Evaluation of NutriDense low-phytate corn and added fat in growing and finishing swine diets[1,2]

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ABSTRACT: Two experiments were conducted to evaluate the effects of NutriDense low-phytate corn in conjunction with increasing added dietary fat on growing and finishing pig performance. Diets in both experiments were corn-soybean meal-based, with yellow dent or NutriDense low-phytate corn and 0, 3, or 6% added choice white grease arranged in a 2 × 3 factorial design. There were 25 to 28 pigs per pen and 7 pens (replications) per treatment in both experiments. In Exp. 1, a total of 1,162 gilts with an initial BW of 44.6 kg were used in a 28-d growth study. A constant true ileal digestible (TID) Lys:ME ratio of 2.80 g/Mcal and available P:ME ratio of 0.90 g/Mcal were maintained in all treatment diets. Overall (d 0 to 28), there were no corn source × added fat interactions ($P \geq 0.79$). Regardless of corn source, ADG and G:F increased (linear, $P = 0.03$) with increasing added fat. There were no differences ($P \geq 0.34$) in pig growth performance between those fed NutriDense low-phytate or yellow dent corn. In Exp. 2, a total of 1,128 gilts with an initial BW of 81.6 kg were used in a 28-d growth study. A constant TID Lys:ME ratio of 2.15 g/Mcal of ME and available P:ME ratio of 0.75 g/Mcal were maintained in all treatment diets. Overall (d 0 to 28), there was a tendency ($P = 0.07$) for a corn source × added fat interaction for G:F, which can be explained by the improved G:F in pigs fed yellow dent corn only when 6% fat was added to the diet, whereas G:F was improved at both 3 and 6% added fat in pigs fed NutriDense low-phytate corn. There were no differences ($P \geq 0.18$) in growth performance between pigs fed NutriDense low-phytate or yellow dent corn. These results indicate that increasing added fat improved growth performance regardless of the corn source. In addition, growth performance was similar for pigs fed NutriDense low-phytate or yellow dent corn.

Key words: growth, low-phytate corn, swine, yellow dent corn

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INTRODUCTION

Improvements in genetic selection have resulted in new varieties of corn with greater concentrations of energy and other nutrients, such as AA, than conventional yellow dent corn. In addition to these improvements, some varieties have decreased concentrations of phytate P compared with yellow dent corn. Modified corn with improved nutrient content has been successfully fed to swine (Adams and Jensen, 1987; Adeola and Bajjalieh, 1997; O'Quinn et al., 1999) and poultry (Han and Parsons, 1987). One such variety is NutriDense low-phytate corn (BASF Plant Science, Research Triangle Park, NC) that is nutritionally enhanced to provide greater nutrient density than conventional yellow dent corn. NutriDense low-phytate corn also contains approximately 50% available P (BASF Plant Science) compared with yellow dent corn, which has 14% available P (NRC, 1998).

Hastad et al. (2005) and Peter et al. (2001) calculated NutriDense low-phytate corn to have 2.5 and 4% more ME than yellow dent corn, respectively. Although research has shown that NutriDense low-phytate corn contains a greater energy content than yellow dent corn, research has not evaluated its effects when fed in combination with increasing levels of added dietary fat.

NutriDense low-phytate corn also contains 19% more lysine, 5% more sulfur AA, and 6% more threonine than

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Table 1. Analyzed chemical composition of corn sources and values used in diet formulation (as-fed basis)[1]

	Yellow dent corn[2]		NutriDense low-phytate corn[3]	
Item	NRC	Analyzed	BASF	Analyzed
DM, %	89.00	88.55	89.00	88.65
GE, kcal/kg	—	3,905	—	3,753
ME, kcal/kg	3,420	—	3,591	—
Oil, %	3.90	3.52	4.80	3.90
CP, %	8.50	7.06	10.00	9.65
Ca, %	0.03	0.02	0.03	0.03
P, %	0.28	0.17	0.32	0.30
Available P,[4] %	0.04	—	0.16	—
Lys, %	0.26	0.25	0.32	0.32
Ile, %	0.28	0.24	0.41	0.36
Leu, %	0.99	0.82	1.35	1.25
Met, %	0.17	0.14	0.21	0.18
Met and Cys, %	0.36	0.29	0.43	0.38
Thr, %	0.29	0.25	0.34	0.31
Trp, %	0.06	0.05	0.08	0.06
Val, %	0.39	0.33	0.55	0.49

[1]Analyzed energy and nutrient values represent the mean of a single sample analyzed in duplicate.
[2]The values reported by the NRC (1998) were used in diet formulation.
[3]BASF Plant Science, Research Triangle Park, NC. The values provided by the supplier were used in diet formulation.
[4]Availability of the P in NutriDense low-phytate corn was estimated to be 50%.

normal yellow dent corn (Hastad et al., 2005; BASF Plant Science). The increased AA concentrations may also be expected to have greater digestibility because Pedersen et al. (2007) observed NutriDense corn, a corn variety with traits similar to NutriDense low-phytate corn, to have greater AA digestibility than yellow dent corn.

Thus, the objectives of these large-scale growing and finishing pig experiments were to 1) determine the feeding value of NutriDense low-phytate corn compared with yellow dent corn; and 2) determine potential interactions with corn type and added dietary fat.

MATERIALS AND METHODS

General

The experimental protocols used in these studies were approved by the Kansas State University Institutional Animal Care and Use Committee.

Two experiments were conducted in the winter at a commercial research facility in southwestern Minnesota. The facility was composed of 4 individual barns (12.5 × 76.2 m each), and each barn had forty-eight 3.05 × 5.49-m pens. All pens contained one 4-hole, dry self feeder, and one cup waterer to allow for ad libitum access to feed and water. Each barn had completely slatted floors and a deep pit for manure storage. The barns were curtain sided and operated on natural ventilation during the summer and mechanically assisted ventilation during the winter.

In both 28-d studies, pens of pigs (Line 1050 × 337, PIC, Franklin, KY; 24 to 26 pigs per pen) were weighed and assigned randomly to 6 dietary treatments, with 7 pens per treatment in 1 barn on the research site. Experiment 1 used a total of 1,162 gilts, with an initial BW of 44.6 kg, and Exp. 2 used a total of 1,128 gilts, with an initial BW of 81.6 kg. Each pen contained 25 to 28 pigs. All dietary treatments were formulated using nutrient values reported by the NRC (1998) and provided by BASF Plant Science (Table 1). Dietary treatments in both experiments were arranged in a 2 × 3 factorial, with the main effects of corn variety (NutriDense low-phytate corn or yellow dent corn) and added fat (0, 3, or 6% choice white grease; Tables 2 and 3). A constant true ileal digestible (**TID**) Lys:ME ratio of 2.80 g/Mcal for Exp. 1 and 2.15 g/Mcal for Exp. 2 was maintained in all treatment diets. Because the availability of the P in NutriDense low-phytate corn was estimated to be 50%, NutriDense low-phytate corn diets contained less inorganic supplemental P. The available P:ME ratio was maintained at 0.90 g/Mcal in Exp. 1 and 0.75 g/Mcal in Exp. 2. NutriDense low-phytate corn and yellow dent corn samples were chemically analyzed for DM, GE, CP, AA, Ca, P, and ether extract (AOAC, 1995; Table 1). Pigs and feeders were weighed on d 0, 14, and 28 to determine ADG, ADFI, and G:F. All diets were fed in meal form with corn ground by a roller mill to approximately 700 μm.

Statistical Analysis

Data from both experiments were analyzed as a randomized complete block design, with the pen as the experimental unit, by ANOVA using the MIXED procedure (SAS Inst. Inc., Cary, NC). Pens were blocked based on average initial pig BW. Linear and quadratic

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

	Yellow dent			NutriDense low-phytate[2]		
Item	0% added fat	3% added fat	6% added fat	0% added fat	3% added fat	6% added fat
Ingredient, %						
Yellow dent corn	71.60	66.82	62.04	—	—	—
NutriDense low-phytate corn	—	—	—	71.80	67.00	62.20
Soybean meal, 46.5% CP	26.14	27.87	29.60	26.25	27.97	29.70
Choice white grease	—	3.00	6.00	—	3.00	6.00
Monocalcium P, 21% P	0.73	0.78	0.83	0.37	0.45	0.52
Limestone	0.90	0.90	0.90	0.95	0.95	0.95
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lys·HCl	0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix[3]	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix[4]	0.08	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition[5]						
Lys, %	0.93	0.97	1.01	0.97	1.01	1.04
Lys:ME, g/Mcal	2.8	2.8	2.8	2.8	2.8	2.8
Met:Lys, %	29	28	27	30	30	29
Met and Cys:Lys, %	59	58	56	62	60	58
Thr:Lys, %	63	63	62	64	63	63
Trp:Lys, %	20	20	20	21	21	21
Total Lys, %	1.05	1.09	1.13	1.10	1.14	1.17
CP, %	18.3	18.7	19.1	19.0	19.4	19.7
ME, kcal/kg	3,338	3,470	3,605	3,470	3,593	3,719
Ca, %	0.59	0.60	0.61	0.54	0.56	0.58
P, %	0.53	0.54	0.55	0.49	0.50	0.51
Available P, %	0.22	0.23	0.25	0.23	0.25	0.26
Available P:ME, g/Mcal	0.90	0.90	0.90	0.90	0.90	0.90

[1]Diet composition was calculated using NRC (1998) composition values for yellow dent corn ingredients.
[2]BASF Plant Science, Research Triangle Park, NC.
[3]Provided per kilogram of diet: 11,023 IU of vitamin A; 1,653 IU of vitamin D_3; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of vitamin B_{12}; 50 mg of niacin; 28 mg of pantothenic acid; and 8 mg of riboflavin.
[4]Provided per kilogram of diet: 16.54 mg Cu from Cu sulfate; 0.149 mg of I from Ca iodate; 165 mg of Fe from Fe sulfate; 38.6 mg of Mn from Mn oxide; 0.149 mg of Se from Na selenite; and 165 mg of Zn from Zn oxide.
[5]Amino acids on a true ileal digestible basis.

polynomial contrasts were used to determine the effects of increasing added fat.

RESULTS

Analytical Analysis

The analyzed nutrient values for yellow dent and NutriDense low-phytate corn were generally similar to the calculated values used in diet formulation (Table 1). One notable difference was with the oil content of NutriDense low-phytate corn which was approximately 18% lower than the nutrient values used in diet formulation. This may explain the lower than expected GE of 3,753 kcal/kg compared with Hastad et al. (2005) who reported a GE of 4,125 kcal/kg for NutriDense low-phytate corn. In addition, the analyzed CP of yellow dent corn was approximately 17% lower than used in diet formulation. However, only minor differences in formulated vs. analyzed AA of Lys, Met, Cys, Trp, and Thr were found; thus, we do not feel these differences were great enough to influence results of these experiments.

Exp. 1

Overall (d 0 to 28), there were no corn source × added fat interactions ($P \geq 0.79$) observed (Table 4). Also, there were no differences in growth performance between pigs fed NutriDense low-phytate corn and yellow dent corn (Table 5). Regardless of corn source, ADG increased (linear, $P = 0.03$) and G:F increased (linear, $P < 0.01$) with increasing dietary fat.

Exp. 2

Overall (d 0 to 28), there was a tendency ($P = 0.07$) for a corn source × added fat interaction in G:F (Table 6). This interaction can be explained by the improved G:F in pigs fed yellow dent corn only when 6% fat was added to the diet, whereas G:F was improved at both 3 and 6% added fat in pigs fed NutriDense low-phytate corn. Despite this tendency for the interaction, ADG (linear, $P < 0.01$) and G:F increased with increasing added fat (Table 7). There was no difference in growth performance between pigs fed NutriDense low-phytate corn and yellow dent corn.

Table 3. Diet composition (Exp. 2; as-fed basis)[1]

	Yellow dent			NutriDense low-phytate[2]		
Ingredient, %	0% added fat	3% added fat	6% added fat	0% added fat	3% added fat	6% added fat
Yellow dent corn	80.34	75.89	71.46	—	—	—
NutriDense low-phytate corn	—	—	—	80.95	76.45	72.00
Soybean meal, 46.5% CP	17.58	18.98	20.36	17.33	18.76	20.14
Choice white grease	—	3.00	6.00	—	3.00	6.00
Monocalcium P, 21% P	0.65	0.70	0.75	0.24	0.31	0.38
Limestone	0.85	0.85	0.85	0.90	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lys·HCl	0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix[3]	0.08	0.08	0.08	0.08	0.08	0.08
Vitamin premix[4]	0.05	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition[5]						
Lys, %	0.72	0.75	0.78	0.75	0.78	0.81
Lys:ME, g/Mcal	2.15	2.15	2.15	2.15	2.15	2.15
Met:Lys, %	32	33	30	34	33	32
Met and Cys:Lys, %	66	66	62	70	67	65
Thr:Lys, %	66	64	64	67	66	65
Trp:Lys, %	20	19	20	21	21	21
Total Lys, %	0.82	0.85	0.88	0.86	0.89	0.92
CP, %	15.1	15.4	15.6	15.7	16.0	16.2
ME, kcal/kg	3,347	3,482	3,614	3,497	3,623	3,749
Ca, %	0.53	0.54	0.55	0.47	0.49	0.50
P, %	0.48	0.49	0.50	0.43	0.44	0.45
Available P, %	0.20	0.21	0.22	0.21	0.22	0.23
Available P:ME, g/Mcal	0.75	0.75	0.75	0.75	0.75	0.75

[1]Diet composition was calculated using NRC (1998) composition values for yellow dent corn ingredients.
[2]BASF Plant Science, Research Triangle Park, NC.
[3]Provided per kilogram of diet: 11,023 IU of vitamin A; 1,653 IU of vitamin D_3; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of vitamin B_{12}; 50 mg of niacin; 28 mg of pantothenic acid; and 8 mg of riboflavin.
[4]Provided per kilogram of diet: 16.54 mg Cu from Cu sulfate; 0.149 mg of I from Ca iodate; 165 mg of Fe from Fe sulfate; 38.6 mg of Mn from Mn oxide; 0.149 mg of Se from Na selenite; and 165 mg of Zn from Zn oxide.
[5]Amino acids on a true ileal digestible basis.

Table 4. Effects of corn source and added fat on growth performance of growing pigs (Exp. 1)[1]

	Yellow dent			NutriDense low-phytate[2]				*P*-value
Item	0% added fat	3% added fat	6% added fat	0% added fat	3% added fat	6% added fat	SE	Source × level
d 0 to 28								
ADG, g	848	872	898	861	875	909	25.0	0.97
ADFI, g	1,883	1,870	1,854	1,954	1,877	1,885	57.5	0.79
G:F, g/g	0.450	0.467	0.485	0.441	0.467	0.481	0.008	0.83

[1]1,162 gilts (25 to 28 pigs per pen with 7 replications per treatment) with an initial BW of 44.6 kg were used in a 28-d study.
[2]BASF Plant Science, Research Triangle Park, NC.

Table 5. Main effects of corn source and added fat on growth performance of growing pigs (Exp. 1)[1]

	Corn source			Added fat, %				*P*-value			
										Fat level	
Item	Yellow dent	NutriDense low phytate[2]	SE	0	3	6	SE	Corn source	Fat level	Linear	Quadratic
d 0 to 28											
ADG, g	873	882	13.9	854	873	904	16.9	0.59	0.08	0.03	0.75
ADFI, g	1,869	1,905	35.0	1,918	1,874	1,869	40.8	0.34	0.53	0.30	0.61
G:F, g/g	0.467	0.463	0.004	0.446	0.467	0.483	0.005	0.48	0.01	0.01	0.73

[1]1,162 gilts (25 to 28 pigs per pen with 7 replications per treatment) with an initial BW of 44.6 kg were used in a 28-d study.
[2]BASF Plant Science, Research Triangle Park, NC.

Table 6. Effects of corn source and added fat on growth performance on finishing pigs (Exp. 2)[1]

	Yellow dent			NutriDense low phytate[2]				*P*-value
Item	0% added fat	3% added fat	6% added fat	0% added fat	3% added fat	6% added fat	SE	Source × level
d 0 to 28								
ADG, g	867	830	916	798	863	910	25.7	0.12
ADFI, g	2,713	2,578	2,573	2,532	2,495	2,555	83.4	0.62
G:F, g/g	0.321	0.322	0.359	0.316	0.345	0.356	0.007	0.07

[1]1,128 gilts (25 to 28 pigs per pen with 7 replications per treatment) with an initial BW of 81.6 kg were used in a 28-d study.
[2]BASF Plant Science, Research Triangle Park, NC.

DISCUSSION

Pigs fed diets containing low-phytate corn varieties have been shown to have similar growth performance to those fed yellow dent corn with added inorganic P (Spencer et al., 2000; Veum et al., 2001). These results are similar to ours where we observed no differences in growth performance of pigs fed diets containing NutriDense low-phytate corn or yellow dent corn.

Although previous research by Hastad et al. (2005) and Peter et al. (2001) determined that NutriDense low-phytate corn had a greater energy content compared with yellow dent corn, we did not observe a similar result. In the present studies with growing and finishing pigs, we did not find a response in ADG or G:F to the anticipated greater energy content of NutriDense low-phytate corn compared with yellow dent corn. This could be due to the oil content of the NutriDense low-phytate corn in this study being lower than that used by Hastad et al. (2005) and similar to NRC (1998) estimates for yellow dent corn. In diet formulation, NutriDense low-phytate corn was given a 5% greater energy value relative to yellow dent corn, which seems to be an overestimation of the actual energy value based on previous research (Peter et al., 2001; Hastad et al., 2005). This overestimation of energy used in diet formulation coupled with the lower than expected ether extract oil analysis in the current study could have caused the lack of growth response to NutriDense low-phytate corn compared with yellow dent corn.

Although pig growth performance was similar for pigs fed NutriDense low-phytate corn and those fed yellow dent corn, NutriDense low-phytate corn does have added environmental advantages because of the low-phytate P concentrations. This was evident because the NutriDense low-phytate corn diets required 37 to 63% less inorganic P supplementation, compared with the yellow dent corn diets. The analyzed NutriDense low-phytate corn had similar AA and P contents compared with the calculated values used in diet formulation. The greater amino acid and available P concentrations in NutriDense low-phytate corn compared with yellow dent corn were accounted for in diet formulation; thus, the similar growth performance between pigs fed NutriDense low-phytate corn and yellow dent corn indicates that the formulation values for these nutrients in NutriDense low-phytate corn are appropriate.

A meta-analysis study consisting of many experiments concluded that added dietary fat improves ADG and G:F in nursery, growing, and finishing pigs (Pettigrew and Moser, 1991). This response was verified more recently in the growing-finishing pig study (De la Llata et al., 2001), which used the same commercial research facility as the present study. Although those experiments utilized yellow dent corn in combination with added dietary fat, the research did not evaluate the effects of added dietary fat in combination with NutriDense low-phytate corn. Although no interactions were observed in Exp. 1, there was a tendency for an interaction between corn source and added fat in Exp. 2 to affect feed efficiency, which was the result of pigs not responding to 3% dietary fat when fed yellow dent corn. This effect was not expected, and the reason for the lack of improvement is not known. However, data from both experiments indicate that improvements in growth performance can be expected when added fat is fed in combination with NutriDense low-phytate corn.

Table 7. Main effects of corn source and added fat on growth performance of finishing pigs (Exp. 2)[1]

	Corn source			Added fat, %				*P*-value			
										Fat level	
Item	Yellow dent	NutriDense low phytate[2]	SE	0	3	6	SE	Corn source	Fat level	Linear	Quadratic
d 0 to 28											
ADG, g	871	857	15.3	833	846	913	18.4	0.50	0.01	0.01	0.22
ADFI, g	2,621	2,527	48.1	2,622	2,536	2,564	59.0	0.18	0.58	0.49	0.44
G:F, g/g	0.334	0.339	0.004	0.319	0.333	0.358	0.005	0.39	0.01	0.01	0.41

[1]1,128 gilts (25 to 28 pigs per pen with 7 replications per treatment) with an initial BW of 81.6 kg were used in a 28-d study.
[2]BASF Plant Science, Research Triangle Park, NC.

In summary, the use of added fat to increase the energy level of the diet improved growth performance of pigs regardless of corn sources. No differences were detected in growth performance of pigs fed NutriDense low-phytate corn compared with pigs fed yellow dent corn. This, combined with the added environmental advantages of NutriDense low-phytate corn, indicates that it can be used in place of yellow dent corn in the growing and finishing pig diets.

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