The Effects of Adding Distiller's Dried Grains with Solubles, with and without Phytase, to Swine Diets on Phosphorus Balance, and Phosphorus Levels and Chemical Forms of Phosphorus in Swine Manure.

Summary Report
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Introduction

Manure nutrient management is an important regulatory and environmental issue for livestock producers. As shown in Table 1, beef cattle produce the largest volume of manure (96.6 million tons) of all livestock and poultry species, followed by dairy cattle (29.1 million tons), and swine (15.5 million tons). However, because of the relatively high concentration of phosphorus in swine manure, the swine industry ranks second, behind the beef industry in the annual amount of phosphorus excreted in manure (Table 2). As a result, pork producers are looking for low cost nutritional strategies that will enable them to reduce the phosphorus content of manure and minimize the need for accessing additional acres of cropland for proper manure application.

Table 1. Quantity of manure, phosphorus concentration in manure, and annual amount of phosphorus excreted by various livestock groups in the U.S.

Species	Manure, Million Tons	% P in Manure	Annual Amt. of P Excreted, Thousand Tons
Beef	96.6	1.07	1029
Dairy	29.1	0.79	230
Sheep	1.8	0.56	10
Swine	15.5	2.97	460
Poultry	15.4	1.62	250
Total	158.9		1979

Source: Cromwell, 2002

Up until recently, livestock producers have generally applied livestock and poultry manure to soil based upon nitrogen needs of the crops grown. Swine manure has a nitrogen:phosphorus ratio of about 3:1, which is lower than that often needed by the types of crops grown on soil where manure has been applied (e.g. corn needs a 6:1 nitrogen:phosphorus ratio). Therefore, when swine manure is applied to meet the nitrogen needs for corn production, excess phosphorus is applied to the soil because corn removes less phosphorus than nitrogen during plant growth. Excess phosphorus in soil has the potential for leaching and runoff, which can contribute to eutrophication of surface

waters. As a result, new federal regulations will require that manure application rates be based upon phosphorus by December 2006.

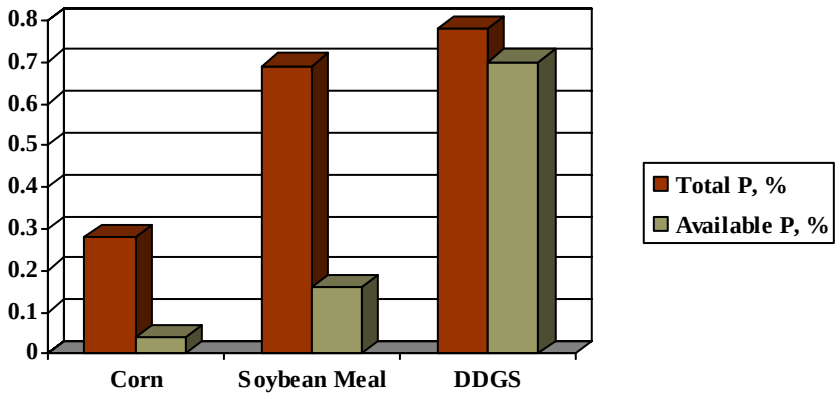
The NRCS Code 590 Standards requires adoption of phosphorus based manure management plan in fields with high or very high soil test phosphorus (STP) levels, STP equal or exceed threshold levels, or a phosphorus site index assessment that indicates a high risk of phosphorus runoff for surface water. The EPA requires that concentrated animal feeding operations (CAFO's) are required to have phosphorus-based management for land application of manure.

Within a pork production system, the nursery phase produces more pounds of $P_2 O_5$ per pound of animal weight per year (0.21 lbs) than any other phase of production (NebGuide G1334, 1997). This is primarily because of the high concentration of phosphorus in nursery diets (needed to meet their daily phosphorus requirement), and the relatively low amount of feed intake and manure output compared to other phases of production. Manure phosphorus composition is not only affected by age of the animal and diet, but is also affected by the amount and type of bedding used (if any) and manure storage method.

Phosphorus compounds in manure vary in solubility, availability for plant uptake, and absorption potential in soils. Soils contain between 100 to 3000 ppm phosphorus. The soluble phosphorus fraction is relatively small compared to the reactive and stable phosphorus fractions, but it is the form that is readily available for plant uptake, and is comprised predominantly of orthophosphates. Reactive phosphorus is found in fresh organic material and is converted over time to soluble phosphorus. Stable phosphorus is the largest portion of soil phosphorus and consists of crystalline compounds with very low solubility and is not in a chemical form available for plant uptake.

There are several approaches that can be used to reduce phosphorus excretion in swine manure. First, feed ingredients that are high in digestible or bioavailable phosphorus should be used in swine diets. Most swine diets in the U.S. are comprised of corn and soybean meal. These ingredients are relatively high in phytic acid (an undigestible form of phosphorus) which results in low levels of available phosphorus compared to the total amount of phosphorus they contribute to the diet (Figure 1). As a result, the unavailable portion of phosphorus in the diet is excreted in manure.

Figure 1. Comparison of Total and Available Phosphorus in Corn, Soybean Meal, and Corn Distiller's Dried Grains with Solubles.



Recent research results from the University of Minnesota have shown that the total phosphorus concentration in high quality, golden corn distiller's dried grains with solubles (DDGS) is approximately 0.89% and the relative bioavailability of phosphorus is approximately 90%. As a result, the available phosphorus content of DDGS is approximately 0.80% (Figure 1), and significantly higher than contributed by corn and soybean meal. The increased phosphorus availability of corn DDGS is a result of the microbial phytase produced as corn goes through the fermentation process to produce ethanol and DDGS.

A second practical approach to reduce swine manure phosphorus excretion is to minimize the "safety margin" for phosphorus when formulating diets. Nutritionists formulate swine diets above the estimated requirements to minimize the risk of a nutrient deficiency and reduced performance due to the normal variability in nutrient requirements among pigs in a group, and the variability in nutrient levels of feed ingredients. Minimizing the safety margin for phosphorus when formulating swine diets, along with good feeder management to reduce feed wastage, can significantly reduce phosphorus excretion in swine manure.

The addition of phytase to practical swine diets is another commonly used method to improve the utilization of phosphorus in corn-soybean meal based diets by the pig. Phytase is a commercially available enzyme that is becoming a routine addition to corn and soybean meal based swine diets. It is effective in liberating chemically bound phosphorus in the form of phytic acid, in corn and soybean meal to improve phosphorus digestibility. As a result, the dietary level of supplemental phosphorus (dicalcium phosphate) is reduced, and manure phosphorus excretion can be reduced by as much as 30 to 50%. However, the magnitude of the reduction in manure P when phytase is added to the diet is affected by several factors including: dietary level of total and available phosphorus relative to the pig's phosphorus requirement, amount of phytase added to the diet, dietary calcium to phosphorus ratio, and the level of vitamin D in the diet. Adding 225 FTU (phytase units) per pound of complete feed along with 18.8% DDGS (high in available phosphorus) will replace all of the supplemental inorganic phosphorus in a grow-finish pig diet. Depending upon feed ingredient prices, formulating diets containing DDGS and phytase may reduce diet cost, as well as significantly reduce manure phosphorus excretion. No studies have been conducted to evaluate the use of DDGS and phytase in swine diets on nutrient balance and manure P excretion.

Another important nutritional strategy to reduce phosphorus in swine manure is to formulate diets to have a 1:1 to 1.5:1 calcium-to-phosphorus ratio. The addition of phytase to swine diets has been shown to improve the bioavailability of calcium and zinc, and improve protein digestibility. However, because calcium levels in grain based diets are relatively low, bioavailability of calcium has been considered to be of little importance. A suggested total Ca:total P ratio in grain based diets is between 1:1 and 1.25:1 (NRC, 1998). A wide Ca:P ratio lowers P absorption, resulting in reduced growth rate and bone calcification, especially if diets are marginal in phosphorus. When diets are formulated on an available phosphorus basis, the suggested ratio for calcium:available

phosphorus is between 2:1 and 3:1 (NRC, 1998). There are no published data regarding the optimal Ca:available P ratio when phytase and DDGS are added to swine diets.

When practical swine diets are formulated on an available phosphorus basis, the addition of corn DDGS to the diet reduces the amount of inorganic phosphorus that must be supplemented, which often reduces diet cost and manure phosphorus excretion. Many pork producers have reported that manure phosphorus levels declined when they began feeding diets containing 10% DDGS to grow-finish pigs. Based upon our calculations, it can be estimated that including 10 to 20% DDGS in grow-finish diets can reduce phosphorus excretion by approximately 6 to 12%. No studies have been conducted to determine the effects of feeding diets containing DDGS, when formulated on an available P basis, on the amount of reduction of P in swine manure.

Furthermore, there are no data regarding the chemical forms of phosphorus excreted in manure from pigs fed diets containing DDGS or phytase. There are several chemical forms in which P is found in manure including orthophosphates, pyrophosphates, organic P, inorganic P, particulate P. The chemical forms of P in manure determine the availability of P for crop nutrient uptake as well as the P mobility in the soil, which is a potential concern for pollution due to runoff after manure has been applied. Unpublished data from the University of Minnesota have shown that feeding diets containing low phytate corn to pigs significantly increases the availability of P in manure and increases P mobility in the soil. Because of the potential soil fertility and environmental impacts of feeding grain-based diets containing DDGS and phytase to pigs, it is essential to characterize the chemical forms of P in swine manure of pigs fed these types of diets.

Pork producers frequently ask questions regarding the environmental and agronomic impact from applying manure from pigs fed diets containing DDGS and phytase to cropland. With the new CAFO regulations for phosphorus management of livestock manure, and the potential reduction in manure P when DDGS is added to swine diets, DDGS could become a feed ingredient that will be routinely added to swine diets because of its high available phosphorus content. Combined with phytase, DDGS could be a valuable “tool” in reducing manure phosphorus in commercial swine operations.

Therefore, in order to evaluate the impact of adding DDGS and phytase to swine diets, a series of three experiments were conducted using nursery age pigs, with the objectives to:

1. Determine the effect of formulating diets containing 10 or 20% DDGS on a total and available phosphorus basis on manure phosphorus excretion.
2. Determine the effects of adding phytase to DDGS diets on manure phosphorus excretion, chemical forms of P in swine manure, calcium excretion, zinc excretion, and nitrogen excretion.
3. Determine the optimal Ca: available phosphorus ratio in corn-soybean meal based diets containing DDGS and phytase.

Experiment 1

This experiment was conducted to determine the effect of dietary DDGS level and diet formulation method on manure phosphorus excretion in nursery pigs (23 lbs.). Nursery pigs (n = 40) were chosen for these studies because of their relatively high manure phosphorus excretion per unit of body weight, and their relatively high sensitivity to digestibility of feed ingredients. It was assumed that if a significant reduction in manure phosphorus excretion with nursery pigs when DDGS is added to the diet, an equal or greater reduction would be expected for grow-finish pigs and sows.

Five experimental diets were fed (8 pigs per dietary treatment). The control diet was a corn-soybean meal diet formulated on a total phosphorus basis, and other four experimental diets contained either 10 or 20% high quality golden DDGS, and were formulated on either a total or available phosphorus basis. Diets containing DDGS had lower levels of supplemental phosphorus (dicalcium phosphorus) and higher levels of supplemental calcium (ground limestone) in order to equalize calcium and total or available phosphorus levels among the diets. The addition of DDGS to the diet also increased the level of crude protein (nitrogen) in order to keep dietary lysine levels constant across dietary treatments.

All pigs were fed an amount of their assigned experimental diet equivalent to 2.5% of their body weight twice daily, and feed intake was not different among dietary treatments. Pigs fed diets containing 10% and 20% DDGS had a 15% and 30% increase in daily fecal output, respectively, compared to pigs fed the corn-soybean meal control diet. This was due to a 2.2% and 5.1% reduction in dry matter (diet) digestibility for pigs fed the 10% and 20% DDGS diets, respectively. This reduction in dry matter digestibility was likely due to the excess crude protein (nitrogen) and higher fiber levels in the DDGS diets.

However, pigs fed the 10% and 20% DDGS diets had 15.5% and 34.1% lower phosphorus levels in their feces, respectively, compared to pigs fed the corn-soybean meal diet. This result is consistent with field reports from pork producers who have observed a significant reduction in manure phosphorus levels when DDGS is added to grow-finish pig diets. Despite the significant reduction in phosphorus content of feces, the increase in daily fecal excretion that was observed when DDGS diets were fed, resulted in no significant reduction in total daily phosphorus excretion. Numerically, adding 10% DDGS to the diet reduced daily fecal phosphorus excretion by 2.0%, and adding 20% DDGS reduced daily fecal phosphorus excretion by 5.9%, but due to variation in pig responses with dietary treatments groups, these reductions were not statistically significant. Very small amounts of phosphorus is excreted in urine and adding DDGS to the diet had no effect on urine phosphorus excretion.

Pigs fed the 20% DDGS diet tended to retain more phosphorus in their body, tended to retain more phosphorus as a percentage of phosphorus intake, and tended to excrete less total phosphorus in manure, compared to pigs fed the corn-soybean meal control diet. These results confirm that the phosphorus availability estimate for DDGS previously

reported by the University of Minnesota is valid, and that adding 20% DDGS to a nursery diet tends to reduce the proportion of phosphorus excreted in manure relative to the amount the pig consumes. If the appropriate enzymes can be identified and added to swine DDGS diets to improve dry matter digestibility, the addition of DDGS to the diet will have a greater impact on reducing total manure phosphorus excretion. Formulating nursery diets on an available phosphorus basis reduced daily total phosphorus intake, reduced fecal phosphorus concentration by 5.7%, and numerically reduced daily total phosphorus excretion by 5.8%.

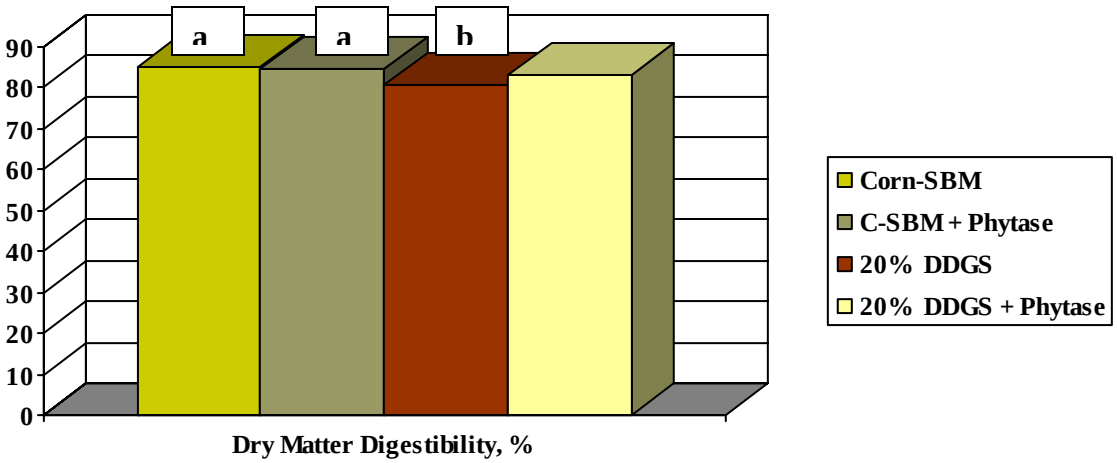
The dietary phytate concentrations were not affected by adding 10 or 20% DDGS to the diet, but fecal phytate phosphorus concentration was reduced by 27.7% when 10% DDGS was added to the diet, and by 42.6% when 20% DDGS was added to the diet compared to the amount of phytate excreted by pigs fed the corn-soybean meal control diet. As a result, fecal phyate excretion tended to be reduced when 10 or 20% DDGS was added to the diet. Furthermore, adding DDGS to nursery pig diets slightly increases manure pH, but this increase in pH is probably of little consequence to soil fertility and cropping systems. Adding 20% DDGS to nursery diets and formulating on an available phosphorus basis, reduced the amount of particulate P in manure compared to when 10% DDGS was added to the diet and formulating on a total phosphorus basis. However, there were no differences among dietary treatments for the amount of soluble P excreted in the manure.

Experiment 2

This experiment was conducted to determine the effects of adding 20% DDGS and/or phytase to corn-soybean meal diets, when formulated on an available phosphorus basis, on manure phosphorus excretion in nursery pigs. A total of 32 pigs (22.3 lbs in initial body weight), were assigned to one of four dietary treatments, providing 8 replicates per dietary treatment. All diets were formulated on an available phosphorus basis and consisted of a corn-soybean meal control diet, corn-soybean meal + phytase, corn-soybean meal + 20% DDGS, and a corn-soybean meal + 20% DDGS + phytase diet. Diets containing DDGS had lower levels of supplemental phosphorus (dicalcium phosphorus) and higher levels of supplemental calcium (ground limestone) in order to equalize calcium and total or available phosphorus levels among the diets. The addition of DDGS to the diet also increased the level of crude protein (nitrogen) in order to keep dietary lysine levels constant across dietary treatments.

All pigs were fed an amount of their assigned experimental diet equivalent to 2.5% of their body weight twice daily, and feed intake was not different among dietary treatments. Diets containing phytase had lower dietary concentrations of total phosphorus compared to diets not supplemented with phytase, which tended to reduce daily phosphorus intake. These results are expected because adding phytase to the diet and formulating on an available phosphorus basis reduces the total amount of phosphorus consumed by the pig.

When 20% DDGS was added to the diet, dry matter digestibility was reduced by 3.5% compared to corn-soybean meal diets. However, this reduction in dry matter digestibility is less than the 5.1% reduction obtained in experiment 1 when 20% DDGS was added to the diet. However, it is interesting that when phytase is added to a 20% DDGS diet, dry matter digestibility was numerically higher (83.1%) compared to when no phytase was added to the 20% DDGS diet (80.9%), shown in Figure 2.



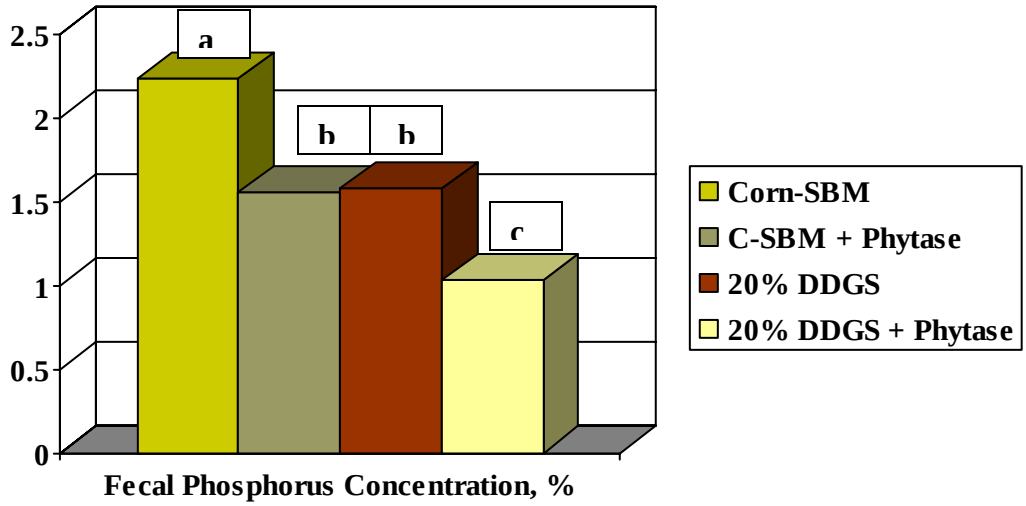
a,b Means with different superscripts are significantly different (P < .05).

Figure 2. Effect of Feeding Corn-SBM Diets With or Without 20% DDGS or Phytase on Dry Matter Digestibility (%)

Adding phytase to the corn-soybean meal diet reduced fecal phosphorus concentration by 30.5%, which was comparable to the reduction in fecal phosphorus concentration when 20% DDGS was added to the diet (29.1%) compared to the corn-soybean meal control diet, but less than the fecal phosphorus concentration reduction observed when 20% DDGS was added to the diet in experiment 1 (34.1%). Adding both phytase and 20% DDGS to the diet further reduced fecal phosphorus concentration by about 34% compared feeding diets with only phytase or 20% DDGS, and by 53.8% compared to feeding the corn-soybean meal control diet without phytase. These results suggest that an additive or synergistic effect for phytase and DDGS for reducing fecal phosphorus concentrations. Phytase appears effective in improving phosphorus availability in DDGS, beyond the high phosphorus availability already present in DDGS. In fact, pigs fed the 20% DDGS diet with phytase had 17.3%, 11.6%, and 22.0% higher phosphorus digestibility than pigs fed the 20% DDGS diet, corn-soybean meal + phytase diet, and the corn-soybean meal control diet, respectively (Figure 3).

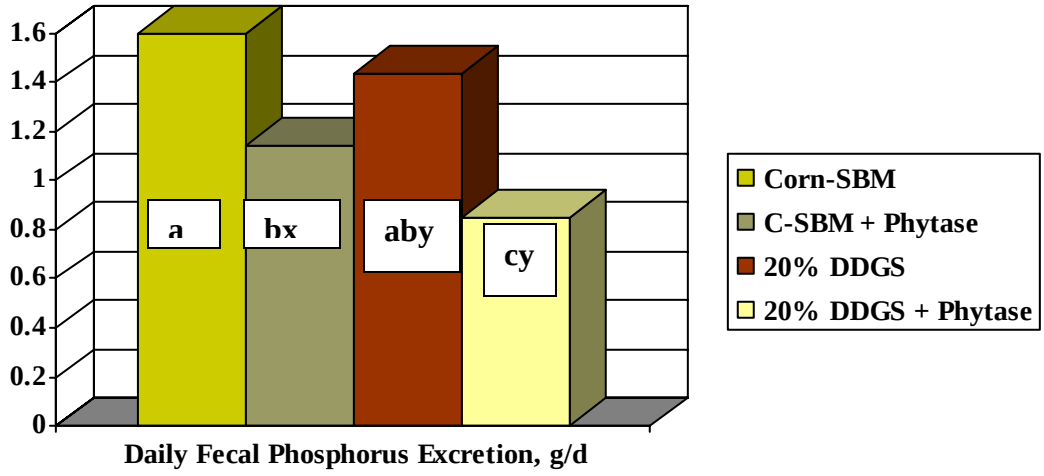
Unlike the results obtained from experiment 1, adding 20% DDGS to the diet tended to reduce daily fecal phosphorus excretion by 16.8% compared to pigs fed the corn-soybean meal control diet. This was a result of a lower reduction in dry matter digestibility observed in experiment 2 compared to experiment 1. These results suggest that adding DDGS to the diet is effective in not only reducing the phosphorus concentration of swine

manure, but also total phosphorus excretion. Although the addition of phytase to corn-soybean meal nursery diets is more effective in reducing total phosphorus excretion than when 20% DDGS is added to the diet (32.5% vs. 16.8% reduction, respectively), the combination of adding 20% DDGS and phytase to the diet resulted in the greatest reduction in total phosphorus excretion in manure (46.9%) as shown in Figure 4.



a,b Means with different superscripts are significantly different (P < .05).

Figure 3. Effect of Feeding Corn-SBM Diets With or Without 20% DDGS or Phytase on Fecal Phosphorus Concentration (%).



a,b,c Means with different superscripts are significantly different (P < .05).
x,y Means with different superscripts are significantly different (P < .15).

Figure 4. Effect of Feeding Corn-SBM Diets With or Without 20% DDGS or Phytase on Daily Fecal Phosphorus Excretion (g/d)

Experiment 3

This experiment was conducted to determine the effects of adding 20% DDGS and phytase to corn-soybean meal diets and using different calcium:available phosphorus ratios, on manure phosphorus excretion in nursery pigs. A total of 48 pigs (29.1 lbs in initial body weight), were assigned to one of six dietary treatments, providing 8 replicates per dietary treatment. All diets were formulated on an available phosphorus basis and consisted of either corn-soybean meal diets with calcium:available phosphorus ratios of 2:1, 2.5:1, and 3:1, or corn-soybean meal + 20% DDGS + phytase diets containing calcium:available phosphorus ratios of 2:1, 2.5:1, and 3:1. Diets containing DDGS had lower levels of supplemental phosphorus (dicalcium phosphorus) and higher levels of supplemental calcium (ground limestone) in order to equalize calcium and total or available phosphorus levels among the diets.

All pigs were fed an amount of their assigned experimental diet equivalent to 2.5% of their body weight twice daily. Feed intake was not different among dietary treatments, but the DDGS diets had lower phosphorus concentrations, resulting in lower daily phosphorus intake. Pigs fed the corn-soybean meal diets with 2:1 and 2.5:1 Ca:available P ratios had lower daily fecal excretion and higher dry matter digestibility than pigs fed the 20% DDGS diet containing a 3:1 Ca:available P ratio. These results suggest that lower Ca:available P ratios (2:1 and 2.5:1) minimize fecal excretion and optimize dry matter digestibility.

As observed in previous experiments, adding 20% DDGS and phytase to nursery diets reduces fecal phosphorus concentration by 41.7% compared to corn-soybean meal diets without phytase. However, this reduction in fecal phosphorus concentration was lower in this experiment compared to the 53.8% reduction observed in experiment 2. Although dry matter digestibility was lower for pigs fed the 20% DDGS + phytase diets compared to pigs fed the corn-soybean meal diets, the greater reduction in fecal phosphorus concentration resulting from higher phosphorus digestibility, resulted in a 35.4% reduction in manure phosphorus excretion.

Formulating nursery diets to contain a 2:1 Ca:available P ratio resulted in a trend for lower daily fecal excretion, lower daily fecal P excretion, and higher P digestibility, urine P concentration and excretion compared to diets with 2.5:1 and 3:1 Ca:available P ratios. The net effect is that formulating diets using a 2:1 Ca:available P ratio tends to provide the highest P retained as a percentage of P intake and the lowest total P excretion.

Summary

Results from these studies show that high quality corn DDGS can be added to swine nursery diets to reduce manure phosphorus concentrations, and reduce total phosphorus excretion depending upon the extent of the reduction in dry matter digestibility that occurs when DDGS is added to the diet. Adding DDGS at a level of 20% to nursery pig diets formulated on an available P basis may have minimal effects on total P excretion (5.9% reduction observed in experiment 1), or a tendency to have a greater effect on total

P excretion (16.1% reduction observed in experiment 2). Although phytase significantly reduces, and DDGS tends to reduce total phosphorus excretion, the greatest impact for reducing total P excretion in manure is when nursery diets contain both phytase and 20% DDGS. In order to optimize P retention and minimize P excretion, a 2:1 Ca:available P ratio should be used when formulating diets containing phytase and DDGS on an available P basis.

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