About the author

Dr Michael Pack, of Finnfeeds International, provides technical back-up for the application and development of enzyme products for poultry in his role as Technical Services Manager. He recently joined Finnfeeds from Degussa AG (Germany) where he spent six years as Research Manager: Poultry and Aquaculture after gaining his PhD from the University of Bonn.

Turning grain into gain

Better use could be made of barley and oats, traditional feed grains that are widely cultivated and which offer many nutritional benefits

IN MANY TEMPERATE AREAS, barley and to a lesser degree oats, contribute a major portion to the overall production of cereal grains. For the EU-12 countries barley production in 1994/95 was almost 40 million tonnes, about 75 per cent of which are used to produce animal feeds. Feed use of barley is largely concentrated in only four countries: Germany, France, the UK and Spain account for more than 80 per cent of the total barley usage in animal feeds throughout the EU-12. Of course there are other areas in the world with a substantial consumption of the two grains for feed production. These include Canada, the Nordic countries, numerous countries in Eastern Europe, New Zealand and certain areas in Australia and the USA.

Oats have a more regional importance due to their inferior yield. Nevertheless, there is significant use for animal feeds in some countries - mainly in ruminant and horse feeds, but some find their way into monogastric feeds as well. There are some five million tonnes consumed in the US, about two million tonnes each in Canada, Poland, Germany and about one million tonnes each in Australia, Sweden, and Finland (FAO 1990). There used to be a large consumption of feed oats in the former Soviet Union (> 15 million tonnes), but it is unclear what the current situation is.

> ***"a seasonal challenge for the nutritionist is to make efficient use of new crop grains every year."***

Both barley and oats have a long tradition of being the major grains in feeds mixed on-farm, whereas feed compounders used to prefer corn and wheat. In many parts of the world, where corn, sorghum or wheat are the grains of choice for pig and poultry feeds, nutritionists and animal producers may not have any experience with the use of barley and oats at all and possibly wouldn't consider using them, even if available at competitive prices. Factors other than climatic and soil conditions contribute to the large diversity in the attitudes towards, and the actual inclusion rates of, barley and oats in different types of diets. This paper highlights some of these factors and explores the benefits of a more widespread use of barley and oats.

Composition of cereal grains

From a nutritional point of view, both nutrient contents and possible constraints for different types of diets need to be evaluated. Table 1 summarises data on the composition of barley and oats and compares them to wheat and maize.

It is clear that maize and wheat will he the preferred cereals for non-ruminant diets, if a high energy content is vital. It is interesting to consider the factors contributing to the differences in metabolisable energy. The major difference is the composition of the carbohydrate fractions: the fibre polysaccharides (non-starch polysaccharides) are elevated in barley and oats at the expense of starch. The differences in the ME levels, however, are bigger than one would expect - due to the detrimental effects of the fibre on overall digestion. Table 1 shows that the fibre predominantly consists of arabinoxylans and cellulose in the case of maize and wheat, with ß-glucans and lignin more

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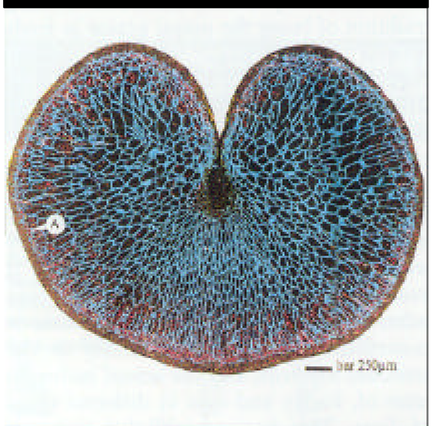
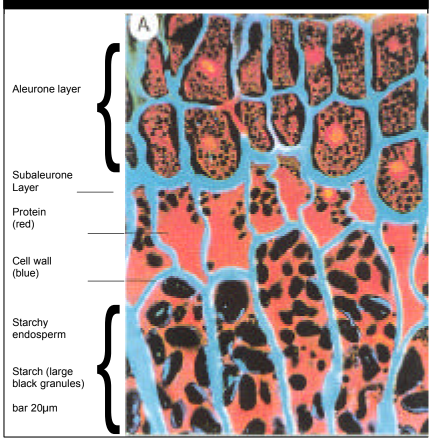
BARLEY WHOLEGRAIN



MICROSTRUCTURE OF BARLEY



important in barley and oats. The polysaccharide chains in these fibre components are linked via bonds that are not accessible for the endogenous digestive enzymes in poultry and pigs. A large portion of the mixed-link ß-glucans in barley and oats are water-soluble and lead to the formation of highly viscous digesta in the small intestine. This feature is the key to understanding and improving the nutritional value of these two cereal grains in monogastrics, particularly in poultry. Other differences can he seen in the amino acid and the fatty acid composition. Barley and particularly oats have a higher content of lysine in their proteins than corn and wheat, thus improving the dietary amino acid balance at a given crude protein content. Also, oats are high in linoleic acid, which is an important factor determining egg weight. Another important difference between the grains is in their content of xanthophyll pigments. Depending on the required skin or egg yolk colour, it may be necessary to add natural or synthetic pigments, if maize is replaced by one of the alternative grains.

Improving the nutritional value of barey and oats

The effects of the soluble fibre on nutrient digestion and animal performance are complex. The high viscosity of the digesta in the small intestine slows down the passage rate through the gut and can depress feed intake. At the same time, absorption from the intestinal lumen seems to be impaired. This is usually accompanied by wet and sticky litter problems in broilers and a high portion of dirty eggs in layers. These negative effects can largely be removed by the addition of feed enzymes with ß-glucanase activity. Their effect is to break down the long polysaccharide chains to smaller pieces which no longer cause viscosity in the gut. The effect of ß-glucanase addition to a barley based broiler ration on gut viscosity and subsequent growth performance can be seen in Table 2. Digesta viscosity and water content of the excreta are decreased, resulting in significant improvements in growth and feed conversion. In addition, variability in body weight is also very much reduced (here measured as coefficient of variation, CV).

Similar observations were recently reported by Spanish researchers Almirall and co-workers (table 3). In the barley diet, even though containing as much as 60 per cent barley and calculated to have 9 per cent less ME than the corn diet, enzyme addition compensated for most of the difference in performance. The reduced viscosity led to much faster digesta passage rate as indicated by the reduced time required to excrete 50 per cent of an added indigestible marker.

In a digestibility study done with young chicks, significant increases in fat, protein and amino acid digestibility were observed. Increased fat digestibility with enzyme addition was previously reported by Friesen et al. (1992) in diets based on barley or oats.

A fair amount of barley is used for layer diets in some countries. In a recent experiment at the University of Queensland, Australia, enzyme addition to either barley (71 per cent) or barley/wheat (35/42 per cent) based rations for layers 41 to 53 weeks of age was tested. Results reported in table 4 reveal a positive response both in laying performance and in feed conversion.

Improved nutrient digestibility from enzyme addition is also observed in pigs. Ileal digestibility of energy and protein in cannulated pigs of about 25 kg bodyweight were significantly enhanced in barley of both high and normal bushel weights (table 5).

These positive effects on digestion are well reflected in a survey of 57 individual feeding trials investigating the growth and feed conversion responses of pigs to barley rations supplemented with enzymes (figures 1 and 2). In 24 trials involving 1700 pigs up to 27 kg bodyweight, the average response was +5.8 per cent in weight gain and 4.8 per cent less feed per kg gain. Similarly, trials with a total 7500 grower / finisher pigs indicate an average improvement of 3.1 per cent in weight gain and 4.4 per cent in feed conversion due to the addition of a barley-specific enzyme product. Pigs can also benefit from reduced incidence of digestive disorders and, subsequently, reduced medication, and growth can be clearly more uniform.

More recently, attempts have been made to either dehull oats ('groats') or to breed naked oats. Similarly, hulless barley has been tested. The energy content is higher in these grains due to their lower fibre content, but the content of soluble ß-glucans is also elevated, resulting in the same problems from high digesta viscosity as with ordinary breeds. Farrell (1991) tested inclusion rates of up to 84 per cent naked oats in broiler diets and compared them to wheat based diets, in both cases with and without enzyme addition (table 6). The addition of the enzyme increased the dietary ME of the naked oats from 11.7 to 13.3 MJ/kg, thus bringing it close to the 13.4 MJ ME in the wheat tested.

A seasonal challenge for the nutritionist is to make efficient use of new crop grains every year. Although there may be a strong economic incentive to use new harvest barley as early as possible, it is well established that fresh grains very often tend to cause digestive disorders. Most likely, the reason for this is again in the soluble ß-glucan fraction, which varies considerably depending on weather conditions around harvest and variety (Hesselman 1983, Graham 1994). Enzyme addition has been demonstrated to alleviate the negative effects of new crop barley. In a recent trial in grower pigs performed in Austria, performance was substantially improved by addition of a ß-glucanase product to new crop barley (table 7).

The opportunities from using new crop barley during seasonal windows of competitive prices are obvious. By reducing the risk of digestive disorders and erratic animal performance, replacing more expensive grains in the diets with the new crop can lead to substantial savings.

Practical application

The data presented so far may highlight the opportunities arising from having barley and sometimes even oats available. In compound feed production, least cost formulation results in a permanent competition amongst the full range of ingredients on the market at a given time. The question therefore is how to take full advantage of the effects already outlined.

A major argument for the use of barley along with the proper enzyme supplement is the reduced risk from variability in feed quality and subsequent animal performance. Scott and Bedford (1996) compiled a survey of 17 barley cultivars, in which both hulled and hulless breeds were included. The ME content for broilers and the actual feed conversion on diets based on the individual barley varieties showed a consistent improvement from enzyme addition and, equally important, much better uniformity of barley ME values and bird feed conversion (figure 3).

On average, ME was increased from 2750 kcal to 3063 kcal per kg, with standard deviation being reduced from ± 124 kcal to ± 87 kcal. Thus, the energy content was elevated close to that normally expected for wheat.

This was clearly reflected in bird feed conversion (figure 3), which was also not only improved from 1.62 to 1.40 kg feed per kg gain, but was much less variable within the diets supplemented with the enzyme (standard deviation went down from ± 0.13 to ± 0.04). This will open up new opportunities to either include barley in high-energy diets, or reduce safety margins and correspondingly fat addition in diets already including barley.

FIGURE 1 EFFECTS OF ENZYME ADDITION IN 24 TRIALS PERFORMED IN YOUNG PIGS 8-27 KG BODY WEIGHT FED BARLEY DIETS

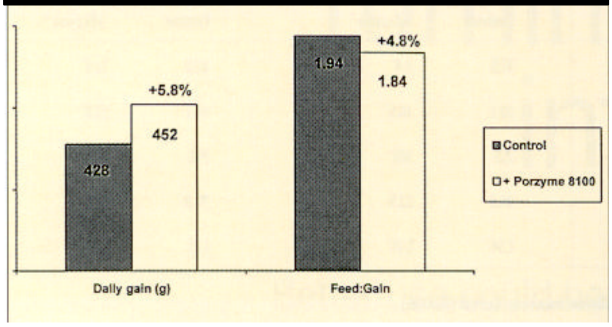


FIGURE 2 EFFECTS OF ENZYME ADDITION IN 35 TRIALS PERFORMED IN GROWING/FINISHING PIGS 24-97 KG BODY WEIGHT FED BARLEY DIETS

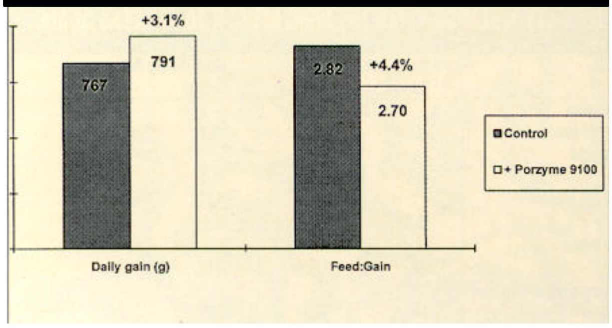
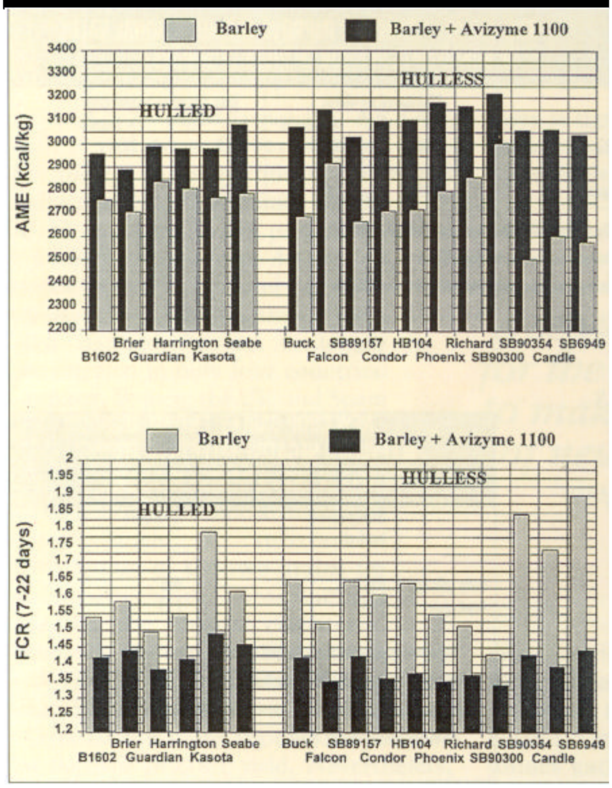


FIGURE3 CONTROLLING VARIABILITY IN BARLEY: EFFECTS OF ENZYME ADDITION TO BROILER DIETS BASED ON DIFFERENT BARLEY VARIETIES (BROILERS, 28 DAYS OF AGE)



In summary, there are essentially two ways to use barley with enzyme addition. This can either be to add the enzyme to an otherwise unchanged diet ('over-the-top'), or alternatively to adjust the matrix values for energy, protein and amino acids according to the predicted effects of the enzyme on the quality of barley. This includes uplifts of +10 per cent for the ME value and +15 per cent for the protein and amino acid values of barley with Avizyme 1100 used for broiler diets containing up to 60 per cent barley.

"Barley and particularly oats have a higher content of lysine in their proteins than corn and wheat, thus improving the dietary amino acid balance at a given crude protein content"

The application of this concept has been successfully tested in pen trials and under field conditions. For grower and finisher pigs, a six per cent uplift in the DE value of barley is recommended in diets supplemented with Porzyme 9100. Other benefits of using enzyme addition include a larger flexibility in ingredient inclusion and releasing formulation constraints on either the grain itself, or even on other ingredients such as animal fats. The challenge is for the nutritionist to exploit this potential under the conditions of his operation.

See tables on next page

TABLE 1 COMPOSITION OF BARLEY & OATS AS COMPARED TO WHEAT & MAIZE (% AS IS)

	Maize	Wheat	Barley	Oats
ME Poultry (MJ/kg)	13.8	12.8	11.5	10.5
(kcal/kg)	3300	3050	2750	2500
ME Pigs (MJ/kg)	13.7	13.7	12.0	11.0
(kcal/kg)	3275	3275	2870	2625
Crude protein	8	12	10	11
-Lysine (% of CP)	3.0	2.8	3.6	4.2
- Methione (% of CP)	2.1	1.6	1.7	1.7
- Threonine (% of CP)	3.6	2.9	3.4	3.5
Crude fat	3.5	2	2.5	5
Linoleic acid	2.0	0.5	0.9	1.6
Starch	64	62	56	41
Total fibre*	7.9	9.7	16.7	26.4
- Cellulose	2.4	2.3	3.8	8.0
- Arabinoxylans	4.4	5.3	6.2	8.2
- ß-Glucans	0.1	0.7	3.9	3.0
- Lignin	0.5	0.7	1.9	4.5
Xanthophyll (Img/kg)	18	2	-	-

*Fibre polysaccharides + lignin
(Aman & Graham et al 1987, Degussa 1996)

TABLE 3 INFLUENCE OF ENZYME ADDITION ON PERMORMANCE (0-21 DAYS) AND INTESTINAL PARAMETERS (21-23 DAYS) IN BROILERS FED BARLEY BASED DIETS RELATIVE TO A CORN POSITIVE CONTROL DIET

	Barley based control diet	Barley based diet + Enzyme[1]	Corn based positive control diet
Weight gain (g,0-21 d)	508	575*	630
Feed intake (g,0-21 d)	806	855*	916
Feed: gain (0-21 d)	1.61	1.53	1.47
Digesta dry viscosity (cPs)	29	3*	-
Digesta dry matter (%)	16.5	18.0	-
50% Marker excretion (min)	533	329*	-
Excrea digestibility (%)			
- fat	72.3	82.2*	-
- starch	95.8	97.9	-
- protein	77.1	83.4*	-
- lysine	82.4	86.8*	-
- methionine	89.4	92.8*	-

*Significantly different from barley control diet (P<0.05)
[1]Avizyme 1100, Finnfeeds International (Almirall & Esteve-Garcia, 1994, Almirall et al, 1995)

TABLE 5 ILEAL DIGESTIBILITY OF NUTRIENTS IN BARLEY DIETS FED TO PIGS AS AFFECTED BY ENZYME ADDITION (25 KG BODYWEIGHT, DIETS CONTAINING 77% BARLEY)

Barley type	High bushel weight (76 Kg/hl)		Low bushel weight(66 Kg/hl)	
Ileal digestibility (%)	Control	+Enzyme[1]	Control	+Enzyme[1]
- Energy	67	69	66	71
- Protien	74	76	73	77

Significant effect of enzyme addition (P<0.05), no effect of bushel weight
[1]Porzyme 9100, Finnfeeds International (McCracken et al. 1996)

For further information please contact the author.

TABLE 2 EFFECTS OF ENZYME ADDITION TO DIETS BASED ON BARLEY OR OATS, BROILERS 0-21 DAYS OF AGE

	Barley diets		Oats diets	
	Control[1]	+Enzyme[2]	Control[1]	+Enzyme[2]
Digesta viscosity (cPs)	57.9	8.4*	62.8	12.0*
Excreta dry matter (%)	40.1	46.5*	46.1	51.0*
Weight gain (g)	255	308*	253	303*
CV in weight gain (%)	34.3	23.5	20.9	11.6
Feed: gain	1.34	1.24*	1.28	1.23

*Significantly different from resp.Control (P<0.05)
[1]Average results for 6 different varieties of barley and oats
[2]Avizyme 1100, Finnfeeds International
(Scott & Bedford, Agriculture Canada, Agassiz, BC)

TABLE 4 EFFECTS OF ENZYME ADDITION TO BARLEY OR BARLEY/WHEAT DIETS FED TO LAYING HENS, 41 TO 53 WEEKS OF AGE

	Barley diet		Wheat/barley diet	
	Control	+Enzyme	Control	+Enzyme
Egg numbers (per 100 hens per day)	71.1[a]	78.1[c]	69.4[a]	75.9[b]
Egg weight (g)	61.6[a]	61.0[a]	59.8[b]	59.8[b]
Daily egg mass (g/d)	43.8[ab]	47.6[b]	41.5[a]	45.3[ab]
Feed intake (g/d)	117.7[b]	125.4[a]	116.4[b]	118.5[b]
Feed per g egg mass (g/g)	2.69[ab]	2.63[a]	2.81[b]	2.61[a]

[ab]Means not sharing a superscript differ significantly (P<0.05)
[1]Avizyme 2100, [2]Avizyme 2300, Finnfeeds International
(Mannion & Cresswell, 1996, Gatton College, Univ. of Queensland, Australia

TABLE 6 THE USE OF ENZYMES TO IMPROVE THE NUTRITIONAL VALUE OF NAKED OATS IN BROILER DIETS (3-17 DAYS)

	Diet based on Wheat		Diet based on naked oats	
	-	+Enzyme[1]	-	+Enzyme[2]
Weight gain (g/d)	22.6	24.6	17.5	23.4*
Feed: gain	1.68	1.54*	1.85	1.53*

*Significantly different from resp.Control (P<0.05)
[1]Avizyme tx, Finnfeeds International
[2]Avizyme sx, Finnfeeds International (Farrell 1991)

TABLE 7 NEW CROP BARLEY: ENZYME ADDITION ALLEVIATES NEGATIVE EFFECTS OF FRESH GRAINS IN GROWER PIGS (30-50 KG)

	Barley based Control	+Enzyme[1]
Daily gain (g)	603	683*
Feed: gain	2.54	2.27*

*Significantly different from Control (P<0.05)
[1]Porzyme 9100, Finnfeeds International
(Wetscherek & Schulze, 1996, Universität für Bodenkultur, Abteilung Tierernährung, Wien)

Keywords: Porzyme 8100, Porzyme 9100, Pig, Piglet, Barley, Oats, Hulless barley, New crop, Swine, Hectolitre weight,