Practical application of new

to wheat based pig feeds

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Wheat is a major energy and protein source for non-ruminant feeds on a world-wide basis. Latest data from the International Wheat Council estimate the use of wheat in animal feeds at 115 million tonnes in the 12 months to June 1994, which represents around 20 per cent of the total quantity consumed globally each year (Feed International, 1994). The primary user for animal feed is Europe, including Russia and the Republics of the former Soviet Union, which together account for over 60 per cent of the total livestock intake. Canada, Australia and Japan also regularly use wheat in their animal diets. In contrast, little wheat finds its way into livestock feed in Asia, Africa or Latin America, and in the United States the usage is relatively low - no more than 7 million tonnes, or 10 per cent of the national crop.

Pigs are important consumers of both wheat and wheat by-products destined for the animal feed market. In countries with relatively high feed wheat usage, such as the UK, total inclusion of wheat 'products' in pig diets will often be around 40-50 per cent in compound feeds (Dean 1994), with a tendency for even higher levels to be used by home mill and mixers. 'Typical' formulations for grower/finishers in the UK will, therefore, place considerable reliance on wheat and wheat by-product feeding value, to achieve desired levels of energy and protein/amino acids in the finished ration (Table 1).

Table 1 Contribution of wheat and wheat by-products to digestible energy (DE, MJ/kg) and digestible lysine (dig. lys per cent) levels in 'typical' UK grower/finisher rations

	Inclusion level (%)	*% total DE in ration*	*% total dig. lys in ration*
Wheat	35	36	9
Wheatfeed	15	13	8
Total	50	49	17

Assumes: DE for wheat of 14.0 MJ/kg; wheatfeed 11.5 MJ/kg
dig. lys for wheat of 0.24 per cent, wheatfeed 0.46 per cent
'Standard' grower/finisher diet: 13.5 MJ/kg; 0.9 per cent digestible lysine

Practical problems with feeding high wheat diets to pigs

Although wheat is an attractive raw material to pig feed formulation in many countries on a cost per unit of energy basis, it is often associated with a number of negative feeding characteristics.

Gastric ulceration

One of the key criticisms of high wheat diets has been their propensity to induce gastric ulceration in pigs housed in strawless finishing pens. Recent Danish work on this particular problem has identified the positive benefits of efficient rolling techniques in reducing gastric ulceration, when compared to fine grinding of the grain (4.5mm. Keller Nielsen 1994). Expansion of wheat diets after roller milling is also claimed to reduce the incidence. (Feed International, 1994.)

Colitis

Colitis is a non-specific scour problem which is principally found in fast-growing young pigs (15-40kg), but can occur at any stage in the growth cycle. It is characterised by the passing of loose 'pancake-like' faeces, sometimes with mucus. Growth rate and FCR is usually compromised, although not invariably. High wheat levels are traditionally implicated in the condition, although levels of other key raw materials (e.g. soya bean meal) are also suspected when cases arise. Barley-based diets appear to offer some respite and pelleting seems to exacerbate the condition (Taylor 1990). Definitive studies illustrating the role of wheat, specifically, in the aetiology of the disease remain to be carried out.

Gluten and non-starch polysaccharide (NSP) content

The gluten proteins in wheat (gliadins and glutenins) are insoluble in water and are structurally linked to wheat pentosans in the endosperrn wall (principally arabinoxylans).

Wheat arabinoxylans are partially soluble in the gut and are known to increase the viscosity of the gut contents in poultry (Bedford 1994, Morgan 1994). As a consequence, the availability of nutrients for absorption is decreased, diffusional constraints may limit endogenous enzyme activity in the chyme and there is often increased bacterial fermentation within the ileum. Similar effects may occur in pigs offered high wheat diets, although key physiological differences between pigs and poultry may alter the magnitude or nature of this response. This aspect is examined later in this article.

Specific problems with the gluten content of wheat have also been observed in pigs. Penny (1993) in an abattoir slaughter study describes the appearance of 'dough balls' in the stomach contents of finisher pigs fed high wheat diets (60 per cent), although numerically the incidence was low (4-5 per cent on one farm) and their chemical composition was not examined.

The feeding value of wheat and wheat by-products for pigs

The 'hardness' of wheat is a measure of the degree of adhesion between starch and protein in the endosperm, with hard wheat having a high degree of adhesion to form a 'protein matrix'. Feeding trials on hard and soft wheats with pigs have generally shown little difference in feeding value (Magowan 1990) although some studies have shown higher amino acid availabilities in hard wheat (Ivan and Farrell 1976).

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Table 2: Measurements of the DE (MJ/kg dry matter) value for wheat, using grower/finisher pigs

Reference	*Country*	*Mean DE (MJ/kg DM)*	*Range*	*Highest - lowest value (MJ)*	*No. of samples*
1	Canada	15.8	15.0-16.4	1.4	7
2	Australia	16.2	15.7-16.9	1.1	8
3	UK	16.1	15.1-16.4	1.3	8
4	Canada	16.3	15.5-17.0	1.5	15
5	UK	15.4	14.4-16.0	1.6	32

References: 1: Bowland 1974; 2: Batterham et al 1980; 3: Wiseman and Cole 1980; 4: de Lange et al 1993; 5: Wiseman et al 1994.

Table 2 summarises a range of studies where DE values have been determined for various wheat samples, in the UK, Canada and Australia. Variations of the order of 1.5 - 1.6 MJ/kg have been observed between 'high' and' low' energy wheats in the larger trials. In commercial practice, therefore, much wider variations are likely to be encountered both within, and more especially between, sample years.

Wheat by-products are, not surprisingly, a more heterogeneous range of raw materials, differences between them being determined by the 'efficiency' of the prior flour milling process. Batterham et al (1980) working with samples of bran, mill run and pollard found a mean DE value of 14.2 MJ/kg DM and a range of 3.7 MJ/kg DM (12.5 - 16.2, n = 8). Again, in commercial practice, much wider variations in feeding value would be encountered - illustrating the importance feed compounders place on sourcing these raw materials.

Chemical predictors of the feeding value of wheat and wheat by-products for pigs

de Lange et al (1993) in a recent study working with a number of Canadian wheats for grower/finisher pigs found the best prediction equations for wheat DE were those incorporating both protein level and the hemicellulose fraction. (Table 3). Similarly, Batterham et al (1980) found prediction equations incorporating NDF gave a higher R^2 value than those using ADF, again illustrating the importance of the hemicellulose component.

Table 3 Predictors of the DE content of feed wheat (de Lange et al 1993)

DE (kcal/kg DM)	
= 3179 + 11.9 x starch (%)	R^2 = 0.11 P= 0.22
= 2998 + 16.3 x bushel weight (lb/bu)	R^2 = 0.43 P <0.01
= 3712 + 34.5 x protein (%) - 89.4 x ADF(%)	R^2 = 0.65 P <0.01
= 3584 + 38.3 x protein (%) - 16.0 x NDF(%)	R^2 = 0.75 P <0.01

Studies by Batterham et al (1980) on wheat by-products found that equations incorporating both bulk density and ADF level gave the best description of measured DE values, whereas Henry (1976) found NDF level in wheat by-products was a marginally better predictor of DE value than either ADF or CF (R^2 values 0.958, 0.941 and 0.938 respectively.) e.g. DE (MJ/kg) = 27.76 - 0.016 bulk density (kg/m^3) - 0.085 ADF (g/kg) R^2 = 0.89 Batterham et al (1980)

All studies indicate the importance, in particular, of the non-starch polysaccharide component to energy digestibility in these raw materials. Similarly, it has been suggested that the amount of fibre-bound protein in cereal grains corresponds well to protein/amino acid digestibility values in pigs (Rybka et al 1992, Table 4)

Table 4 Protein and amino acids associated with dietary fibre fractions isolated from cereal grains - values expressed as a per cent of total grain nitrogen or amino acid.

	Nitrogen	*Lysine*	*Threonine*	*Methionine + Cysteine*
Rye	19.7-20.2	25	23	27
Wheat	14.4-19.6	22	22	19
Triticale	17.6-20.8	26	21	30
Barley	26.0-27.9	40	36	33

The above studies illustrate the interest in the potential of in-feed enzymes to upgrade, or reduce the variability in feeding value, of wheat and wheat by-products using enzymes targeted against their carbohydrate and protein components.

Pigs - a role for feed enzymes?

Most recent reviews of published work on feed enzymes for non-ruminants conclude that the effects of in-feed addition are often numerically greater in poultry than in pigs and that effects, in general, are more consistent (e.g. Dierick 1989, Dierick and Decuypere 1994a). It is also recognised, however, that conclusions are difficult to draw given that many published studies have used single enzyme preparations, often with ill-defined or variable activities (Dierick and Decuypere 1994b). At the other extreme, in some pig trials where significant effects have been observed with enzyme 'blends' it is unclear which particular enzyme activities have been primarily responsible.

Basic physiological differences between pigs and poultry as well as variations in typical feed substrates would suggest that the two species may differ in both the level and type of enzyme activity they require. (Table 5)

Table 5: Some physiological differences between pigs and poultry which may influence the response to feed enzymes

1. Digesta dry matter content	On equivalent diets the chick has a higher dry matter content in its digesta. Piglet 12-13 per cent Chick 17-18 per cent
2. Hindgut capacities	Pig > 30 per cent of total gut Poultry < 10 per cent of total gut The influence of the hindgut microflora will be greater in the pig - e.g. VFA production and contribution to energy metabolism Microflora in the small intestine will also be more influential in pigs. (Graham and Pettersson 1989)
3. Pre-gastric digestion	The presence of the crop in poultry provides a pre-gastric 'reaction chamber' (2-3 h @ pH 6.3)

In poultry offered wheat and barley-based diets, one of the primary modes of action of feed enzymes is to significantly reduce digesta viscosity in the small intestine of the bird - an effect attributable to reducing levels of certain partially-soluble non-starch polysaccharides e.g. beta-glucans in barley, arabinoxylans in wheat. Supplemental protease additions enhance this effect e.g. Morgan (1995), Bedford (1994).

In pigs, the influence of viscosity in the gut on nutrient digestibility is less clear. Recent studies by Bedford et al (1992) and Inborr (1994), both working with potentially high viscosity diets (e.g. based on hulless barley) have shown that numerically the values for pigs are much lower than those seen in poultry. In Inborr's study, however, addition of a suitable beta-glucanase preparation did significantly reduce the absolute viscosity value

Table 6: Trials showing the effects of beta-glucanase supplementation of barley-based diets for young pigs (9-15 kg) on animal performance and intestinal viscosity.

Parameter	*Control*	*Trial 1* *+Enzymes*	*Sig.*	*Control*	*Trial 2* *+Enzymes*	*Sig.*
Weight gain/growth rate	212 g/d	219g/d	P=0.07	5.24kg	6.14kg	*
FCE	0.61	0.63	P=0.06	0.57	0.65	P=0.10
Viscosity in small intestine (cps)	3.3	2.2	*	3.1	2.8	ns
Digesta dry matter in ileum (%)	13.6	14.3	*	12.1	12.6	ns

**p<0.05 Trial 1: derived from Inborr (1994); Trial 2: Bedford et al (1992)*
n.b.for comparative purposes 'typical' chick values on similar diets would be in the range 8 - 150 cps.

(Table 6). Similar responses have recently been reported in wheat-based diets by Sudendey and Kamphues (1995), although again the absolute viscosity values in the small intestine were low (control 1.74cf. plus enzyme 1.45, $p < 0.05$.) It should be noted, however, that recent commercial poultry trials carried out by FFI have shown that, even at relatively low starting viscosities, birds can show a cost-effective response to *Avizyme* addition. This could be explained in part by the logarithmic relationship which exists between viscosity and bird performance (Bedford and Classen 1992). Thus, in simple terms, a reduction in viscosity of 90 centipoise units (cps) from 100 to 10cps should give the same improvement in chick performance as reducing the viscosity by 9 centipoise units from 10 to 1 cps.

It is apparent from these studies that, irrespective of the possible role of gut viscosity, pig growth and feed utilisation were positively influenced by enzyme addition. This agrees with many commercial trials using *Porzyme* products, on both barley and wheat-based diets, which have shown similar positive shifts in pig performance of 4 to 6 per cent in growth rate and FCR (Figure 1). Further studies are warranted in pigs to examine the relevance of viscosity to enzyme response in more detail, in both wheat and barley-based diets. The use of 'isolated' anti-nutritional factors to magnify responses in the animal may also be a valid experimental approach (e.g. Choct and Annison, 1992)

Effects of feed enzymes on endogenous enzyme production

The differences in gut viscosity reported by Inborr (1994, Table 6) for piglets offered barley-based diets with and without beta-glucanase supplementation were, interestingly, associated with marked changes in the levels of endogenous enzymes present in the digesta. Supplementation of the diet with exogenous enzymes appeared to reduce levels of endogenous enzyme output (Table 7). Further research would be useful to verify this effect because it may indicate a possible protein and energy 'sparing' effect of enzymes which, at marginal protein intakes, could underlie improvements in animal performance observed in a number of trials.

Figure 1: Summary data from 53 trials showing the effects of multi-enzyme systems (Porzyme SP and TP) on pig performance (8-25 kg)

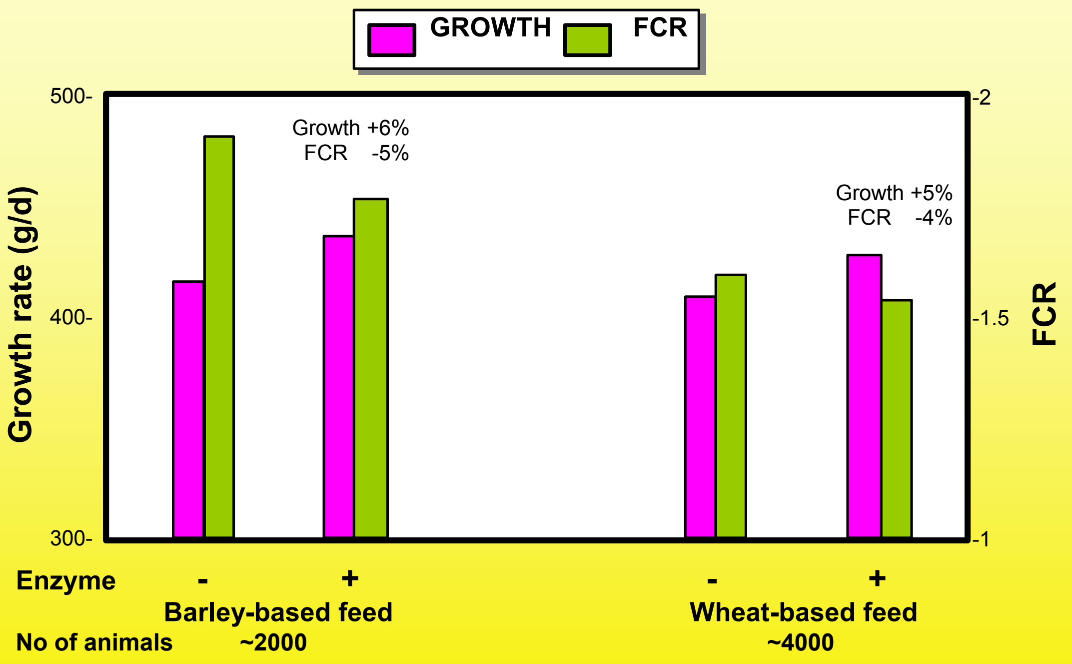

Table 7 The effects of enzyme addition to the diet on pancreatic enzyme output, as measured in the digesta. Barley-based diets, 9-15kg piglets (derived from Inborr, 1994)

	Control	*+Enzymes*
Digesta viscosity (cps)	3.3	2.2*
Digesta dry matter (%)	13.6	14.3*
Endogenous enzyme levels (mU/g digesta DM)		
Trypsin	10.0	5.8*
Chymotrypsin	0.15	0.11 p < 0.1
Lipase	95.8	51.4 p < 0.1
Amylase	866	451*

**p < 0.05*

Similar effects on endogenous enzyme production are elicited by diets, containing no wheat or barley, but formulated to contain other ingredients with a potential to increase water holding capacity (e.g. citrus pulp, alfalfa meal, Decuypere et al, 1994; Dierick and Decuypere 1994, Table 8).

Table 8 Effects of increasing the water-holding capacity (WHC) of the diet on nitrogen flow, and source, at the terminal ileum.
Low WHC diet = 2.7 g/g ; High WHC diet = 3.4 g/g
(g water per g fresh insoluble sample, AACC 88-04)

	Experiment 1 (High WHC diet relative to low WHC diet)	*Experiment 2 (High WHC diet relative to low WHC diet)*
Water soluble nitrogen (g/d)	+ 37 per cent	+ 18 per cent
Bacterial and cellular debris nitrogen (g/d)	+ 44 per cent	+ 23 per cent
Undigested feed nitrogen (g/d)	+ 1 per cent	- 2 per cent
Total digesta (g/d)	+ 58 per cent	+ 22 per cent

Experiment 1 = 72 per cent of ad lib, Experiment 2 = 85 per cent of ad lib. Measured in female pigs (25-50kg) with pre-caecal cannulae.

New Porzyme products for wheat-based pig feeds

Fundamental research studies on a number of different xylanase and protease sources, described by Morgan (1995), has afforded an opportunity to look at their potential application to pig feeds containing high wheat levels. Although, as mentioned above, mechanisms of action remain to be described more precisely for the pig, early results with the products have been encouraging, both in young pigs and grower/finishers (Table 9). Further appraisals of these products are ongoing at both research and commercial level.

Table 9 Recent studies on two new high xylanase products for pigs ~ Porzyme 8300 (for starters) and Porzyme 9300 (for grower/finishers)

a) Weaner pigs, 6 kg - 24 kg, 60 - 70 per cent wheat

	Wheat control		*+ Porzyme 8300*	
4 - 7 weeks				
Daily gain (g)	243 a	(100)	284 b	(117)
Daily feed intake (g)	343	(100)	363	(106)
FCR	1.42	(100)	1.29	(91)
4 - 10 weeks				
Daily gain (g)	417 a	(100)	452 b	(109)
Daily feed intake (g)	608	(100)	663	(109)
FCR	1.45	(100)	1.42	(98)

a, b Means not sharing a postscript differ significantly (P < 0.05)

b) Grower/finisher pigs, 30-105 kg, ad lib feeding, 50 - 60 per cent wheat

	Wheat control		*+ Porzyme 9300*	
Daily gain (g)	853 a	(100)	973 b	(114)
Daily feed intake (g)	2625	(100)	2874	(109)
FCR	3.12	(100)	2.98	(96)
Days to finish	88.8 a		77.6 b	

a, b Means not sharing a postscript differ significantly (P < 0.05)

c) Grower/finisher pigs, 25-105 kg, ad lib feeding, 84 per cent wheat

	Wheat control		*+ Porzyme 9300*	
Daily gain (g)	766 a	(100)	825 b	(108)
Daily feed intake (g)	2376	(100)	2486	(105)
FCR	3.10	(100)	3	(97)
Days to finish	104		98	

a, b Means not sharing a postscript differ significantly (P < 0.05)

d) Grower/finisher pigs, 23-90 kg, ad lib feeding, 47 per cent wheat & wheat by-products

	Wheat control		*+ Porzyme 9300*	
Daily gain (g)	667 a	(100)	725 b	(109)
Daily feed intake (g)	1953	(100)	2103	(108)
FCR	2.93	(100)	2.90	(99)
Days on trial	94		94	

a, b Means not sharing a postscript differ significantly (P < 0.05)

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