Profitable use of new enzymes in pig production

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Modern genotypes of pig have a tremendous capacity for lean gain that is seldom realised under commercial conditions.

The twin vagaries of disease challenge and rising raw material prices are a particular and persistent threat to the profitability and competitiveness of the global pig industry. It is, therefore, imperative that the industry avails itself of well proven, new technologies that can have a positive impact on pig performance and profitability.

Fluctuating raw material prices in recent years have been driven by an escalating demand for global food production for man and animals, coupled with the increasing diversion of grain from the food chain to ethanol production.

As a consequence, global grain outputs have consistently failed to meet demands in recent years and reserves of grain have fallen from 115 days in 1999-2000 to a projected 53 days in 2007-2008, representing an average annual depletion of 9.2% since the turn of this century (Qualman 2007).

Against this changing raw material background there have also been increasing pressures on the animal industry to:

- Reduce its reliance on sub-therapeutic antibiotic growth promoters.
- Minimise its impact on the environment.

Both of which have required the adoption of alternative strategies involving changes in both feeding and husbandry techniques.

Feed enzyme technology has gained increasing acceptance over the past 15 years and is now seen as one important weapon in the armoury required to feed the modern pig, in a cost efficient and environmentally responsible way.

Fundamental knowledge on the mode of action of feed enzymes has also indicated the role they can play in an integrated approach to counter certain digestive disorders provoked by shifts in dietary raw materials and associated formulations.

This article examines some of the main ways in which enzymes are currently used to improve the economics and sustainability of modern pig production systems.

Enzymes and their use

There are currently three main classes of enzyme that have found a place in commercial feed formulation:

- Phytases.
- Carbohydrases.
- Proteases.

The merits and usage of each will be separately considered.

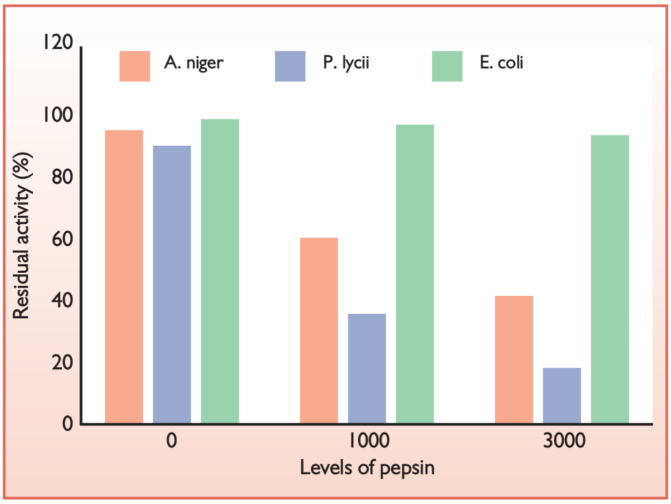


Fig. 2. In vitro residual activity (%) of three different phytase sources from A. niger, P. lycii or E. coli after incubations with increasing levels of pepsin (0-3000U) at pH2.0 and 37°C for 30 minutes (Greiner and Farouk, 2007).

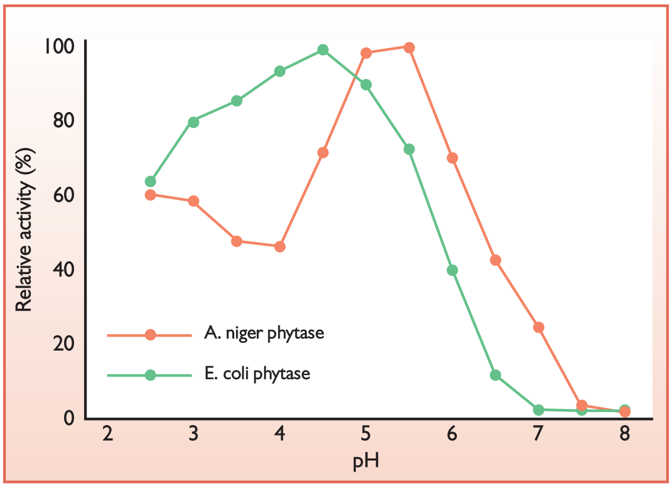
Phytases

Since the introduction of a 'first generation' fungal phytase product in the Netherlands in the early 1990s the acceptance of the use of phytase has expanded rapidly.

It is now estimated that around half of the diets offered to pigs and poultry globally contain an exogenous phytase.

Contributing factors to this rise in application include increasing legislation designed to curb phosphorus pollution, lower feed enzyme inclusion costs relative to inorganic phosphorus supplements and the increasing trend towards the removal of meat and bone meal from mono-gastric diets in many countries.

Fig. 1. The relative activity (%) of E. coli phytase over a pH range of 2.0-4.5 in the proximal digestive tract is 50% higher than A. niger phytase (Wyss et al 1999).



In practical pig feed formulation, nutritionists assign 'matrix values' for both phosphorus and calcium to phytase, under the assumption that typical inclusion rates (for example, 500 FTU/kg feed) of new, 'second generation' phytase products can contribute approximately 0.12% available phosphorus and 0.09% calcium to the final feed.

This adjustment to dietary phosphorus levels when using phytase facilitates reductions in both feed costs and in the amount of phosphorus excreted.

More recent mechanistic research on phytase has also shown its capacity to improve protein and energy utilisation, offering further potential to reduce feed costs.

The claimed advances in second generation phytase products (for example, from E. coli) versus first generation phytase products (for example, from A. niger and P. lycii) principally hinge on differences in enzyme characteristics, such as pH optima and their relative sensitivity to endogenous proteins (for example, pepsin and trypsin) which impinge on the ability of different phytases to break down dietary phytate in the stomach and duodenum.

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Phytate is a potent anti-nutrient, as well as a potential phosphorus source and consequently the speed at which any particular phytase exerts its effects in the gut is critical to its bio-efficacy.

In this respect independent research has shown that certain new phytases (for example, some of those from E. coli) are both more active at acidic pHs than other phytases but, equally important, because of their molecular structure are more resistant to attack by protein digesting, endogenous secretions (Figs. 1 and 2).

The increasing competitiveness of the phytase supply industry in recent years, coupled with cumulative increases in inorganic phosphorus cost, has also created much more interest in the cost effective use of higher phytase levels (for example, in the range 500-1000FTU/kg feed) to reap the multiple benefits of improved nutrient release, further reductions in phosphorus excretion and increased feed cost savings.

Advances in enzyme technology have also led to tremendous improvements in the thermo-tolerance of enzyme products in recent years, enabling them to better survive the rigours of feed processing.

Various heat treatments of feed have been seen as an obligatory contribution to the control of certain disease challenges in pig and poultry production, although the wisdom of this approach is frequently questioned by nutritionists because of its potentially negative impacts on heat sensitive nutrients and the increased likelihood of detrimental cross reactions between nutrients in the diet (for example, Maillard reactions).

Thermotolerance of enzyme products is conventionally achieved by the use of various coating techniques to ensure the enzyme survives the feed conditioning and pelleting process.

Equally, once the enzyme is consumed in the feed, the coating system must break down rapidly to release the enzyme in the stomach

	Positive control	Negative control	Negative control + Danisco xylanase
Daily gain (g)	522[a]	441[b]	491[ab]
Daily feed intake (g)	773[a]	656[b]	765[a]
Feed/gain (g/g)	1.48	1.51	1.56

[a,b] $P<0.05$ * Wheat middlings starch 36.4%; NSP 20.5% (95% insoluble)

Table 1. Effects of xylanase addition (Porzyme 9300, 1kg/tonne) to a corn based diet containing high levels (30%) of wheat middlings on young pig performance (9-20kg).

	Positive control	Negative control	Negative control + Danisco xylanase
Protein digestibility (%)	82.6[a]	71.1[b]	79.2[a]
Energy digestibility (%)	86.9[a]	73.3[c]	80.2[b]

Table 2. Effects of xylanase addition (Porzyme 9300, 1kg/tonne) to a corn based diet containing high levels (25%) of wheat middlings on faecal digestibility of protein and energy.

of the pig so that it can exert its effects on the phytate substrate – releasing bound phosphorus and quickly reducing the anti-nutritional effects of dietary phytate.

In our experience different coating systems can vary substantially in their ability to dissociate in the gut and this, together with variations in the characteristics of the enzymes mentioned above, can underlie substantial differences in relative bio-efficacy (Fig. 3).

A further complication for end users of enzyme products, including phytase, is to ensure that the assay methodologies that are being routinely used to describe products are directly comparable. For example, unit definitions for phytase are frequently described in terms of FTU/kg feed, quoting defined pH and temperature conditions for the assay.

However, as specific buffer systems can also influence the number of units measured, independent of pH and temperature, then unit values on paper can be misleading without sufficient background information.

Customers for enzyme products should, therefore, be aware that in vivo bio-efficacy, after using standardised assay methodologies, is the only way of realistically comparing the value of two competing phytase products.

Table 3. Effects of xylanase addition (Porzyme 9300, 1kg/tonne) on performance (daily gain (%), feed/gain (%)) of pigs fed corn based diets containing varying inclusions of fibrous grain by-products.

Trial No.	Grain by-product	Level (%)	Effect on daily gain (%)	Effect on feed:gain
1	Wheat pollard	20	5.6	10.1
2	Wheat pollard	20	6.7	4.3
3	Rice bran	15	5.9	9.0
4	Rice bran	20	7.9	-
5	Rice bran	15	12.0	-
6	Wheat pollard	43	4.2	3.0
7	Rice bran	20	6.3	1.9
8	Rice bran	30	4.5	3.4
9	Wheat pollard	20	11.3	19.5
10	Rice bran	30	4.1	6.5
11	Rice bran	25	4.0	6.9
12	Wheat pollard	20	5.9	3.2
13	Rice bran	8	5.5	8.1
14	Rice bran	4	5.7	3.8
15	Rice bran	20	4.5	4.7
MEAN		21	6.3	5.6

Carbohydrases

The main carbohydrases currently used in swine feed formulations globally are xylanase, beta-glucanase and amylase. The use of each of these is dependent upon the formulation and to a certain extent, the age of the pig. Other minor carbohydrase activities such as mannanase and alpha-galactosidase are also claimed to be of benefit for specific raw material applications.

Many other activities in products are often claimed by certain enzyme suppliers, but such 'side activities' almost invariably are not subjected to routine quality control (such as on every batch of product supplied to the customer) and their contribution to the bio-efficacy of the product frequently remain unproven to discerning, independent regulatory authorities.

A reasonable first criterion for proof of bio-efficacy of a product and its key component activities is to observe, for example, the EU list of approved enzyme products, and as important, the claimed activities on any one particular product.

Under these circumstances claimed 'side activities' almost invariably do not feature – illustrating that their in vivo relevance remains unproven to independent scientific reviewers within the EU.

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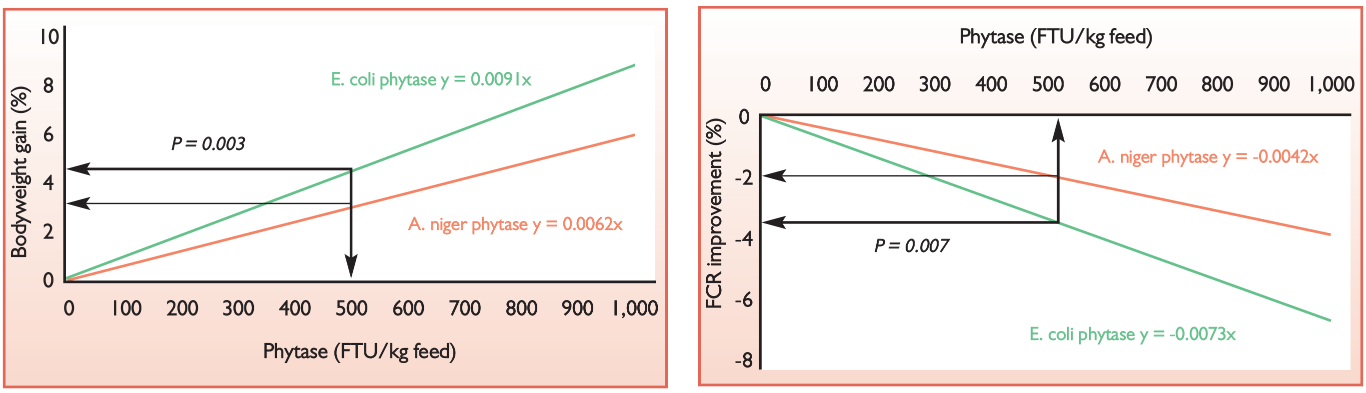
Fig. 3. Relative bio-efficacy of two phytase sources in seven performance trials with pigs (weight range 8-112kg). All diets were reduced in calcium and phosphorus, and incremental levels of each phytase were added. Bio-efficacy ratios were 1.47 and 1.73 for bodyweight gain and FCR improvements respectively. E. coli 25 treatment comparisons, A. niger 14 treatment comparisons.



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Xylanase is a core activity in many enzyme products and its importance is a reflection of the prevalence of arabinoxylan as a substrate in the fibre portion of many key grains and grain by-products (Fig. 4).

The recent increasing use of fibrous raw materials such as Distillers Dried Grains with Solubles (DDGS) in the diets of poultry and to a greater degree, in grower-finisher pigs has sparked increasing interest in the use of xylanase based products for this application.

The arabinoxylan in DDGS can be expected to be particularly susceptible to xylanase action in the same way as by-products from the grain milling industry (for example, wheat and rice by-products).

Dietary fibre generally increases gut fill and passage rate and concurrently, increases the water holding capacity of the feed, thereby, restricting both nutrient intake (via reduced feed intake) and hampering the release of water soluble nutrients in the gut (Fig. 5).

A xylanase used for this application must be proven to be particularly effective against insoluble arabinoxylan, as this is the predominant component in raw materials of this type (>95% of the total arabinoxylan content shown in Fig. 4).

Research by Danisco in recent years has shown many examples, whereby addition of a particularly effective fungal xylanase has improved both the digestibility of the diet and the performance of pigs fed fibre rich rations of this type (Tables 1 to 3).

These applications are particularly pertinent with the huge rise in bioethanol production, both currently and planned in the next few years, and the resultant rise in the supply of DDGS to the animal feed industry.

In our experience the application of xylanase, in addition to a 'routine' application of phytase for phosphorus release, appears to be the 'backbone' of successful enzyme systems for this type of diet.

Amylase, to aid the digestion of starch in the diet, appears to be particularly pertinent to the young pig where a low food intake post weaning is associated with a slow maturation of α-amylase secretion by the pancreas and compromised digestibility.

Amylase supplementation also allows the use of less cooked grain in the diet, with resultant benefits in feed cost reduction, without compromising young pig performance after weaning.

Proteases

As with amylase, the addition of protease to pig feeds has been found to be particularly beneficial in the young pig after weaning.

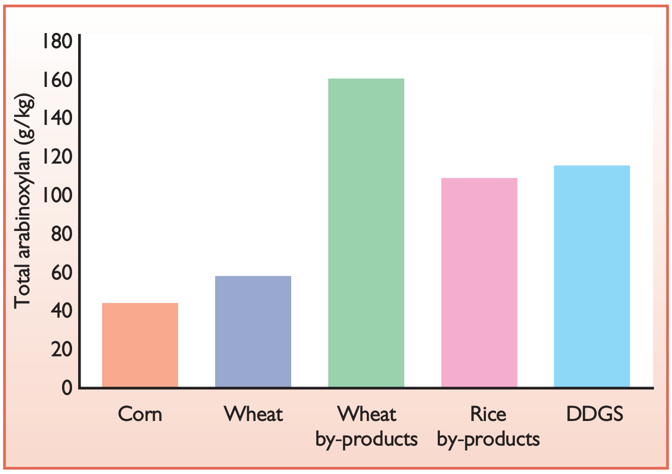


Fig. 4. Relative arabinoxylan content (g/kg) of grain and grain by-products (derived from various sources).

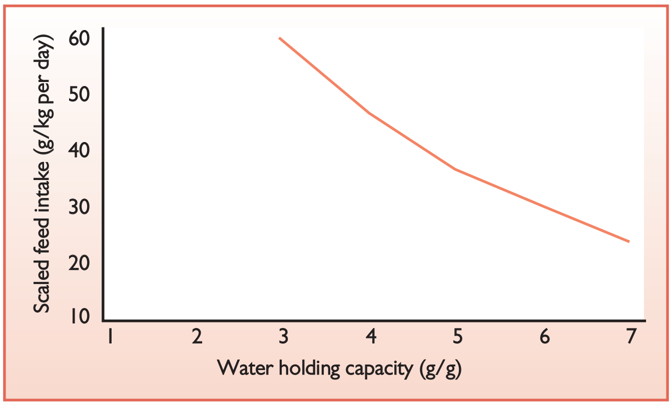
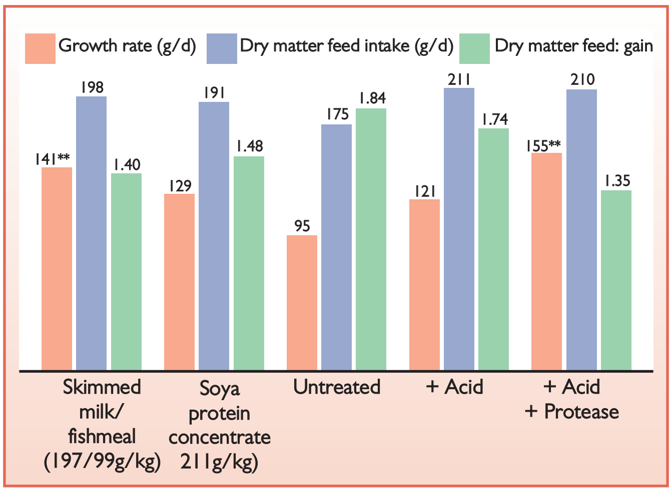


Fig. 5. Effect of the water holding capacity of the feed (g/g), as influenced by various dietary fibre inclusions, on scaled feed intake (g/kg bodyweight per day) in pigs over the weight range 12-36kg (Kyriazakis and Emmans, 1995).

The protein anti-nutrients in many vegetable proteins (for example, trypsin inhibitors and lectins), as well as the complex storage proteins themselves (for example, glycinin and β-conglycinin in soya products), can compromise young pig performance through a combination of reduced digestibility and stimulation of increased endogenous losses.

Adding protease to soya products for inclusion into young pig diets has been found to enhance pig performance, thereby, offering viable alternatives to increasingly expensive animal protein sources (for example, milk products; fishmeal, Fig. 6). The supply of value added, specialised feed ingredients using enzyme technology as part of the process is already well established in the feed industry, as is the addition of proteases directly in the feed to enhance the digestibility of certain component raw materials.

Fig. 6. Effect of protease pre-treatment of soybean meal (292g/kg in a corn based diet) on piglet performance in the first seven days post-weaning. **Significant difference (P<0.01) versus untreated soya control group.



Further advances in these technologies over the next few years can be expected to have a significant impact on the economics of pig production.

Performance of the young pig post-weaning is the area of production that could benefit greatly from these advances, as this sector has been shown to be particularly badly affected by the withdrawal of antibiotic growth promoters and the increased stringency on the use of prescription medication that is nowadays particularly prevalent in Europe.

Role of feed enzymes

Studies in recent years have highlighted the clear interactions between disease challenge and diet digestibility.

Certain anti-nutrients in feed (for example, soluble and insoluble fibres; 'resistant' starch) have been shown to be provocative to pigs under certain chronic or acute disease challenges, so the addition of appropriate enzymes to target these anti-nutrients has been found to be particularly beneficial.

Future focus and development in this area is expected, especially in conjunction with formulation changes that incorporate more fibrous raw materials.

Future perspectives

To fully exploit the genetic potential for lean growth of modern pig genotypes will require a multi-disciplinary approach.

In the nutrition sector, feed additives that can reduce the maintenance energy and protein costs of the animal will be at a premium – effectively freeing more nutrients to fuel lean growth and thereby improving the efficiency of lean meat production.

Well researched feed enzymes are one such product, allowing some flexibility for the formulator to incorporate novel and cheaper raw material sources, without compromising pig performance or the environment.

Concurrently, enzymes are likely to have an important modulating role in the dynamics of the gut microflora, working in conjunction with certain other feed additives to offset the effects of antibiotic growth promoter withdrawal and the reduced use of prescription medications. ■