New Designer Genes in Corn

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One of the hottest topics at the recent Midwestern Section Meeting of the American Society of Animal Science in Des Moines this past March, and at the World Pork Expo, also in Des Moines earlier this month, was the release of information about two new genetically modified corns -- low phytic acid corn (also called low phytate corn) and high oil corn. This paper will review the recent findings just released on low phytate corn. A review of the latest information on high oil corn will be addressed in the next issue.

Genetically modified cereal grains have been around for awhile. One of the first mutant genes found to modify the composition of cereal grains was the *opaque-2* gene in corn, discovered in the mid-1960's. This gene changes the type of protein and results in a 50% or greater increase in the lysine content of corn. This discovery resulted in a great deal of excitement in nutrition circles and in the swine industry for several years. Unfortunately, plant breeders were not able to solve all of the agronomic problems associated with this gene. A problem was that the endosperm (starch) portion of the grain was floury in nature and was somewhat susceptible to insect and mechanical damage. Furthermore, the light test weight of *opaque-2* corn caused reduced yields. As a result, *opaque-2* corn did not become nearly as popular as was originally predicted.

This discovery, however, prompted plant genetics to search for other genes that would alter the composition of cereals. Since the discovery of the original high lysine corn, other genes have been found that improve the chemical composition of cereal grains. *Floury-2*, *sugary-2*, and *waxy* are examples of mutant genes that alter the protein and carbohydrate fractions of corn. High protein and high lysine strains of grain sorghum, barley, and oats also have been identified.

While the major emphasis of the commercial seed industry has been to increase yields and disease resistance, attention is now being paid by some companies to find ways of improving some of the nutritional traits in cereal grains, soybeans and other oilseeds by breeding desirable traits into existing hybrids.

Low Phytate Corn

One of the most exciting discoveries to surface in corn breeding in recent years is the discovery of low phytic acid (low phytate) genes. Low phytate genes were first discovered by Dr. Victor Raboy, a USDA plant breeder at Montana State University. These mutant genes (one of which is called the *lpa1* gene) blocks the synthesis of phytic acid in corn seeds as they are produced on the ear without affecting the amount of total phosphorus. As a result, the inorganic phosphorus content of corn is markedly increased. One of the major seed companies, Pioneer Hi-Bred International, has put the mutant *lpa1* gene into some of its hybrid corn lines.

What makes this discovery so exciting? It is because of the tremendous potential that this corn has for reducing environmental pollution from high-phosphorus pig and poultry manure.

Most (60-80%) of the phosphorus in corn is in a complex form called phytic acid (or phytate). Pigs and poultry do not have the digestive enzyme (phytase) in their gastrointestinal tract to break down the phytate, so most of the phosphorus in corn and soybean meal passes through the tract unused and is excreted in the manure. Naturally, this excreted phosphorus can potentially contribute to environmental pollution if high-phosphorus manure is applied to cropland and the excess phosphorus eventually finds its way into surface waters.

Low phytate corn has about half as much phytate phosphorus as normal corn (Table 1). And better yet, this mutant corn has about two to three times more highly digestible inorganic phosphorus than normal corn (Table 1).

This past year, we had the opportunity to work with Optimum Quality Grains, L.L.C., a joint venture involving Pioneer Hi-Bred International and Dupont, in testing this new type of corn. In studies with pigs and chicks, we found that the phosphorus in low phytate corn was about three to four times more bioavailable than the phosphorus in normal corn. Specifically, we found in pig studies that this gene increased the bioavailability of phosphorus from approximately 20% in normal corn up to 75% in low phytate corn. In chicks, the bioavailability of phosphorus was increased from 10% in normal corn to 50% in low phytate corn.

This finding is very significant because it means that, when low phytate corn is fed, less supplemental phosphorus is needed to meet the animal's dietary phosphorus requirements. Results of feeding tests conducted at UK with both growing pigs (Table 2) and finishing pigs (Table 3) indicate that feeding pigs low phytate corn-soybean meal diets with 0.1% less total phosphorus than normal results in similar performance and bone mineralization as in pigs fed normal corn-soybean meal diets. From other experiments, we estimate that 0.1% less dietary phosphorus will result in a 20-30% reduction in excreted phosphorus.

Even with the feeding of low phytate corn, there is still quite a bit of unusable phytate phosphorus in diets that originates from soybean meal. We presently have experiments underway at the UK to assess the effects of adding a microbial phytase supplement to corn-soybean meal diets containing either normal corn or low phytate corn. Also, low phytate soybeans are on the horizon. All of these new technologies -- supplemental phytase, low phytate corn and low phytate soybeans -- have tremendous potential as a means of reducing the problems of phosphorus excretion in pork production systems.

Preliminary testing by Optimal Quality Grains, L.L.C. indicates that low phytate corn yields as well as normal corn. Also, the protein, lysine, starch, and other important nutritional traits are not affected by the low phytate gene. The gene apparently only affects the type of phosphorus in the corn grain. A side benefit of the reduced phytic acid (which is a strong chelating agent) is that binding of zinc and other trace minerals is less likely to occur in the intestinal tract when this type of corn is fed. Thus, dietary levels of some of trace elements such as zinc can also be reduced, which will also reduce excretion of these trace elements.

Optimum Quality Grains estimates that seed will be commercially available for planting in two years, or in the spring of year 2000.

Table 1. Composition of Normal and Low Phytate Corn[a]

	Normal corn	Low phytate corn
Total phosphorus, %	.25	.28
Phytate phosphorus, %	.20	.10
Inorganic phosphorus, %	.05	.18

[a]Provided by Optimum Quality Grains, L.L.C., a joint venture of Pioneer Hi-Bred International and Dupont. The normal and low phytate corns were near-isogenic except for the *lpa1* gene.

Table 2. Performance of Growing Pigs Fed Corn-Soy Diets with Normal or Low Phytate Corn with Varying Amounts of Supplemental Phosphorus[a]

	Normal corn				Low phytate corn			
Total P, %[b]	.59	.50	.42	.33	.59	.50	.42	.33
Bioavailable P, %[c]	.35	.26	.18	.09	.45	.37	.28	.20
Daily gain, lb	1.78	1.76	1.61	1.37	1.74	1.72	1.72	1.70
Feed/gain	2.37	2.37	2.44	2.79	2.39	2.54	2.38	2.35
Bone traits								
Femur strength, kg	308	301	234	125	332	332	298	208
MM strength, kg[d]	90	86	66	41	87	89	85	64
MM ash, %	50.6	50.6	48.7	45.2	51.0	50.9	50.4	46.9

[a]University of Kentucky experiment involving five replications of two pigs/pen from 51 to 112 lb body weight. Dietary lysine was .80% and dietary calcium was .65%.
[b]The diets with .33% total phosphorus had no supplemental phosphorus.
[c]Based on the following bioavailabilities: normal corn, 20%; low phytate corn, 75%; soybean meal, 25%; dicalcium phosphate, 100%.
[d]MM = average of third and fourth metacarpal and metatarsal bones.

Table 3. Performance of Finishing Pigs Fed Corn-Soy Diets with Normal or Low Phytate Corn with Varying Amounts of Supplemental Phosphorus[a]

Total P, %	Normal corn			Low phytate corn		
Phase 1[b]	.45	.39	.33	.45	.39	.33
Phase 2[b,c]	.42	.36	.30	.42	.36	.30
Bioavailable P, %[d]	.24	.17	.10	.34	.27	.20
Phase 1						
Daily gain, lb	2.11	2.11	2.00	2.18	2.14	2.16
Feed/gain	2.23	3.10	3.31	3.12	3.11	3.07
Entire experiment						
Daily gain, lb	2.16	2.16	2.09	2.14	2.16	2.18
Feed/gain	3.44	3.38	3.48	3.39	3.39	3.35
Bone and carcass traits						
MM strength, kg[e]	181	177	156	181	185	187
Carcass lean, %	53.7	53.9	53.0	54.0	54.0	53.7

[a]University of Kentucky experiment involving six replications of five pigs/pen from 115 to 240 lb body weight.
[b]Phase 1 was from 115 to 170 lb and Phase 2 was from 170 to 240 lb body weight. Dietary lysine was .85 and .65%, and dietary calcium was .54 and .52% during Phase 1 and 2, respectively.
[c]The diets with .30% total phosphorus had no supplemental phosphorus.
[d]Based on the following bioavailabilities: normal corn, 20%; low phytate corn, 75%; soybean meal, 25%; dicalcium phosphate, 100%.
[e]MM = average of third and fourth metacarpal and metatarsal bones.

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