High-oil corn in diets of growing pigs

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Abstract

Progress in corn improvement research has produced varieties with higher concentrations of certain nutrients. Normally, corn contains about 3.5% ether extract which is relatively well utilized by pigs. Three varieties of corn with higher oil content and improved fatty acid profile relative to conventional corn were recently developed. The utilization of varieties of corn that contain higher oil could provide an alternative method of increasing the energy density of swine diets and produce diets that are less dusty. Energy- and nutrient-dense diets have the potential to improve feed efficiency, which could be economically beneficial to the swine industry. This study was conducted to compare nutrient and energy utilization of high-oil corn varieties with regular corn, and to compare the growth performance of growing pigs when fed diets containing high-oil corn.

Experimental Procedures

Experiment 1. Four diets were formulated to contain 97% of one of four varieties of corn (Control, TC1, TC2 and X122 varieties) and 3% minerals and vitamins (Table 1). Diets were formulated such that the test grain was the only source of protein and energy. The four diets were fed to 24 crossbred barrows (Hampshire x Duroc sires by Yorkshire x Landrace dams) at 6 pigs/diet in a metabolism trial involving total but separate collection of feces and urine.

Experiment 2. Four diets formulated to contain 79% of one of the four corn varieties, 18.25% soybean meal (48% CP), 2.45% vitamins and minerals, and .3% lysine HCl (Table 1) were fed to 24 crossbred barrows (Yorkshire-Landrace dams by Hampshire-Duroc sires) at 6 pigs/diet in a metabolism trial as described above. Because part of the dietary energy was supplied by soybean meal, digestible energy (DE) and metabolizable energy (ME) for the corn were calculated by difference, subtracting the value for soybean meal from that of the total diet.

Experiment 3. The same four diets that were used in Exp. 2 were fed to forty 45-lb crossbred pigs (20 barrows and 20 gilts) at 10 pigs/diet in a 28-d growth performance study. Pigs were blocked by weight and sex and assigned to diets. Pigs were housed individually in 5.77 ft x 2.76 ft pens with slatted concrete floors in an environmentally-controlled building, and were allowed ad-libitum access to feed and water for 28 d. Pig weights and feed intake were monitored weekly.

Results and Discussion

Chemical composition analyses of the three high-oil corn varieties and the regular control corn used in the three experiments are presented in Table 2. Crude protein and essential amino acid contents of the high-oil corn varieties (TC1, TC2 and X122) were higher than those of the regular corn. Concentrations of lysine, tryptophan, threonine and methionine, the first four limiting amino acids in practical diets for pigs, were slightly higher in the high-oil corn varieties than in the regular corn. Ether extract was higher in the high-oil corn varieties than in the regular corn (5.4 to 9.7% vs. 4.2%). This resulted in higher gross energy values

for the high-oil corn varieties than the regular corn (Table 2). Among the high-oil corn varieties, TC1 had the highest ether extract content and gross energy value.

The digestibility of dry matter was similar among the corn varieties except for TC2, which had a lower ($P < .05$) dry matter digestibility than the regular corn (Table 3). Corn was the only source of protein in the diets used in Exp. 1. Daily nitrogen retained was higher ($P < .05$) for variety X122 than other corn varieties. The higher ether extract content of the high-oil corn varieties resulted in higher ($P < .05$) ether extract intake; pigs fed TC1 (which had the highest ether extract content) had the highest ether extract intake, whereas pigs fed the regular corn (which had the lowest ether extract content) had the lowest intake (Table 3). Ether extract absorbed followed the same pattern as ether extract intake. Daily gross energy intake was consistent with the changes in gross energy content of the corn varieties; pigs fed the high-oil corn varieties had higher ($P < .05$) gross energy intake than pigs fed regular corn (Table 3). The energy absorbed and retained on a daily basis was similar across grains; however, when expressed as a percentage of intake, energy digestibility and retention were higher ($P < .05$) for regular corn than for two of the high-oil corn varieties (TC2 and X122). Daily energy absorbed or retained were similar across grains, regardless of whether or not the values were adjusted for energy intake.

In Exp. 2, soybean meal and lysine HCl provided additional sources of nitrogen and energy in the diets. As in Exp. 1, dry matter digestibility was similar among all corn varieties except TC2 (Table 4). Nitrogen digestibility was highest ($P < .05$) in the diet containing variety TC1 and lowest in the regular corn. Nitrogen retention (% of intake) was higher ($P < .05$) in the diet containing variety TC1 than in the diet containing variety TC2. Biological value was similar across diets (Table 4). The digestibility of ether extract was lower ($P < .05$) in the diet containing regular corn than in the diets containing the high-oil corn varieties. The digestibility of energy in diets containing regular corn and two of the high-oil corn varieties (TC1 and X122) were similar ($P > .05$). Energy digestibility in the diet containing variety TC2 was lower ($P < .05$) than other high-oil varieties. Energy retention was also lowest ($P < .05$) in the diet containing variety TC2 (Table 4). Increased dietary fat is known to delay gastric emptying rate and reduce passage rate of digesta as it moves through the gastrointestinal tract. The increased retention time might provide nutrients more time for digestion, and thus increase the digestibility.

The digestible and metabolizable energy values of the four varieties of corn are presented in Table 5. Regardless of whether it was determined directly or by difference, the digestible energy content of the regular corn was lower ($P < .05$) than any of the high-oil corn varieties. The high-oil corn containing the highest ether extract concentration (TC1) had a higher ($P < .05$) digestible energy value than the other two high-oil corn varieties. Metabolizable energy was lower for regular corn ($P < .05$) than for any of the high-oil corn varieties. The difference method (Exp. 2) generally gave higher digestible and metabolizable energy values than the direct method (Table 5); this was statistically significant for TC1 ($P < .05$) and X122 ($P < .10$).

Experiment 3 was a 28-d growth performance study in which the same diets used in Exp. 2 were fed to 20 barrows and 20 gilts. Data showing the growth response are presented in Table 6. Growth performance of pigs fed a diet containing the regular corn was similar ($P > .05$) to those fed the diets containing high-oil corn. However, there was a trend for a higher weight gain in pigs fed diets containing high-oil corn than in pigs fed regular corn. Pigs fed the diet containing the high-oil corn variety TC1 gained 9% more weight daily than pigs fed the diet containing the regular corn. The tendency for an improvement in growth rate at similar feed intake resulted in a trend toward an improvement in feed efficiency, with pigs fed the diet containing high-oil corn having 8 to 10% greater feed efficiency than pigs fed regular corn (Table 6). The trends for greater weight gain and feed efficiency in pigs fed diets containing high oil corn in Exp. 3 are consistent with the generally higher nutrient and energy retention observed in Exp. 1 and 2.

Because of limited ingestive capacity, young pigs (weighing less than 110 lb) do not consume sufficient energy to achieve their growth potential. In the present growth performance experiment with 55-lb pigs, substitution of high-oil corn for regular corn increased the digestible energy intake (as seen in higher DE

values in Exp. 2, Table 5) while total feed intake remained essentially unchanged (Table 6). The constraint to growth by the limited ingestive capacity and energy intake was thus lessened through high-oil corn substitution, as seen in the tendency for a 3 to 9% improvement in growth rate and 8 to 10% improvement in feed efficiency.

In conclusion, results of these experiments with growing pigs indicate efficient utilization of nutrients in diets containing high-oil corn. Utilization by the growing pig and the ease of handling and mixing uniformly into complete feeds make high-oil corn an attractive source of supplemental energy in pig diets.

Application

High-oil corn contains more nutrients and energy than regular corn. The digestible energy values of high-oil corn (5.4 to 9.7% ether extract) range from 1.55 to 1.62 Mcal/lb (as-fed basis) compared to 1.5 Mcal/lb (as-fed basis) for regular corn (4.2% ether extract). The metabolizable energy values were 98.4% of respective digestible energy values. Substitution of high-oil corn for regular corn on a weight-for-weight basis in nutrient-adequate diets of growing pigs tended to improve weight gain and feed efficiency by 3 to 9% and 8 to 10%, respectively. High-oil corn will be a valuable additional ingredient for use in increasing the energy density of swine diets.

Table 1. Composition of diets on as-fed basis (lb/1,000 lb)

	Experiment	
Ingredient	1	2 and 3
Corn[a]	970	790
Soybean meal (48% CP)		182.50
Dicalcium phosphate	17.75	12.25
Calcium carbonate	7.50	7.50
Salt	2.50	2.50
Lysine HCl		3.00
Vitamin premix[b]	1.25	1.25
Trace mineral premix[c]	.50	.50
Selenium premix[d]	.50	.50
Total	1,000.00	1,000.00

[a] Corn varieties used were Control, TC1, TC2, and X122. See Table 2 for composition.

[b] Provided the following per 2.2 lb of diet: vitamin A, 2,910 IU; vitamin D3, 291 IU; vitamin E, 11 IU; menadione sodium bisulfite, .75 mg; riboflavin, 3.0 mg; 11.63 mg; niacin, 17.5 mg; vitamin B12, 15.5 ug.

[c] Provided the following per 2.2 lb of diet: Zn, 100 mg; Fe, 50 mg; Mn, 27.5 mg; Cu, 5.5 mg; I, 750 ug.

[d] Supplied 300 ug Se/2.2 lb of diet.

Table 2. Nutrient composition of the corn varieties

Item	Control	TC1	TC2	X122
Dry matter, %	87.2	88.6	88.4	87.8
Ether extract, %	4.19	9.73	5.85	5.41
Gross energy, Mcal/lb	1.76	1.93	1.90	1.85
Crude protein, %	7.19	7.86	7.45	9.07
Essential amino acids, %				
Arginine	.39	.46	.41	.42
Histidine	.23	.25	.24	.28
Isoleucine	.30	.32	.30	.35
Leucine	1.03	1.02	.95	.45
Lysine	.25	.31	.28	.31
Methionine	.17	.19	.20	.21
Phenylalanine	.41	.42	.38	.34
Threonine	.29	.30	.29	.31
Tryptophan	.06	.08	.07	.07
Valine	.40	.45	.40	.48

Table 3. Nutrient and energy balance in Experiment 1.[a]

	Corn variety				
Item	Control	TC1	TC2	X122	SE
Dry matter digestibility, %	89.5[b]	87.7[bc]	86.8[c]	87.5[bc]	.67
Nitrogen intake, g/d	12.7[e]	13.7[c]	13.[1d]	15.5[b]	.05
Nitrogen absorbed, g/d	9.8[d]	10.5[c]	10.0[cd]	11.9[b]	.19
Nitrogen retained, g/d	6.7[c]	6.5[c]	7.0[c]	8.6[b]	.34
Nitrogen digestibility, %	76.9	76.1	76.3	76.6	1.45
Nitrogen retention, % of intake	51.9[bc]	47.3[c]	52.9[bc]	55.3[b]	2.63
Biological value, %	67.4[bc]	62.2[c]	69.1[bc]	72.4[b]	3.25
Ether extract intake, g/d	34.5 [e]	78.1 [b]	68.6 [c]	59.5 [d]	.68
Ether extract absorbed, g/d	21.26[d]	50.63[b]	40.18[c]	32.52[c]	3.53
Ether extract digestibility, %	61.5	64.6	58.1	56	5.30
Energy intake, Mcal/d	4.10[e]	4.55[b]	4.43[c]	4.39[d]	.007
Energy absorbed, Mcal/d	3.62	3.93	3.75	3.75	.04
Energy retained, Mcal/d	3.57	3.86	3.69	3.67	.04
Energy digestibility, %	88.2[b]	86.2[bc]	84.5[c]	85.6[c]	.86
Energy retention, % of intake	86.9[b]	84.8[bc]	83.2[c]	84.2[c]	.92
n	6	6	6	6	

[a] Data are means from 55-lb barrows.

[b,c,d,e] Means in the same row with different superscripts are significantly different (P<.05).

Table 4. Digestibility of nutrients in diets containing four corn varieties in Experiment 2 [a]

	Diets				
Item	Control	TC1	TC2	X122	SE
Dry matter digestibility, %	86.5[cb]	87.3[c]	85.3[b]	86.6[c]	.44
Nitrogen digestibility, %	79.7[d]	85.4[b]	82.8[c]	82.8[c]	.87
Nitrogen retention, % of intake	61.0[bc]	65.5[b]	59.7[c]	58.0[c]	2.15
Biological value, %	76.5	76.7	72.1	70.1	2.50
Ether extract digestibility, %	17.5[d]	56.7[b]	46.5[c]	59.0[b]	2.08
Energy digestibility, %	85.1[b]	85.7[b]	83.5[c]	85.5[b]	.48
Energy retention, % of intake	82.8[b]	83.4[b]	81.2[c]	83.2[b]	.50
n	6	6	6	6	

[a] Data are means from 55-lb barrows.

[b,c,d] Means in the same row with different superscripts are significantly different (P<.05).

Table 5. Digestible and metabolizable energy values of four corn varieties in Experiments 1 and 2 [a]

		Experiment (Method)			
		1	2		P-value for
Item	Corn	(Direct)	(By difference)	SE	1 vs 2 b
Digestible energy, Mcal/lb	Control	1.50[e]	1.51[e]		NS
	TC1	1.62[c]	1.68[c]		.03
	TC2	1.55[d]	1.58[d]		NS
	X122	1.55[d]	1.59[d]		.09
				.013	
Metabolizable energy, Mcal/lb	Control	1.47[e]	1.49[e]		NS
	TC1	1.59[c]	1.66[c]		.02
	TC2	1.52[d]	1.56[d]		NS
	X122	1.53[d]	1.57[d]		.09
				.014	

N		6	6		

[a]Data are means from 55-lb barrows on as-fed basis.

[b]Probability value of the difference between Experiment 1 and 2; NS indicates P > .10.

[c,d,e]Means in the same column with different superscripts are significantly different (P<.05).

Table 6. Performance of pigs fed diets containing four corn varieties in Experiment 3.

	Diets				
Item	Control	TC1	TC2	X122	SE
Initial weight, lb	42.9	42.7	42.7	42.7	.55
Final weight, lb	84.7	87.8	86	86.9	1.67
Gain, lb/d	1.50	1.63	1.54	1.58	.055
Feed, lb/d	3.85	3.83	3.65	3.81	.125
Gain:feed	.39	.43	.42	.42	.029
n	10	10	10	10	