National Swine Nutrition Guide
factsheet
Pork Information Gateway

Feed Additives for Swine - Enzymes and Phytase

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Introduction

Even though pig feed is ground, it must still be broken down into even smaller molecules in order to be absorbed from the digestive tract. For example, proteins must be broken down into amino acids and starch must be broken down into glucose. The digestion of feed in the pig is achieved through the use of enzymes that the pig naturally secretes from its stomach, pancreas and small intestine.
However, the pig's array of enzymes is not capable of breaking down all components of its diet. Since the pig is unable to fully utilize all components of its diet, specific enzymes can be added to the feed to help break down complex carbohydrates, protein and phytate. These enzymes are called carbohydrases, proteases, and phytases, respectively. They are derived from bacteria and yeasts. At the time of writing, almost 200 different enzymes and enzyme products were available worldwide to the pork industry.

Objectives

- Understand why dietary enzymes may be added to swine diets
- Discuss the most common types of dietary enzymes

Understanding dietary enzyme use in swine diets

Enzymes are most commonly used when the dietary ingredients contain relatively higher amounts of fiber [1]. The various forms of fiber in the pig's diet will not be well digested by the pig; as a result, a large portion of the fiber in the diet passes through the small intestine intact, and the only breakdown that can occur is through fermentation by bacteria and yeast in the cecum and large intestine. Diets containing higher fiber cereal grains, such as barley, are supplemented with enzymes more frequently and with greater success then diets that are corn based. In fact, responses to dietary enzymes in corn based diets are limited and generally little or no growth benefit will be seen from their use [2].

Another application of enzymes is to break down the phytate molecule that binds phosphorus and some other mineral elements in plant based feedstuffs. Because a significant portion of phosphorus in the diet of the pig is bound to phytate, it will not be well digested by the pig.

The use of enzymes in the diet is not limited to the pig. Indeed, they are sometimes used in the human diet. For example, some people are unable to digest lactose, or milk sugar, and in some cases, adding the enzyme lactase will bring relief. Lactase is a carbohydrase, because lactose is a carbohydrate.
The science of enzymes in pig diets continues to rapidly evolve. New technologies are able to develop enzymes that are not only more specific in their dietary target, but they have improved adaptability to the gut of the pig.

Most common types of dietary enzymes

Carbohydrases

The main carbohydrate in the pig's diet is glucose, provided by starch in corn. More than 95% of the starch in corn can be digested. However, not all carbohydrate in corn is starch. The more complex carbohydrates are called fiber and are not well utilized by the pig.

In corn co-products, such as distillers dried grains (DDGS), this fiber fraction is concentrated, just like protein and fat, and thus represents a higher portion of DDG's than in the native corn. Producers will see this in their barns; if they feed diets containing significant levels of DDG's, more fiber is apparent in the manure and accumulates in the pits. This is visual proof that corn fiber is not well utilized by the pig.

Other grains that might be used in pig diets include wheat, barley, sorghum and milo. All contain varying amounts of fiber that is poorly used by the pig.

Specific enzymes are available in the marketplace to help the pig digest fiber. These are called carbohydrases, because they break down carbohydrates. They are often named after the specific target carbohydrate they attack. Thus, one will hear and read about amylases, pectinases, B-glucanases , xylanases, cellulases, etc. Amylases break down amylase, pectinases break down pectin, etc.

Carbohydrases are most effective in the diet of the young pig. No one really knows why, but it may be due to the poorer digestive capability of the young pig. If a pork producer wants to focus the use of carbohydrases on his farm, the nursery is the place to do it [3].

Enzyme manufacturers design enzymes, or blends of enzymes called enzyme cocktails, to work with specific types of diets. The type and quantity of enzyme used should be according to the manufacturer's instructions. However, the type of enzyme used should match the type of fiber found in the diet [4].

Proteases

Just as carbohydrases attack carbohydrates, proteases attack proteins. Thus, proteases may be added to pig diets to help the pig digest proteins that are resistant to the digestive enzymes which naturally occur in the intestine of the pig. However, due to the relatively high protein digestibility of soybean meal and other common protein sources, the amount of protein not broken down for absorption is limited. Thus, the capacity for responses in growth rate or feed efficiency is currently limited with these protease products.

Phytases

Phytate is a complex molecule that exists in feed ingredients of plant origin [Figure 1.; 5]. About 28% of phytate is phosphorus, but much of this phosphorus is of little value to the pig, because it secretes only small and inadequate amounts of the phytase enzyme. As a result, pork producers have traditionally had to add phosphorus-rich ingredients to the diet to ensure that the pig's requirement for this mineral is met. This approach was necessary, but costly and had potential consequences for the environment; undigested phosphorus passes through the pig and enriches manure with phosphorus. If manure is applied to crop land at excessive rates, phosphorus will accumulate in the soil.

In 1990, it was first demonstrated that adding phytase of microbial origin to pig diets increased the availability of phosphorus, thus reducing the amount of phosphorus that must be added to the diet. The technology has been rapidly adopted by the pig industry around the world, and now is a common ingredient in practical diets [6].

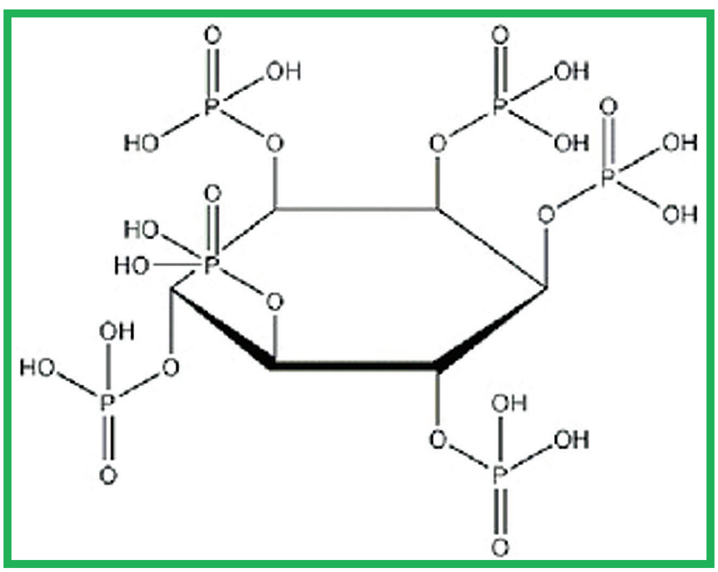

Figure 1. Phytate molecule.

The phytase enzyme has been known to exist for more than a century. As it relates to swine, there are four possible sources of phytase that must be considered. Second, the microflora which inhabits the hindgut of the pig possesses phytase activity. However, the breakdown of phytate in the large intestine is of little value to the pig, because there is little absorption of phosphorus once the digesta leaves the small intestine. Third, some ingredients, such as wheat, barley, triticale and rye also contain the enzyme; this phytase is believed to be particularly susceptible to heat, such that pelleting is assumed to virtually eliminate any benefit from plant-based phytase. Finally, exogenous phytase of bacterial or yeast origin can be added to the diet.

So-called exogenous phytase is derived principally from bacteria (e.coli) or fungi (Aspergillus niger, peniophora lycii). Phytase activity is typically reported in phytase units (FTU); in a laboratory setting, one FTU liberates 1 umol of inorganic phosphate per minute from 0.0051 mol/L of sodium phytate at pH 5.5 and at 37^{0}C. However, some products on the market use different units, making it difficult to compare products.

There are a variety of commercially-available phytases that are approved for use in US pork production [7]. These phytases can be characterized as 3- or 6-phytases, depending upon where they begin dephosphorylating the inositol ring of the phytate enzyme. Those characterized as 3-phytases, such as Natuphos and OptiPhos, begin dephosphorylation at the 3 carbon on this ring. In contrast, 6-phytases, such as Phyzyme, Ronozyme, and Quantum, begin dephosphorylating the inositol ring beginning at the 6 carbon. The position in which the dephosphorylation occurs has been proposed to affect the efficacy of the phytase and its potency at various pH levels, however supporting research in pigs is scarce.

Typically, phytases have been added to the diet at 225 FTU/lb (AOOC method of analysis), but recent increases in the cost of supplemental phosphorus have seen some nutritionists recommending 350 FTU/lb or more depending on the dietary ingredients included. Although the effectiveness of phytases may vary among products, it is believed that 225 FTU/lb of phytase may release up to 0.10% phosphorus in corn based diets. However, consult with your phytase supplier about specific recommendations and release values to avoid over or underestimations of phosphorus release from your phytase source.

It is certain that newer phytase products will be introduced to the marketplace in the future. The principle targets of innovation are thermo-stability, resistance to endogenous proteolytic enzymes and pH optima that are reflective of the conditions in the stomach and duodenum of the pig. Indeed, products are currently on the market that possesses significant stability during pelleting.

There remains some controversy with respect to the ability of the phytase enzyme to increase the availability of nutrients other than phosphorus. Some research has suggested an improvement in amino acid and/or energy availability, while others have not. The benefit if it exists at all is very small, in the range of 2%, and is dependent on many factors, including diet composition [8].

There are a number of factors that will affect the efficacy of exogenous enzymes. Because phytase exists as a complex with magnesium, pH is an important issue. The solubility of phytate, and thus susceptibility to phytase, increases as pH declines; similarly, solubility rapidly declines when pH rises above 5. The presence of inorganic phosphate, and a wide ratio of calcium to phosphorus, will both impair the effectiveness of exogenous phytase. It is generally recommended that the Ca:P ratio should be close to 1:1 in order to maximize the success of phytase use. Finally, the use of high levels of zinc is contraindicated when phytase is being used. It has been shown, for example, that 1,500 ppm zinc reduces the release of phosphorus from phytate; this is probably due to the formation of highly stable Zn-phytate complexes. Therefore, phytase will be less effective in nursery diets containing high levels of zinc. One study showed an almost 30% reduction in phytase efficacy when 1,500 ppm of zinc was added to the diet [9].

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Frequently asked questions

How do I decide whether or not to use enzymes in my diets?

Enzymes are most effective in the diet of the young pig, whose digestive capabilities are less well developed than in older pigs. Thus, enzyme use is much more common in starter diets than in finisher diets and are much less commonly used in sow diets. However, in corn based diets, the lack of growth response to dietary carbohydrases and proteases does not justify their use at this time.

How do I decide which enzymes to use in my diets?

The enzyme selected for a given diet will depend on the ingredients contained in that diet because enzymes have specific target compounds. For example, xylanases are most effective in diets containing wheat, and glucanases are most effective in diets containing barley. Because corn has less fiber than many other grains, the response to enzymes in corn tends to be less than seen in more fibrous diets.

Why do some people refer to the use of phytase as environmentally desirable?

Much of the naturally occurring phosphorus in plant-based ingredients is not available to the pig, the undigested phosphorus goes through the pig and into the manure. When phytase is used, and diets are properly balanced, less phosphorus passes through the pig undigested and therefore the quantity of phosphorus in the manure is reduced. Thus, less land is required to spread this manure on cropland in an environmentally sustainable manner. Also, when phytase is used, less inorganic phosphorus, like monocalcium phosphate, is required in the diet; since these phosphate sources must be mined from the ground and are available in finite quantities, the use of phytase reduces the need to mine phosphates and ensure these sources will continue to supply the needs of the livestock industry well into the future.

Do I need to re-formulate my diets if I use an enzyme?

When talking about phytase, the answer is a definite yes. There is no logic to adding phytase to a diet to make the naturally occurring phosphorus more available to the pig, and then continue to add the same amount of phosphorus supplements to the diet. The solution is to formulate diets on an available or digestible phosphorus basis and attach a "phosphorus equivalent" value to phytase. A trained nutritionist is required to ensure this is done correctly, meaning full value for the phytase is achieved but the risk of a phosphorus deficiency is avoided.

For other enzymes, the answer is less clear. If the objective of using carbohydrases is to lower feed cost, then the energy level of the diet should be reduced by the quantity of energy and amino acids one expects will be released by the enzyme. However, if the objective is to increase performance, then reformulation of the diet is unnecessary if the enzyme is expected to increase energy and amino acids by the same proportion.

Is there a withdrawal period for dietary enzymes?

Just like any other protein, enzymes are broken down in the digestive tract so no metabolites are absorbed or residues excreted through the feces that would require a withdrawal period.

If I feed DDGS or other cereal by-products should I add enzymes?

Phytase can be used in diets containing cereal by-products such as corn DDGS. However, corn DDGS contains more available phosphorus than corn itself, so formulation should be on the basis of digestible or available phosphorus. Research has shown that phytase and DDGS can be effectively used in combination to reduce feed costs; of course, phytase and DDGS have to be priced appropriately to achieve savings.

How do they make an enzyme (phytase) heat stable to survive pelleting and does that change it's effectiveness?

Phytase is made heat stable by a special process to coat the phytase to protect it from breakdown when exposed to higher temperatures. Coated phytase for heat stability does not impair the effectiveness of the phytase enzyme. In addition, research is underway to improve phytase thermo-stability by actually changing the structure of the enzyme.