

Enzymes help feed to remain profitable



SHORTAGES AND HIGH PRICES OF RAW MATERIALS PUT PRESSURE ON FEED MANUFACTURERS TO MAXIMISE THEIR EFFICIENCY OF NUTRIENT UTILISATION. THIS HAS DRIVEN FEED COMPANIES TO USE MORE OR OTHER ENZYMES. MIKE BEDFORD DISCUSSES THE PRINCIPAL ISSUES ARISING FROM USING NSP ENZYMES AND PHYTASE.

NSP (Non-starch polysaccharide) enzymes were first developed and used in barley and then subsequently wheat based diets. Their use coincided with an almost immediate and visible improvement in litter quality and an equally evident improvement in performance (Elwinger & Teglof, 1991). Use of such enzymes in corn based diets is not associated with improved litter quality, simply because there are few such problems associated with corn. In addition, the scale of animal performance response is somewhat muted compared with wheat and particularly barley based diets, and as a result the uptake rate of such products in the market has been relatively slow. Recently, however, the dramatic increase in the price of energy has meant that many feed manufacturers have taken a renewed interest in such enzymes due to the large potential savings they offer.

MODE OF ACTION

It is thought that NSP enzymes function through a composite of three separate activities, the contribution of each activity varying with ingredients and individual birds. These activities include plant (cereal) cell wall destruction, reduction of viscosity and stimulation of beneficial bacteria (Bedford & Schulze, 1998b).

The cell walls of the starchy endosperm of maize are constructed of a small amount of cellulose encrusted with hemicellulose, the bulk of which is arabinoxylan with minor β -glucan components and lesser contents of mannans (Stone, 2004).

Since monogastrics do not possess the necessary enzymatic capacity to degrade plant cell walls, the contents of any cells which remain intact following milling, processing and the grinding action of the teeth or gizzard effectively bypass digestion. Microscopy has shown that there can be an appreciable amount of such material and thus an opportunity for cell wall degrading enzymes to improve on the digestive process (Tervila-Wilo *et al.*, 1996; Parkkonen *et al.*, 1997).

Effective cell wall degradation requires the addition of sufficient amounts of the appropriate enzyme activity such that "holes" are created in the cell walls which are large enough to allow ingress of pancreatic proteases and amylases. Xylanases, and to a lesser extent cellulases (β 1-4 glucanases) have proven most effective in the field (Zanella *et al.*, 1999; Zanella *et al.*, 2004; Leslie *et al.*, 2007). Mannanases and pectinases have targeted the soy more so than the corn fraction of the diet, but with the same endpoint in mind (Jackson *et al.*, 2004). Many studies have shown improvements in starch and to a lesser extent protein digestibility which is indicative of activity of the enzyme towards corn endosperm cell walls.

VISCOSITY REDUCTION

The second mechanism relevant for NSP'ases is that of viscosity reduction. A portion of the hemicellulose may be soluble and of sufficient chain length to create a gel in the intestinal aqueous phase. The greater the chain length and quantity of this material, the more viscous the gel created (Bedford & Classen, 1992).

Viscous gels reduce the rate of diffusion of all solutes (and thus with it the rate of digestion) with the effect being proportional to the viscosity of the solution and most noticeable on the largest solutes. In the case of digestion, fat micelles are the largest solutes of interest and would be most influenced by a viscous intestinal tract (Danicke *et al.*, 2000).

Viscosity, however, is most relevant for rye and barley based diets for poultry, to a lesser extent wheat, and to a minor extent, corn (Bedford & Schulze, 1998a). This is due to the fact that the content and chain length of the soluble viscous fibres is much lower in corn than in other grains, and for this reason viscosity is not so relevant in corn-soy diets. Nevertheless, viscosity varies with variety, climactic conditions during cereal growth, post-harvest handling (e.g. drying) and pelleting/extrusion. It is possible, therefore, under the right set of circumstances, for viscosity to play a role even in a corn-soy diet, but the frequency of such events is likely to be low. Provided that an enzyme is used which can attack the offending soluble fibres, the rate of viscosity reduction can be rapid as only a few, well-targeted attacks towards the middle of the chain are required to dramatically reduce average chain length and hence viscosity.

BREAKING DOWN CELL WALLS

The third mechanism relates to the fact that as a result of the NSP'ase breaking down cell walls or reducing chain length of viscous polymers, smaller fragments of cell wall material are produced. At some point the fragments become small enough (i.e. oligosaccharides) and numerous enough to act as a substrate (pre-biotic) for bacterial fermentation. Xylanases, mannanases and cellulases produce xylo-, manno- or gluco- oligosaccharides respectively.

The benefit of such end products depends upon the type and quantity of the oligosaccharides produced, with different enzymes producing different oligosaccharides. Many beneficial species of bacteria are able to utilise such products to varying degrees and in doing so produce volatile fatty acids which provide a source of energy and pathogen control for the chick (Choct *et al.*, 1999; Bedford & Apajalahti, 2001; Sohail *et al.*, 2003). Care must be taken in selection of the enzyme however, as some products can, if overdosed, reduce the size of the oligosaccharides down to mono-saccharides. If suffi-

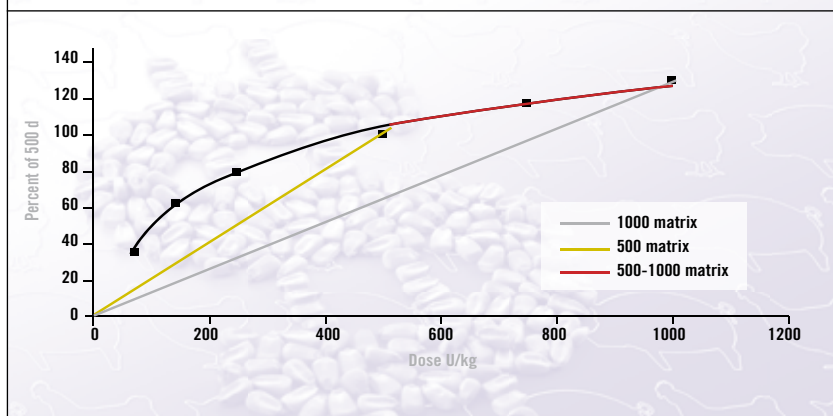


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FIGURE 1 – RELATIONSHIP BETWEEN DOSE OF PHYTASE AND EXPECTED RESPONSE



cient monosaccharide is produced it may result in osmotic diarrhoea and/or poor performance (Schutte, 1990). Such a problem is most likely to occur with endo-xylanases which are not too specific in their requirements for binding to substrate and is particularly an issue with crude preparations which contain substantial amounts of exo- rather than endo-xylanase activity.

VALUE IN PRACTICE

In principal, corn-soy enzymes offer an improvement in the average digestible energy content of the diet by markedly improving digestibility of the poorest quality corn samples whilst having minimal value on the best samples. Unfortunately, with no method available to allow rapid determination of the quality of corn prior to diet manufacture, the only option is to use such an enzyme in all cases.

Since use of the enzyme effectively increases the matrix value of corn, the result is that even when a good quality, un-responsive sample of corn is used in diet manufacture, value has been extracted through the savings created by the higher energy values used in the least cost formulation (LCF). When a poor sample of corn is utilised, the enzyme significantly enhances its digestibility such that the elevated matrix energy value used in the LCF is justified. The net result is consistent cost savings with an added advantage of reduced variability in animal performance as a result of the enzyme reducing the differences in digestible energy content between good and bad samples of corn. There are many different NSP'ases on the market today, all of which differ markedly from one another. Even within the class xylanase, there are enormous differences in pH profiles, end products produced and their ability to attach soluble and/or insoluble xylan structures. It is important that when making a choice the decision is based on the biological performance of the product and not simple in vitro assays, none of which bear much relationship to the environment in which these products act.

PHYTASES

Phytases were originally employed in the 1990's in response to severe penalties for phosphorus (P) pollution imposed on pig and poultry producers in certain geographical areas. They degrade plant phytate P which would otherwise pass through to the manure intact, and as a result of their activity less inorganic P was required in the diet. Without the economic penalties for waste disposal, the use of phytase would not have been established at this time since the cost savings in inorganic phosphate were offset by the cost of the enzyme. With time, however, the cost of the enzyme reduced and that of the nutrients spared by use of this enzyme increased (for various reasons, e.g. ban on meat and bone meal in EU), such that its use spread through much of the EU in the mid and late 1990's. As understanding of its mode of action improved, and with the realisation that this enzyme may spare more than P and Calcium (Ca), its use spread further, in that it is currently the most commonly used feed enzyme in the world.

MODE OF ACTION

Phytases release P from phytate, and as a result enable the compounder to reduce the use of inorganic phosphates in the ration. As more P is removed from phytate, the less able it is to bind or chelate minerals, starch or proteins either directly or via ionic bridges (Selle & Ravindran, 2007). As a result, use of phytase may directly improve the digestibility not only of P and divalent cations such as Ca, magnesium and zinc, but also of energy and protein.

More recently it has been shown that phytate itself is an active anti-nutrient, and may interact with the gut in such a way as to stimulate the small intestinal immune system and enhance production and losses of mucin proteins (Cowieson *et al.*, 2004). Destruction of phytate reduces this anti-nutritive effect in a directly proportional manner, and as a result energy and amino acids that would have been used in a maintenance activity (immune surveillance and intestinal turnover) can be directed towards productive energy instead.

It must be noted that this effect of phytase is mostly a post-adsorptive effect, and as a result the value of this activity is not captured in simple AME or even TME assays. The recent development of *E. coli* derived phytases has significantly improved the value proposition for broilers in particular. An equivalent 500 unit dose from an *E. coli* source delivers 20-30% more nutrients than the same dose of an *Aspergillus* phytase (Augspurger *et al.*, 2003), and its effect is more consistent due to its more suitable pH profile and greater stability towards pepsin digestion in the intestinal tract (Igbasan *et al.*, 2000). Some *E. coli* phytases have been further enhanced either by genetic modification or coat-

ing to make them even more tolerant of the feed manufacturing process.

All of the above has significantly improved the ability of such products to reduce feed costs which is fortuitous given recent events.

VALUE IN PRACTICE

Phytase is quite unlike the NSP'ase enzymes for corn soy diets in that the dosage used in practice, even that of the *E. coli* phytases is well below that of the biological optimum. In fact the benefit of this enzyme is linearly related to logarithmic increments in dose – i.e. improvement in P digestibility is doubled with a 10 fold increment in dose. Despite the extension of the nutritional matrices of most phytases into energy and amino acids, the economic incentive for feed manufacturers to increase the dosage of phytase used has not been sufficiently obvious.

Clearly, with increasing ingredient costs, such tenets are being reconsidered. A clear problem in the use of phytase in LCF is that whilst the benefit of the enzyme increases in a linear fashion with logarithmic increments in dose, the LCF linearly relates dose to benefit. For example, if a phytase is included as an ingredient with a matrix of nutrients for 500 units, and the LCF selects only 250 units of phytase, it will assume that the phytase has provided only 50% of the given matrix, whereas in reality the actual value is closer to 75% for such a dose. This relationship is shown in *Figure 1*.

The feed formulator is therefore faced with an economic problem. If shadow prices encourage greater use of phytase, then the traditional approach would be to replace the 500 unit product matrix with a 1000 unit product. This 1000 unit product has a lesser nutrient matrix per unit of activity but a maximum inclusion rate which is double that of the 500 unit product. At the maximum inclusion rates the 1000 unit product delivers 30% more nutrients than the 500 unit product.

These two matrices are represented by the straight regression lines which pass through the origin in *Figure 1*. The problem is that the actual value of the enzyme is represented by the log curve in *Figure 1*.

Use of any dose below the product maximum results in the LCF assuming that the enzyme delivers less value than it actually does in vivo. This loss is represented as the difference between the curve and either of the straight regression lines. As a result the true optimum will not be found and a large part of the value of the enzyme is lost.

A solution under these circumstances is to have two ingredients in the LCF.

One would be the standard 500 unit product with its given matrix, the second would be a new 500 to 1000 unit product which would have a matrix defined as the difference between the 500 and 1000 unit matrix prod-

ucts. For example, if the 500 unit product had an AvP value of 0.1% and the 1000 unit product a value of 0.13%, then the 500 to 1000 unit product would have a value of 0.03% AvP. Since the cost of the two products is exactly the same per gram, the second product with the lower matrix value would not be pulled into the LCF until the full 500 units of the former had been used. The error in the LCF for solutions between 500 and 1000 units of use would be markedly reduced as is evident from the proximity of the logarithmic curve to that of the 500 to 1000 units matrix line represented in red. Such approaches will help maximise the value that a feed compounder can extract from this enzyme particularly when high ingredient prices justify much greater inclusion levels of phytase.

ENZYME DELIVERY TO THE ANIMAL

One source of variability which must be addressed by the enzyme manufacturer is that of consistent delivery of the enzyme to the bird.

This means that the enzyme must be able to survive or bypass the thermal stresses of the feed manufacturing process, act under the rigours of the intestinal tract, and be simple to assay in premix, mash and pelleted feed for quality control purposes. Various solutions to this are offered, ranging from truly thermostable enzymes with no susceptibility to problems associated with the assay (e.g. binding to fibres of the feed, especially pelleted; inhibition by TAXI or XIP inhibitors found in e.g. wheat, barley or triticale; use of coated enzymes; post pellet liquid application).

The intrinsically thermostable enzymes are clearly the best solution, with compromises arising from the use of either coating or post-pelleting application which vary with each product.

CONCLUSIONS

Recent changes in the cost-structure of the feed industry have significantly altered the value of P and energy. Enzymes which influence the utilisation of these nutrients are now being considered in situations which would have been uneconomic in the past, and in some cases at inclusion levels which would never have been contemplated.

Such changes have forced the enzyme industry not only to review how it should support such products, but also to consider how to provide products better suited to the task. The combination of better products and more considered application advice should help mitigate at least some of the financial burden being placed on the feed industry by current world events. <-

References are available on request