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Finding new keys to phytate challenge

With pressure on the animal industry to sustain profitability in the face of volatile raw material prices, nutritionists must maximize value from feed additives.

By **CEINWEN GILBERT, DAVID SWANN** and **GARY PARTRIDGE***

THE feed and livestock production industries continue to be challenged by a combination of high raw material prices and constant meat prices.

In these times of squeezed profit margins, it is, therefore, particularly important to fully exploit the value potential of various feed additives.

Phytase enzymes are used extensively in monogastric nutrition, and the customer is spoiled with choices in terms of potential suppliers. Many customers use phytase primarily as a way of reducing inorganic phosphorus inclusions in the diet while, at the same time, achieving current net feed cost savings of around $3-4 per ton at a traditional phytase inclusion rate of 500 phytase units (FTU) per kilogram of feed.

However, there is an increasing body of scientific evidence to support the view that certain phytases can bring further value in monogastric diets through their effects on energy, protein and amino acid availability. In doing so, this can approximately triple their cost-saving potential at current raw material prices and traditional inclusion rates to around $12 per ton.

Recent research has also highlighted that even greater improvements in net feed cost savings and live performance can potentially be achieved by including much higher levels of phytase (so-called "super-dosing"). However, to exploit all of this untapped potential, it's important to understand the basis for these "extra-phosphoric" effects and how new developments in phytase technology are pushing the boundaries in terms of knowledge about the mode of action and ultimate cost-saving potential of phytase.

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Anti-nutrient challenge

The substrate for phytase is dietary phytate, which is present in varying amounts in a range of vegetable-based raw materials (Figure 1). Recent research has emphasized that phytate is not only a potential phosphorus source — thanks to the action of phytase enzymes — but also a potent anti-nutrient that can reduce the availability of many other nutrients to the animal.

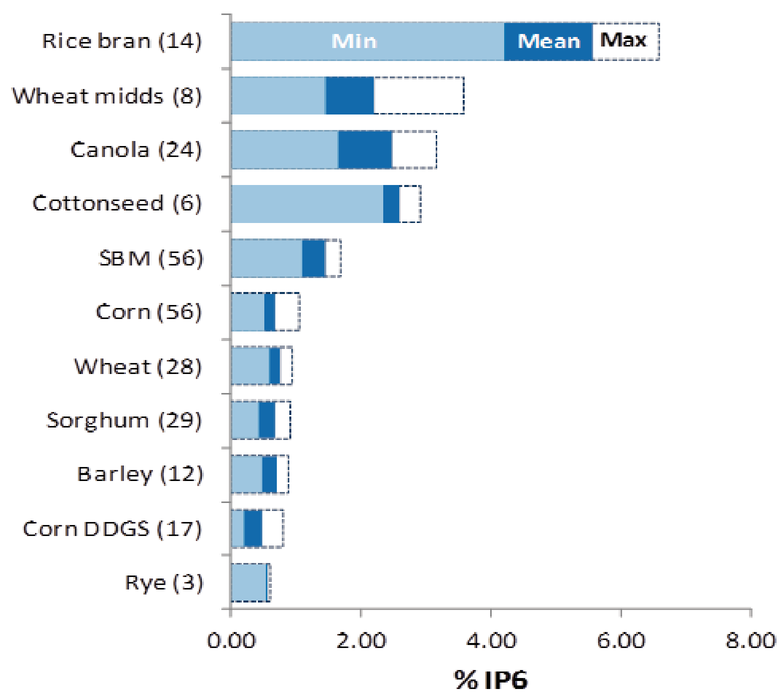
Phytate functions as an anti-nutrient by disturbing the gut physiology of the animal. When phytate is solubilized at a low pH in the upper gut (e.g., the proventriculus and gizzard of the bird, Figure 2), it forms insoluble complexes with amino acids and other nutrients, rendering them unavailable for digestion by the animal's own (endogenous) secretions.

Physiologically speaking, this triggers the animal to produce even more endogenous secretions (e.g., pepsin and hydrochloric acid) to try to overcome this anti-nutrient effect of phytate. However, this innate physiological response comes at a cost to the animal in terms of more energy and amino acids being channeled into "maintenance" activities while leaving less available for productive purposes.

The production of more hydrochloric acid, in particular, stimulates the gut to secrete more mucin — again, adding to maintenance costs — and also triggers sodium bicarbonate production in the upper small intestine to buffer this increased acid production.

The solution to this physiological

1. Levels of phytate (IP6) and its variability in feed raw materials



Note: Numbers of samples provided in parentheses.

Source: Danisco Animal Nutrition global phytate survey.

challenge posed by phytate is to use a phytase enzyme that has a very high relative activity at a low pH (2.5-4.5) in the gut — to break down dietary phytate rapidly before it can bind useful nutrients such as amino acids. Recent studies have shown, for example, a direct positive correlation between phytate breakdown by phytase and improvements in protein and amino acid digestibility.

Since an enzyme is a protein itself, such a phytase also has to be inherently stable in the presence of the animal's own protein-digesting enzymes (e.g., pepsin).

Phytate consists of an inositol ring with six phosphate groups (IP6). Removing just one of these phosphate groups using phytase (e.g., to convert IP6 to IP5) has been shown, in recently published research, to substantially reduce the ability of the phytate molecule to bind protein and amino acids at a low pH.

Consequently, a phytase enzyme that rapidly cleaves a phosphate group from one phytate molecule and then moves on to another phytate molecule will have considerable value in terms of its potential to reduce the anti-nutrient effects of phytate.

A phytase enzyme with a different mode of action — for example, sequentially cleaving phosphate groups around the inositol ring before moving onto another phytate molecule — will be good at releasing phosphorus from phytate but will have smaller effects on the release of other nutrients bound by phytate.

Given the above requirements for an "ideal" phytase, a rigorous selection program is required in order to push the boundaries in terms of improving phytase bioefficacy.

New developments

Phytase is the most widely researched feed enzyme, and new sources of phytase are regularly being investigated and commercialized.

Extensive research by Danisco Animal Nutrition in recent years has resulted in the identification of a new phytase source with improved characteristics compared to the current range of *Escherichia coli* phytases.

The new phytase (Axtra PHY) is a bacterial (*Buttiauxella* spp.) phytase expressed in *Trichoderma reesei*. This new *Buttiauxella* phytase was selected on the basis of a number of critical criteria measured *in vitro* and then extensively tested over several years in animal trials to ensure that its *in vitro* promise was fully realized *in vivo*. The focus in the selection process was to combine the ability to rapidly release phosphate groups at the same time as countering the anti-nutrient properties of phytate, thereby alleviating phytate's negative effects on nutrient availability.

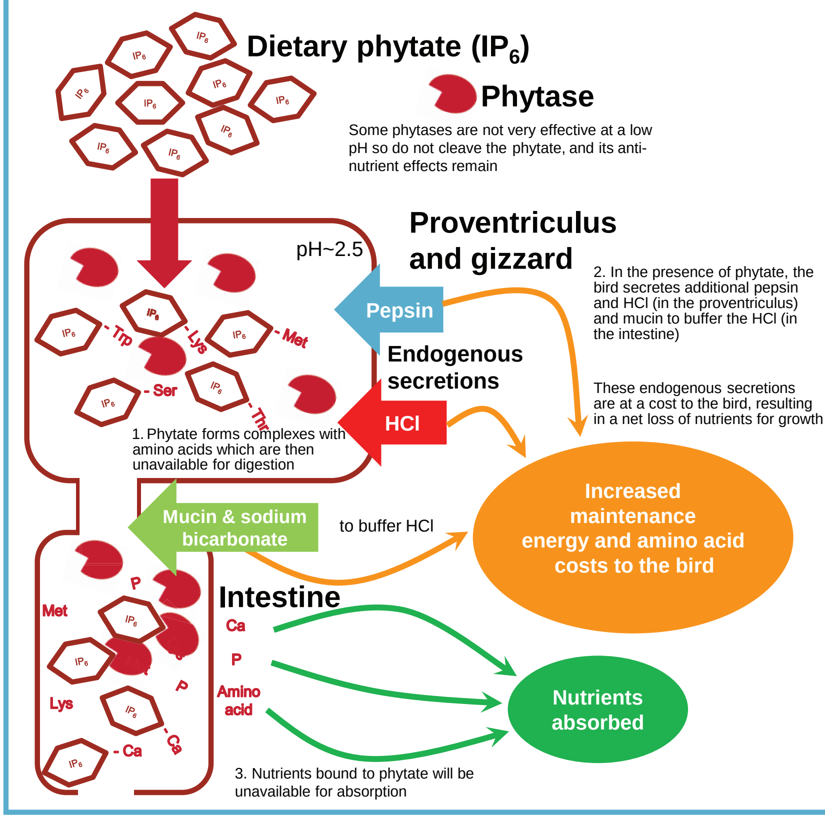
The newly developed phytase shows a higher activity at a low pH than current *E. coli* phytases (Figure 3). This means that it has an improved potential to reduce the negative effects of phytate on protein, amino acid and energy availability. It also shows improved stability to pepsin *in vitro* compared to *E. coli* phytase. This characteristic, as already mentioned, can effectively contribute to improved bioefficacy in the animal.

In a recent series of independent animal trials at Schothorst Feed Research in the Netherlands, the bioefficacy of the new *Buttiauxella* phytase was compared against three *E. coli* phytases whereby each product was added in sequential amounts up to 1,000 FTU/kg of feed (Figure 4).

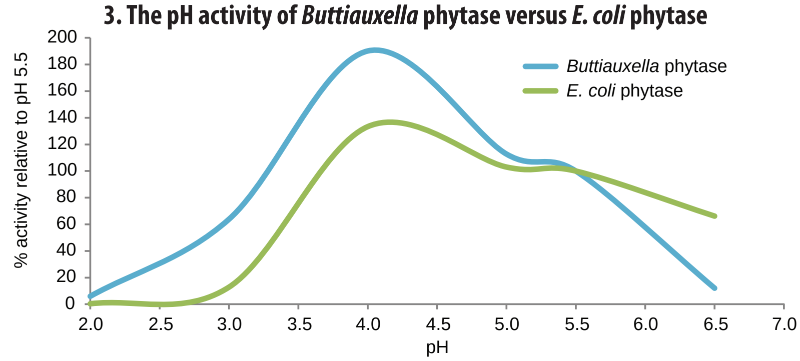
In these studies, the relative bioefficacy for the new phytase was 79% higher, in terms of ileal phosphorus digestibility, than the overall response of the three *E. coli* products. This translates into an improvement in phosphorus release of around 20% versus the *E. coli* phytases at traditional inclusion levels, e.g., 500 FTU/kg of feed.

Further, in a series of 10 broiler ileal digestibility studies over a three-year period, generating around 300 data points for each nutrient analysis, the new phytase was found to have substantially improved effects on energy and amino acid digestibility versus an existing *E. coli*

2. Anti-nutrient effects of phytate in poultry

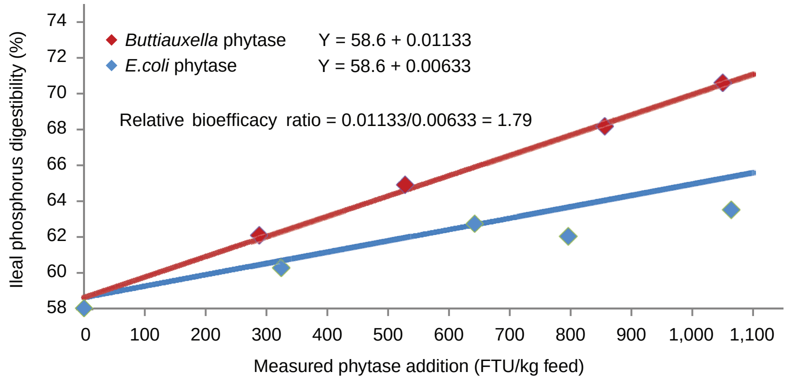


3. The pH activity of *Buttiauxella* phytase versus *E. coli* phytase

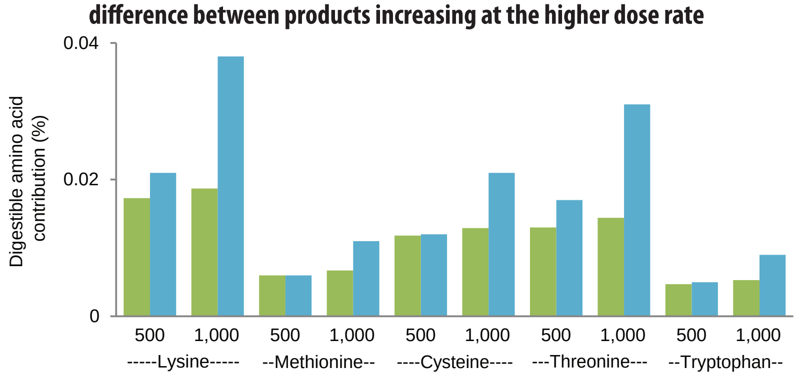


Note: The activity of the new phytase is higher at a low pH, offering increased ability to reduce the anti-nutrient effects of phytate in the upper gut, where dietary phytate is in solution.

4. Relative bio-efficacy of a new *Buttiauxella* phytase versus the overall response to three leading *E. coli* phytases in terms of ileal phosphorus digestibility



5. Comparison of the relative digestible amino acid release from *E. coli* phytase (green bars) and new *Buttiauxella* spp. phytase (blue bars) at 500 and 1,000 FTU/kg feed additions, showing the magnitude of difference between products increasing at the higher dose rate



reference product.

Improvements of up to 30% in individual amino acid digestibility were seen at traditional phytase inclusion levels, illustrating the ability of the new phytase to work effectively at a low pH to counter the anti-nutrient effects of phytate with consequent benefits to nutrient release.

Improvements in energy availability of around 7% were also seen, adding further to the potential value of the product in commercial diets.

When translated into cost-saving opportunities in typical broiler diets, the above improvements in phosphorus availability are worth around an extra $1 per ton at current raw material prices versus an existing *E. coli* reference product when phytase is added at 500 FTU/kg of feed.

However, the greatest potential for feed cost savings with phytase addition comes when considering opportunities for amino acid and energy release in feed formulations. As stated earlier, these are currently worth around $12 per ton with the new developments in phytase technology, based on the improved mode-of-action knowledge, adding considerably to this value equation (about $1.50 per ton more compared to an *E. coli* reference product).

Extensive dose response work with the new *Buttiauxella* phytase has also illustrated that benefits in amino acid release are magnified at higher phytase doses compared to an *E. coli* reference product (e.g., at 1,000 versus 500 FTU/kg of feed; Figure 5).

Furthermore, when even higher levels of the *Buttiauxella* phytase were used (up to 2,000 FTU/kg of feed), amino acid digestibility responses continued to increase, offering clear economic net benefits at these higher doses during times of high prices for protein sources.

With the current pressure on the animal industry to sustain profitability in the face of volatile raw material prices, it is incumbent on nutritionists to maximize value from scientifically well-proven feed additives such as phytase. Recent advances in phytase enzyme technology will enable feed and animal producers to reap the benefits in feed cost savings from such new products without compromising animal performance.

References

Relevant references are available upon request from sue.pollicott@dupont.com. ■