Key role for feed enzymes in minimising the environmental impact of poultry production

Carbohydrase/protease complexes and phytases could assume an increasing role in helping poultry producers to meet more stringent environmental legislation in Europe, the USA and elsewhere. By contributing to reductions in both total excreta and the critical components in it, these feed enzymes will help poultry producers to maintain flock sizes, without falling foul of pollution controls.

Andrea Barletta

With global demand for poultry meat forecast to increase by 2.2% per year until 2014, the outlook for the industry looks rosy. However, increasing demand will increase the magnitude of issues that face producers today, including the need to be more cost-effective to compete economically in an increasingly competitive global market place, meet ever more stringent standards of food safety and welfare, and to combat the challenges posed by disease and biosecurity.

Whilst all represent major challenges, one of the greatest hurdles for the industry will be to minimise the environmental impact of its activities. Anyone who doubts the scale of the problem need only consider the figures involved. In the US alone, the United States Department of Agriculture (USDA) estimates that farmed livestock and poultry excrete around 500 million tonnes of manures every year. The disposal problem is exacerbated by the concentration of animal production into increasingly large units, which is necessary to obtain the economies of scale required to satisfy demand from retailers and consumers for 'affordable' food.

Andrea Barletta

Inevitably, as individual poultry operations become larger, finding enough spare land on which to spread manure in the vicinity of production sites will become an increasing problem. Apart from the sheer volume, the other primary environmental factors are the levels of nitrogen (N) and phosphorus (P) contained in the manure together with ammonia production. Up to 80% of the N and P fed to poultry is not utilised but excreted into the environment.

Animal manure: opportunity or threat?

Manure is of enormous economic benefit to both arable and ruminant farmers in minimising expenditure on artificial fertilisers that consume non-renewable resources. However, it's not all good news. In large areas of north-west Europe, eastern and mid-western USA, Japan and, increasingly, coastal south-east Asia, the problem is not one of meeting agronomic demands for more

Table 1 The influence of supplemental phytase on phosphorus (P) excretion in growing chicks

	Normal diet	Low -P diet	Low -P diet + 500 U/kg phytase	Change with phytase vs. normal diet
P intake (g)	6.09[a]	2.78[b]	2.92[b]	- 52%
P intake (g/kg weight gain)	11.84[a]	6.24[b]	6.19[b]	- 48%
P retention (% of intake)	40.7[c]	54.5[b]	66.4[a]	+ 63%
P excretion (g/kg weight gain)	7.03[c]	2.84[b]	2.08[a]	- 70%

[abc] Means not sharing a common superscript differ significantly (P<0.05)

Key role for feed enzymes

Table 2 The effect of carbohydrase/protease complexes on ileal and faecal protein/amino acid digestibility in broilers fed wheat and barley based feeds.

	Ileal protein digestibility (%)		Faecal protein digestibility (%)		Faecal amino acid* digestibility (%)		Research Institute**
Enzyme	Control	+Enzyme	Control	+Enzyme	Control	+Enzyme	
Xylanase β-glucanase Protease	62.5b	75.5a (+20.8%)	-	-	-	-	1
Xylanase β-glucanase Protease	63.1b	73.3a (+16.2%)	-	-	-	-	1
Xylanase β-glucanase Protease	69.4b	80.9a (+16.6%)	77.1b	83.4b (+8.3%)	-	-	2
Xylanase β-glucanase Protease	74.1b	83.4a (+12.6%)	-	-	-	-	2
Xylanase Protease	62.5b	77.3a (+23.7%)	-	-	79.3d (+5.9%)	84.0c	3

[ab] Means not sharing a common superscript differ significantly (P<0.05)
[cd] Means not sharing a common superscript differ significantly (P<0.02)
* Average lysine, methionine & threonine
** 1= Montana State University, USA; 2= IRTA, Spain; 3=SAC, Auchincruive, UK

Table 3 The effect of carbohydrase/protease complexes on ileal protein digestibility in layers.

		Ileal protein digestibility (%)	
Type of diet	Enzyme	Control	+Enzyme
Maize	Xylanase	73.9[a]	81.5[b] (+10.3%)
	Amylase		
	Protease		

[ab] Means not sharing a common superscript differ significantly (P<0.05)

Table 4 The influence of supplemental xylanase on manure and nitrogen (N) excretion in chicks

	No enzyme	+Xylanase	Change with xylanase
Water excretion (g/day)	129	114	- 12%
Dry matter digestibility (%)	68.2	71.0	+ 4%
Dry matter excretion (g/kg weight gain)	515.2	451.0	-14%
N excretion (g/kg weight gain)	11.65	10.16	-15%
Total excreta (g/kg weight gain)	2644	2268	-17%

Table 5 The influence of supplemental xylanase on manure and nitrogen excretion in laying hens

	No enzyme	+Xylanase	Change with xylanase
Water excretion* (g/day)	445[a]	417[b]	- 7%
Dry matter digestibility (%)	71.4[a]	72.8[b]	+ 2%
Dry matter excretion (g/kg egg weight)	607.8[a]	568.5[b]	- 7%
Nitrogen digestibility (%)	80.7[a]	81.5[b]	+ 1%
Nitrogen excretion (g/kg egg weight)	11.15[a]	10.52[b]	- 6%
Total excreta (g/kg egg weight)	8773[a]	8164[b]	-7%

* Recorded for 3.5 hours over a 5-day period for 5 weeks
[ab] Means not sharing a common superscript differ significantly (P<0.05)

nutrients but of dealing with the excess. High levels of nitrates and phosphates in surface water cause damaging algal blooms and in drinking water may present a risk to public health. Such findings have led to a greater focus on environmental sustainability and, in many parts of the world, resulted in legislation to reduce the risk of nitrate and phosphate pollution.

Within the EU, it is estimated that 20% of surface water is seriously threatened by pollution. Such is the concern, that the EU's Nitrates Directive requires Member States to implement control programmes, restricting the amount of N that can be applied per hectare. The Water Framework Directive, for example, aims to prevent pollution at source. It sets out a control mechanism to ensure that all pollution sources are sustainably managed and establishes ambitious objectives for groundwater quality and quantity. These measures should ensure that by 2015, all ground and surface waters achieve a 'good status' classification. The EU's Integrated Pollution Prevention and Control Directive seeks to minimise pollution from point sources throughout the region.

Concerns over water quality extend far beyond the EU. In the USA, the quality of almost 40% of water sources is impaired, partly

due to improper management of concentrated animal feeding operations (CAFOs). The US Environmental Protection Agency (EPA) is responsible for managing the National Pollutant Discharge Elimination System (NPDES) permit programme, which regulates the discharge of pollutants from all sources into US waters. In addition to applying for a permit, all CAFOs must develop and implement a nutrient management plan to reduce pollutant discharge into the environment, including N and P excretion by poultry and livestock.

Seeking solutions

By restricting the level of N per hectare that can be applied in the form of livestock manure, the legislation poses problems for livestock producers.

Nutrition is a key area to reducing the environmental impact and there are proven, commercially viable techniques to help achieve that objective. For example, the amounts of N and P excreted into the environment can be reduced by more closely matching feed consumption to the bird's nutrient requirements through careful diet formulation, in combination with management techniques such as phase- and split-sex feeding.

Feeding diets that are more readily digested is another way of reducing feed wastage and manure excretion. Pelleted rather than mash feeds will help, as well as paying attention to particle size, which will improve feed digestibility, and feeding diets that are formulated more precisely according to the availability and digestibility of nutrients rather than average values.

In terms of reducing N excretion, one option is to reduce the level of N-containing compounds in poultry diets by reducing crude protein content. Researchers have shown that the amount of N excreted over four days by 7- to 14-day-old chicks fed diets containing 23%, 21%, 19% and 17% crude protein was 3.93g, 3.26g, 2.35g and 2.19g/chick/day, respectively. They concluded that N excretion could be reduced by 10-20% where dietary crude protein in broiler diets was cut from 21% to 19%, although they noted that reducing the level of crude protein in the diet was detrimental to carcass quality due to an increase in abdominal fat.

Another researcher has demonstrated that while reducing the crude protein of diets fed to laying hens from 17% to 13.5% resulted in a 30% decrease in N excretion, bird performance decreased by 2-3%.

Dealing with the dilemma

The dilemma facing poultry and feed producers is how to produce consistently good quality meat and eggs, cost-effectively, with minimum impact on the environment.

A high proportion of P in cereal grains, oilseed meals and their by-products is bound by phytate. Because they lack the enzymes required to break it down, poultry are only about 30% efficient at digesting P contained in these feed ingredients. Little natural P is utilised and a large percentage passes straight through the animal's digestive tract, causing problems for producers and the environment.

Feeding a highly digestible source of P such as meat and bone meal is efficient, often cost-effective and reduces P excretion, but the practice has been outlawed in many markets. Ensuring that feed satisfies the bird's P requirement therefore requires the addition of expensive inorganic sources but, typically, 20% still remains undigested.

Feed enzymes offer a cost-effective solution. Many leading producers are increasingly recognising the benefits of phytase in reducing nutrient waste, increasing the efficiency of meat production and minimising costs. So effective is it in doing this that since 2000, the US state of Maryland has demanded that all contract feed for chickens includes either phytase or another enzyme or additive to reduce P excretion.

The influence of supplemental phytase on P excretion in growing chicks is apparent from Table 1. This demonstrates that changing from a normal diet to one low in P plus 500 units of added phytase/kg can reduce P intake by 52%, increase P retention by 63% and result in a 70% fall in P excretion.

In terms of reducing N excretion, research in broilers conducted at four establishments in the USA, Spain and the UK has underlined the effectiveness of carbohydrase/protease complexes on ileal or faecal protein and faecal amino acid digestibility. The results, shown in Table 2, demonstrate an average 18% improvement in ileal protein/amino acid digestibility in barley- and wheat-based broiler diets compared with the control. Where faecal protein and amino acid digestibility were measured, enzyme addition increased their digestibility by 8% and 6%, respectively.

Further research into maize diets conducted at the Nutreco Poultry Research Centre in Spain also clearly demonstrated the benefits of carbohydrase/protease complexes on ileal digestibility in layers, as seen in Table 3.

Better solution

Adding just a small amount releases natural P, minimising the need for expensive supplementary P and ensuring that nutrients are more completely digested, enabling poultry producers to reduce feed and production costs without compromising bird performance. In addition, by reducing P output by up to 70% (Table 1), there are clear environmental benefits.

The cell walls of plant feed ingredients enclose and trap nutrients, including those that contain N, for example, amino acids and protein. Soluble fibres in some feed ingredients also dissolve in the bird's gut,

Key role for feed enzymes

forming viscous gels that trap N-containing nutrients and slow the rate of digestion. The bird lacks the necessary enzymes to digest plant cells walls or break down the soluble fibres and so is unable to access the trapped nutrients, which remain undigested and are excreted.

To help resolve this situation, carbohydrase and protease enzyme complexes such as xylanases, beta-glucanase and protease are commonly added to feed. These ensure more complete digestion of nutrients, thereby maximising feed efficiency, minimising feed costs, optimising bird uniformity and reducing N excretion.

Our research to investigate the effect of its supplemental xylanase products on manure in chicks, shown in Table 4, highlights a reduction in N excretion of up to 15%. In addition, by lowering the water-binding capacity of dietary fibre, xylanase reduced water excretion by 12% and dry matter excretion by 14%, resulting in a 17% drop in total excreta output. That has a dramatic positive influence on the environmental impact of poultry production.

Similar research conducted with hens (Table 5) demonstrates that the addition of supplemental xylanase improves dry matter and nitrogen digestibility by 2% and 1% respectively, while facilitating reductions of 6% in N excretion and 7% in water, dry matter and total excreta.

Making an impact

The practical implications of these findings are enormous, both in economic and environmental terms.

It has been calculated that 1000 layers produce 650kg N/year. With the EU Nitrates Directive limiting the amount of organic N that can be spread to 170kg/hectare/year, disposing of 650kg N would require 3.9 hectares (ha) land. Taking as an example the data reported in Table 5, where adding xylanase to feed reduced N excretion by 6%, it follows that 1000 layers would produce 40kg less N/year, reducing total output to 610kg and the area required for disposal to 3.6ha. For every one million layers, 300ha less land would be required for manure disposal.

EU legislation is focused on matching the supply of P from mineral fertilisers and animal manures with the requirements of crops. Although a surplus is permitted, by 2012, it is proposed that this will be just 6kg/ha/year, the equivalent of applying 13.6kg phosphate. Given that the phosphate requirement of winter wheat is 70kg/hectare, the total amount of phosphate that could be applied to a hectare of winter wheat would be 83.6 kg/annum. Assuming that was solely of animal origin, 1000 layers produce around 545kg phosphate/annum, which would supply the total requirements of 6.52ha winter wheat.

Phytase feed enzymes typically reduce P excretion by 30%, which means that those same 1000 layers would produce 380kg of phosphate/annum, which could be applied to 4.5ha winter wheat. So 2000ha less land would be required to dispose of the manure from every one million layers! Given that it requires relatively more land for disposal, P reduction should therefore be the main focus for the animal production industry.

Increasing legislative pressures will undoubtedly force producers to focus on further reducing the environmental impact of their businesses on the environment. Doing so will require a positive approach but there is technology to help. The benefits of feed enzymes in poultry diets are now well proven, not only in terms of improving feed utilisation and the economics of production but also reducing the environmental impact of meat and egg production.

— Andrea Barletta, Global Marketing Director, Danisco Animal Nutrition, UK.

Danisco Animal Nutrition markets a range of feed enzyme products. These include a number of carbohydrase/protease complexes (under the trade name, Avizyme) and a new generation 6-phytase (Phyzyme XP), which is produced in yeast, Schizosaccharomyces pombe.

Reprinted from September 2005 Poultry International