From Microbes TO Pork

The full economic and nutritional potential of cereal grains such as rye, barley, oats and wheat has rarely been realised in monogastric feeding regimes - mainly because animals do not produce the enzymes to hydrolyse non-starch polysaccharides (NSPs) in the small intestine. In this concluding article on enzyme supplementation, Dr Hagen Schulze, Finnfeeds International's pig research manager explains how the digestive tract of the various monogastric animals have to be taken into account when matching the right substrate for optimum efficiency.

In cereal grains, the amount of NSP - the main component of the fibrous cell walls of many plant feedstuffs - ranges from 10 - 20 per cent of dry matter. Such high levels of non-digestible material significantly influence nutrient digestibility of both the grain and the whole diet. Arabinoxylans constitute about 60 per cent of the total NSP found in wheat (Table 1), with much higher levels found in bran and middlings than in wheat itself.

Table 1: Non-starch polysaccharides of wheat, wheat middlings and wheat bran prepared from the same batch of wheat (g/kg dry matter; Finnfeeds International Ltd. database).

	Total	Ara	Xyl	Man	Gal	Glu	U.a.
Wheat							
- soluble NSP	0.91	0.20	0.16	0.04	0.14	0.19	0.13
- total NSP	8.60	1.90	3.30	0.13	0.19	2.70	0.34
Wheat Middlings							
- soluble NSP	0.98	0.23	0.16	0.03	0.17	0.20	0.14
- total NSP	28.01	6.28	10.63	0.34	0.50	9.04	1.12
Wheat Bran							
- soluble NSP	1.01	0.23	0.20	0.03	0.13	0.22	0.15
- total NSP	38.15	8.24	15.42	0.29	0.69	12.08	1.34

'Ara ... Arabinose, Xyl ... Xylose, Man ... Mannose, Gal ... Galactose, Glu… Glucose, U.a....Uronic acid

The wheat kernel comprises a mass of different tissues. Figure 1 shows the microstructure of the wheat kernel and illustrates how starch and proteins are encapsulated by cell walls. Obviously, those nutrients can only be utilised after the cell walls have been broken down.

Figure 1. The microstructure of wheat. Cell walls were stained blue with Calcafluor White and protein was stained red/orange with Acid Fuchsin (Courtesy of Drs Karin Autio & Teija Parkkonen, Cultor Technology Centre, Finland)

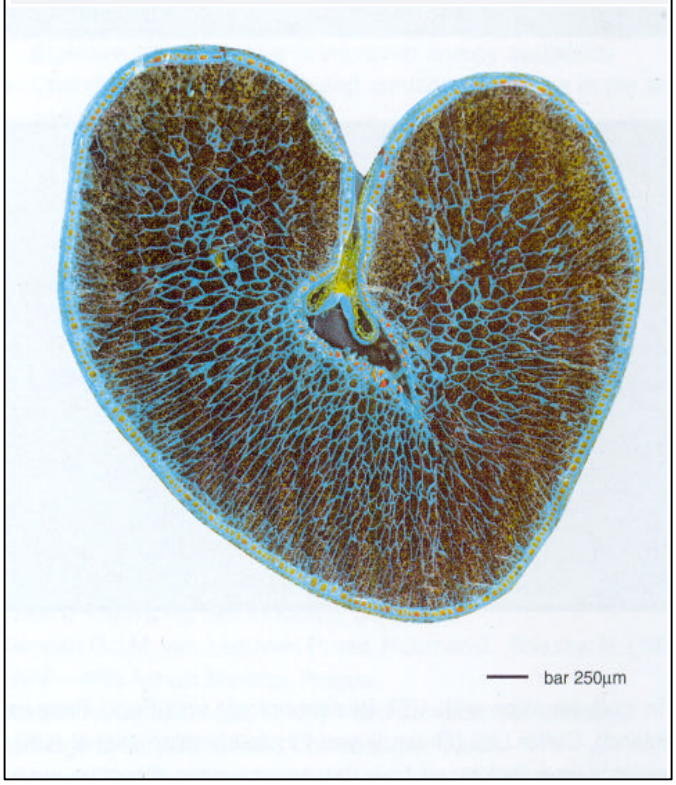

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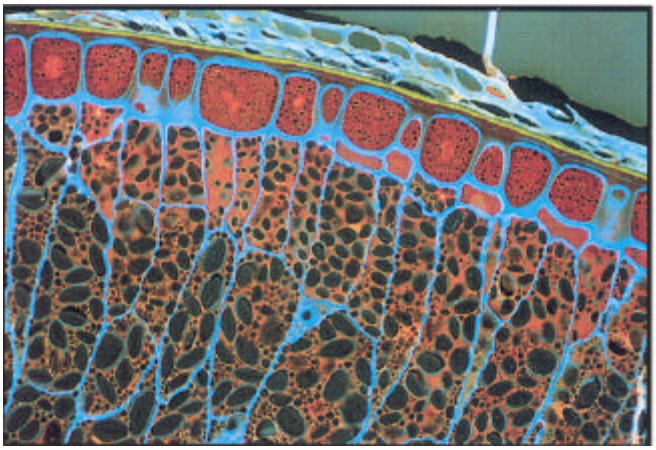
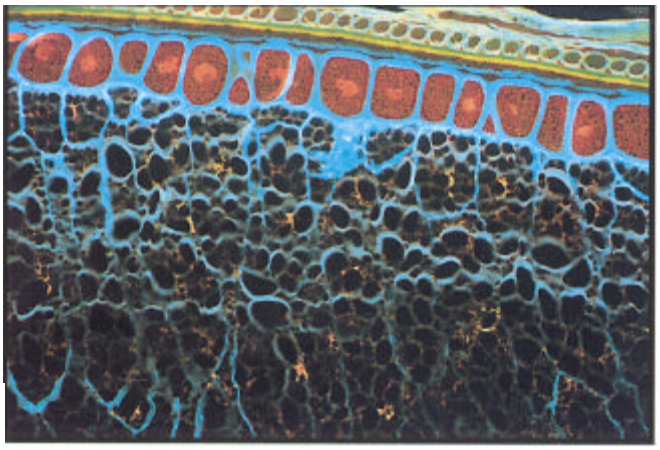
Figure 2. The effect of in vitro digestion on the microstructure of wheat. (a=flourescent microscope; b=bright field microscopy; 1 =control; 2=after digestion; red/brown=protein; black=starch; blue=cell walls.)
Three-step digestion stimulation:
1. 30 min (40 °C) at pH 5.5;
2. 45 min (40 °C) at pH 3.0 adding pepsin;
3. 60 min (40 °C) at pH 6.5 adding pancreatin

1a



2a



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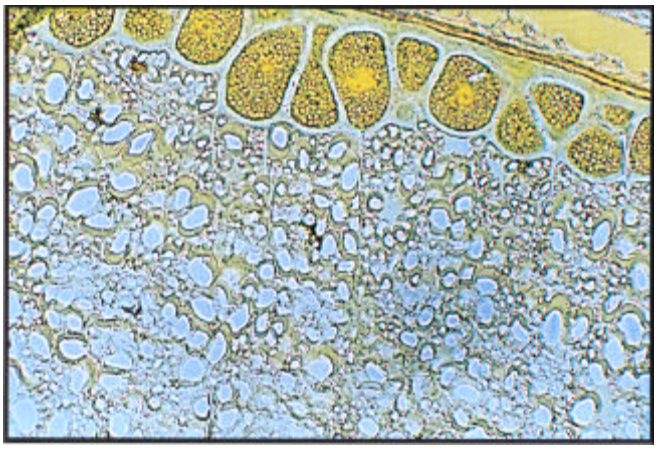

In collaboration with VTT Biotechnology and Food Research (Finland), Cultor Ltd. (Finland) and Finnfeeds International (UK), a project is now looking at how the monogastric digestive system deals with feedstuffs such as wheat. Using an in vitro digestibility model initial results (Figure 2) show that:

- Endosperm protein was made soluble and endosperm starch was completely hydrolysed following a three-stage digestion simulation.
- The aleurone layer and cell walls of the endosperm were not affected by the in vitro digestive process.

This laboratory study reveals that the monogastric animal's own digestive process is not capable of breaking down the cell wall structures of wheat. However, the remaining structures of the aleurone layer and the endosperm cell walls provide potential for using exogenous enzyme sources to increase the nutrient availability of wheat. Since these cell wall structures comprise mainly arabinoxylans, xylan-degrading enzymes should be particularly suitable for the task.

Enzyme characteristics

The hydrolysis of arabinoxylans can be induced through the action of endo 1,4-ß-xylanase, ß- 1,4-xylosidase and a number of debranching activities including α-L-arabinosidase, α-glucuronidase and various esterases (Morgan & Bedford, 1995). Potentially, these enzymes are available from a wide range of microbial sources. The efficacy of the whole process is governed by the structure of the substrate itself (degree of substitution), the types of enzyme activities present (catalytic properties) and the conditions in which they operate (moisture, pH and temperature).

For feed use, xylanases must be stable and active at the various pH and temperature levels found in the gastro-intestinal tract of the target animal species. To be really effective within the gastro-intestinal tract of the monogastric animal, the enzyme must function in the stomach or, more efficiently, within the small intestine. Preferably, it should be capable of working in both regions of the digestive tract.

Target Animal Species

Different feed enzymes or mixtures need to be developed for each animal species to cater for their specific digestive processes (Table 2). This involves a variety of repeated feeding and digestibility/ metabolism trials as well as laboratory studies to highlight the best feed enzyme for each animal group.

Table 2: Some important physiological differences between pigs and poultry which may influence the response to feed enzymes (adapted from Partridge, 1995)

	Pig	Chicken
Pre-gastric digestion	-	crop: ~2 h @ pH 6.5
Ileal digesta dry matter (per cent) on equivalent diets	12 - 13	17 - 18
Hindgut capacity as per cent of total digestive tract	> 30	< 10
Digesta transit time through hindgut (h)	20 - 40	2 - 4

The development of Finnfeeds International's Porzyme pig enzyme range is based on such extensive research and trial work - targeting the best enzyme source and the most efficient inclusion rates for pigs at various stages of growth. For instance, when developing Porzyme 9300, an enzyme product for grower/finisher pigs fed wheat based diets, our studies showed a clear dose response in average daily gain to the amount of xylanase added, with an optimum inclusion level of 1kg of product equivalent/tonne of feed. (Figure 3).

Various trial results prove that feed enzymes are able to improve performance in terms of daily weight gain and feed conversion ratio. The results of 15 feeding trials with Porzyme 9300, involving about 8000 grower/finisher pigs, show an average 6.1 per cent

improvement in average daily gain (Table 3). This gain can be attributed to both an increased feed intake and improved feed efficiency.

Table 3: The effect of Porzyme 9300 addition on performance of grower/finisher pigs - a trial summary: September 1995, 15 trials, about 8000 pigs
(Ref: Finnfeeds International Ltd. database).

	Control	+ Porzyme	% Improvement
Daily Gain (g/d)	842	893	+ 6.1
Daily Feed Intake (g/d)	2280	2332	+ 2.3
Feed: gain	2.70	2.61	+ 3.3

Mode of enzyme action

The primary objective of NSP-degrading enzymes is to break down cell walls thereby making dietary nutrients more available and enabling a more complete digestion of starch and protein in the small intestine. This shift in nutrient digestion is mainly influenced by interactions of cell wall constituents with digestive processes in monogastric animals. Depending on source and structure, the physical properties of NSPs are mainly responsible for their effects on digestive processes.

Adding Porzyrne 9300 feed enzyme to a wheat-based diet fed to grower pigs improved individual and total ileal NSP as well as apparent and true ileal crude protein digestibilities (Table 4). These results provide evidence that the action of degrading wheat cell wall polymers makes wheat nutrients more accessible and renders the whole diet more available for hydrolysis and absorption.

For poultry, one of the primary modes of action by enzymes when added to wheat-based rations is to reduce viscosity in the small intestine of the bird - associated with partial degradation of soluble arabinoxylans in the digesta. However, the high water content of pig digesta (Table 2) suggest that viscosity effects may be less relevant in pigs than in poultry. Indeed research has shown that absolute viscosity values are lower in pigs, approximately 2 cP, whereas our experience shows that poultry on the same type of diet would be likely to have values in the range 5 – 200 cP.

Nevertheless, even these low viscosities may still have a significant impact on digestibility and animal performance. Adding Porzyme to a wheat-based diet significantly reduced absolute digesta viscosity values in the stomach and small intestine of young growing pigs (Table 5). Previous work done by Bedford et al. (1992) and Inborr et al. (1994) support this.

One effect of this viscosity reduction could be an improved dry matter outflow from the stomach (Table 5) which may partly explain improved feed intake responses seen from feeding Porzyme.

Table 4: The effect of Porzyme 9300 addition on ileal NSP and mineral as well as crude protein digestibility (per cent) in pigs fed a wheat-based diet
(Ref: Finnfeeds International Ltd. database).

	Control	+ Porzyme 9300
NSP		
- total	22.8	29.9
- arabinose	21.5	27.7
- xylose	20.3	29.7
uronic acid	34.la	40.2b
Minerals		
- Calcium	51.8	55.5
- Phosphorus	59.2	62.0
Crude Protein		
- apparent	86.4	87.2
- true	94.4a	95.2b

a,b P < 0.05

Figure 3. The effect of xylanase inclusion rates in a wheat based grower/finisher ration (84 per cent wheat) on average daily growth rate (ADG)

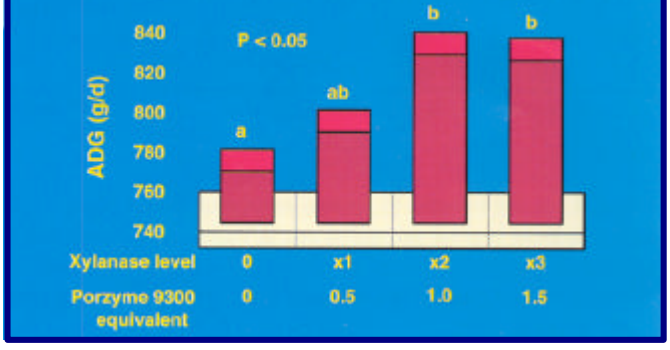

Table 5: The effect of feed enzyme addition on stomach dry matter outflow and digesta viscosity in pigs fed a wheat based diet
(Sudendey & Kampbues, 1995)

		Control	+ Porzyme
Dry Matter outflow (g/kg BW/h)	Stomach	2.27(a)	2.62(b)
Digesta Viscosity (cP)	Stomach	1.40b	1.19a
	Ileum	1.74b	1.45a

(a,b) P < 0. 10; a,b P < 0.05

Conclusions

The benefits from adding feed enzymes can be the result of various modes of action. These include:

- Supplementing the range of self-produced enzymes available in the digestive system of the monogastric animal, resulting in improved digestive capacity
- Disrupting cell wall structure, leading to increased nutrient availability and changes in the physical properties of NSP - such as water-binding-capacity and viscosity
- Shifting nutrient availability and NSP digestion to more efficient digestion sites, resulting in improved energy availability
- Changing the composition and content of bacteria in the small and large intestine
- Improving the efficacy of the animal's own enzymes, which results in reduced maintenance requirements.

The right combination of all these enzyme effects enables the animal to deal more efficiently with different foodstuffs. Responses to enzyme supplementation in pig rations are now becoming more consistent as we learn more about the way they work and which ones are best suited to individual species and their most effective inclusion rates.

Literature

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