Understanding the anti-nutrient effects of phytate in pig diets

by Dr Pete Wilcock, Global Technical Manager, AB Vista.

As the use of phytase feed enzymes has grown in recent years, so too has interest in the potential benefits to be gained not just from the release of valuable phosphorus (P) bound up as phytate, but also from elimination of phytate itself.

The challenge for pig producers is that phytate is both a nutrient – due to its P content – and an anti-nutrient, with an ability to significantly disrupt nutrient digestibility and absorption. Whilst the role of phytate as a source of P is widely recognised, the substantial negative impact of phytate as an anti-nutrient remains much less well understood.

The phytate challenge

Phytate itself, also sometimes referred to as phytin or phytic acid, is the major storage form of P in seeds and is part of a complex that also contains potassium, magnesium and calcium. Originally recognised as a key source of P during seed germination, the presence of phytate is now also known to play an important role in reducing oxidative stress during the germination process, preventing plant embryo death.

In animal nutrition phytate was initially viewed as an extremely valuable potential source of P that could be made available through targeted use of a phytase feed enzyme. However, the focus in recent years has shifted to the anti-nutrient role phytate plays within the digestive tract.

This anti-nutrient effect is substantial, and clearly demonstrated by the data presented in Fig. 1. The average daily gain (ADG), feed conversion ratio (FCR) and average daily feed intake (ADFI) of weaned piglets were all negatively affected by the addition of 2% phytic acid to a significant degree.

In other trials, even a small 0.16% increase in dietary phytate concentration has been shown to reduce ADG by 3% during the starter period.

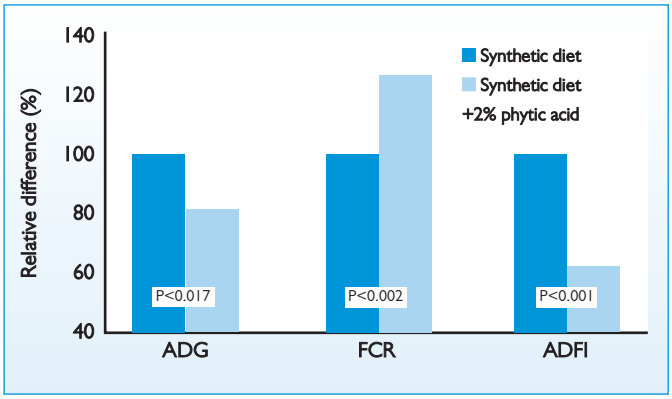
Modes of action

There are several modes of action by which phytate has this negative effect, though all act to reduce digestibility and utilisation of important nutrients supplied in the diet. Key amongst these is the ability of the phytate molecule to bind with both proteins and minerals present in the intestinal tract, resulting not only in reduced availability, but also detrimental endogenous responses by the pig.

Much of this binding effect can be attributed to the negative charge of the phytate molecule itself when in solution, even at the low pH found in the stomach. In addition, this negative charge increases as the pH rises, thereby increasing phytate's ability to react with positively charged cations (primarily divalent cations such as calcium, zinc and copper) as it passes through the digestive tract from the acid stomach to the more neutral pH of the lower intestine.

The net result is the formation of stable salts which then precipitate out of solution, rendering these crucial minerals less available for absorption and utilisation by the pig.

Fig. 1. Performance of piglets 21 days post-weaning fed low or high concentrations of phytic acid (Woyengo, 2010).



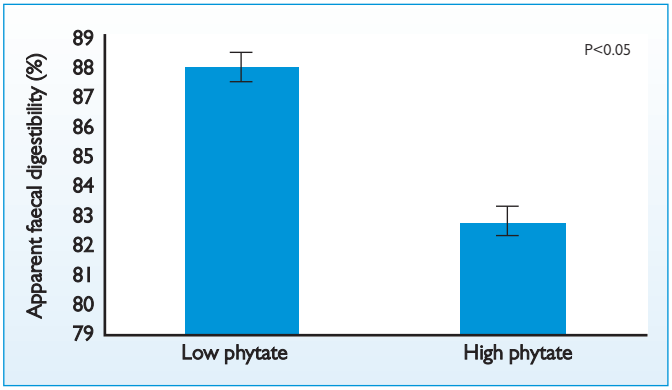


Fig. 2. Apparent faecal energy digestibility (%) of 40kg pigs fed low or high phytate diets (Liao et al., 2005).

Protein digestibility

Dietary phytate can also result in a significant reduction in protein digestibility, though this appears to occur through a different mode of action. For example, in vitro studies have shown that between pH 1.0 and 2.8, the presence of phytate can reduce activation of pepsin, a key enzyme responsible for protein breakdown in the stomach.

Any such reduction in pepsin activity would result in less protein being initially broken down during the acid phase of the digestive process, and lead to a lower overall protein digestibility. Since the pH of the stomach contents is typically in the range pH 2-3, it is highly likely that the anti-nutrient effect of phytate on amino acid digestibility is due to lower pepsin activity.

Whilst this reduced pepsin activation may be overcome by higher production of its precursor, pepsinogen, in the stomach, phytate presence also directly reduces protein solubility and subsequent digestibility. This occurs through feed proteins (positively charged at low pH) binding to phytate (negatively charged), and subsequently co-precipitating.

Finally, the presence of phytate can reduce the activity of the sodium/potassium 'pump', which is crucial to amino acid uptake across the gut wall.

Endogenous losses

The resulting overall reduction in protein digestibility also has an additional negative effect on the pig.

The rise in the level of undigested protein reaching the duodenum increases secretion of the hormones gastrin and cholecystokinin, which in turn stimulate greater production of hydrochloric acid (HCl) and pepsinogen in the stomach whilst reducing gastric emptying.

A greater amount of sodium bicarbonate then has to be secreted into the duodenum to neutralise gut content pH, whilst the additional irritant effect on the gut mucosa leads to extra mucus production to maintain

Continued on page 20

Continued from page 19
protection levels. The net effect is a substantial increase in endogenous losses. In fact, the energy cost of additional secretions and losses in the gastrointestinal tract as a result of phytate anti-nutrient effects has been shown to reduce energy metabolism in pigs by around 8% (see Fig. 2).

Phytate elimination

Perhaps the clearest indication of the impact on performance from the anti-nutrient effects of phytate comes from trials where phytate is effectively eliminated through the use of a highly efficient E. coli phytase at three to four times the standard dose. Known as superdosing, this approach relies on the use of a phytase developed specifically to target near complete phytate destruction, while only accounting for a standard mineral matrix dose during diet formulation.

Fig. 3 shows the results of 19 trials in which superdosing with Quantum Blue phytase was compared to the performance of a matched control diet (red line, 100%) formulated to be nutritionally adequate, including calcium and phosphorus. In 16 of the trials (84%), ADG exceeded that of the control diet, whilst feed conversion efficiency was improved in 14 (74%), and only two trials failed to demonstrate a benefit in either measure.

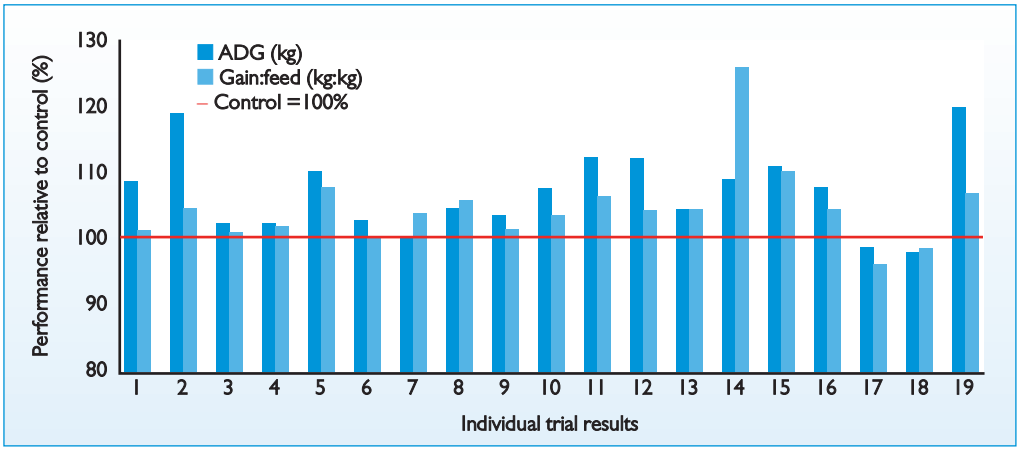


Fig. 3. Influence of 19 superdose treatments using novel E. coli phytase (Quantum Blue) on pig average daily gain (ADG) and feed efficiency (gain:feed) compared to pigs fed the respective control.

Not all phytases are sufficiently active at the pH found in the stomach – or able to continue degrading phytate towards elimination as concentrations fall – to be effective for such superdosing. However, the results in Fig. 3 clearly show the efficacy of Quantum Blue phytase in producing performance benefits beyond simple mineral provision (all diets were adequate in P supply) through phytate elimination.

Substantial financial gains

The net effect of such improvements have far reaching implications, with current estimates suggesting that the anti-nutritional effects of phytate could be costing the global monogastric feed industry over €2 billion/year.

As such, there is little doubt that as awareness of the negative impact of phytate on pig performance and profitability increases, so too will the use of high doses of phytase to achieve phytate elimination.

The arrival of commercial phytases like Quantum Blue specifically developed to maximise phytate destruction will also help to ensure end users are able to achieve consistent results.

This is a factor likely to be critical to the widespread uptake of superdosing as pig producers look to reclaim the revenue currently lost to the anti-nutrient phytate. ■

References are available from the author on request