Abstr.)

NRC. 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.

Peter, C. M., T. M. Parr, and D. H. Baker. 2001. Digestible and metabolizable energy values of nutritionally-enhanced corn hybrids for growing pigs. J. Anim. Sci. 79(Suppl. 2):236. (Abstr.)

Spencer, J. D., G. L. Allee, and T. E. Sauber. 2000. Growing-finishing performance and carcass characteristics of pigs fed normal and genetically modified low-phytate corn. J. Anim. Sci. 78:1529–1536.

Veum, T. L., D. R. Ledoux, V. Raboy, and D. S. Ertl. 2001. Low-phytic acid corn improves nutrient utilization for growing pigs. J. Anim. Sci. 79:2873–2880.

Webster, M. J., R. D. Goodband, M. D. Tokach, J. L. Nelssen, S. S. Dritz, J. C. Woodworth, M. De la Llatta, and N. W. Said. 2002. Evaluating processing temperature and feeding value of extruded-expelled soybean meal on nursery and finishing pig growth performance. J. Anim. Sci. 81:2032–2040.