How enzymes improve the nutritional value of wheat

Andrew Morgan[1], Michael Bedford[1], Asta Tervila Wilo[2], Maarit Hopeakoski-Nurminen[2], Karin Autio[3], Kaisa Poutanen[3] and Teija Parkkonen[3] - 1. Finnfeeds International Ltd, Marlborough, Wiltshire, SN8 1AA, U.K. - 2. Cultor Ltd, Technology Centre, FIN-02460 Kantvik, Finland-3. VTT Biotechnology and Food Research, P.O. Box 1500, FIN-02044 VTT, Finland

Digesta viscosity is a determinant of wheat quality

The endosperm cell walls of wheat, triticale and rye contain a high level of non-starch polysaccharide consisting mainly of arabinoxylans and some mixed-linked beta-glucan (Figure 1). One of the distinctive characteristics of wheat appears to be an aleurone layer with a relatively thick cell wall structure. It has been suggested that the cell walls of wheat endosperm cells make nutrients such as starch and protein less available for digestion.

At least part of the arabinoxylan content of wheat endosperm cell walls is soluble. The recognition that soluble ß-glucans of barley endosperm increase digesta viscosity and thereby reduce digestibility and increase faecal moisture content, at least in poultry, suggested that the arabinoxylans of wheat and rye might exert similar effects. In 1991, it was established that there is a significant correlation between digesta viscosity measured *in vivo* (broilers) and performance parameters such as body weight gain and feed conversion. In the case of enzyme-supplemented wheat and rye-based diets fed to poultry, as

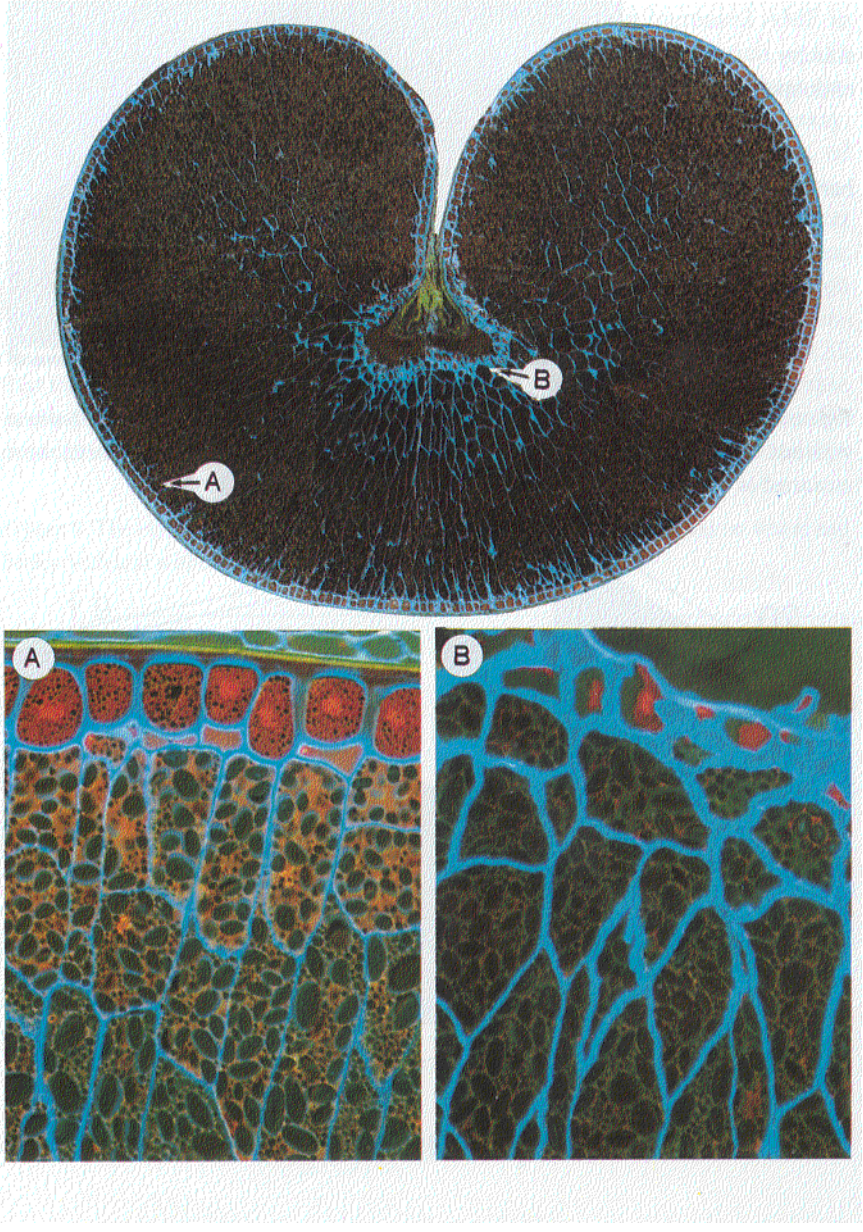


Figure 1. The microstructure of wheat. Cell walls were stained blue with Calcafluor White and protein was stained red/orange with Acid Fuchsin.

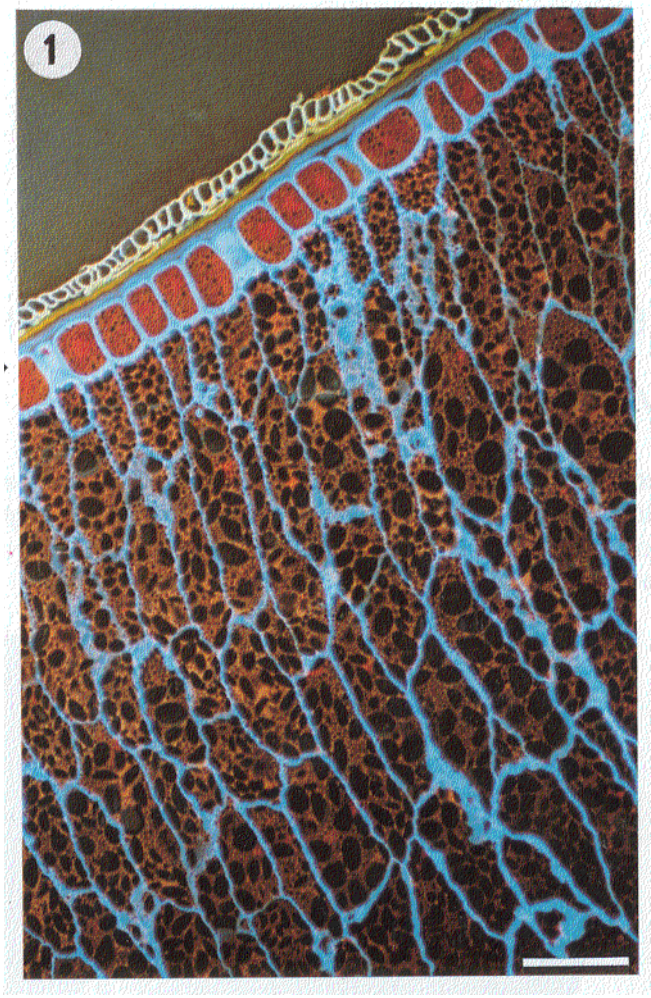
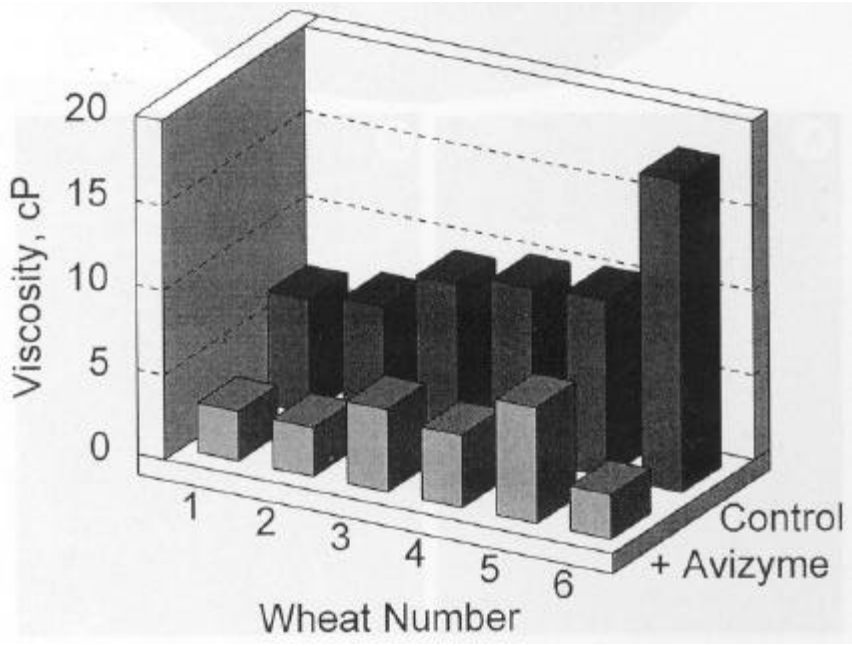


Figure 2. Digesta (intestinal) viscosity of different wheats (diets containing 60 - 67% wheat with and without Avizyme 1300, a feed enzyme product for wheat-based diets) were measured *in vivo* in broilers at 21-22 days (Morgan and Bedford, 1995).



much as 70-80% of the variation in body weight gain and feed conversion ratio (FCR) can be attributed to differences in digesta viscosity. This demonstrates the importance of viscosity in wheat and rye-based diets for broilers and raises the possibility that variability in wheat quality (apparent metabolizable energy AME) might be related to this phenomenon. It is well known that apparent metabolizable energy values (poultry AME) for different wheats can be highly variable with reported values ranging from 11.0 MJ/kg to 16.6 MJ/kg DM and problems of wet litter are sometimes seen in broilers fed high levels of wheat.

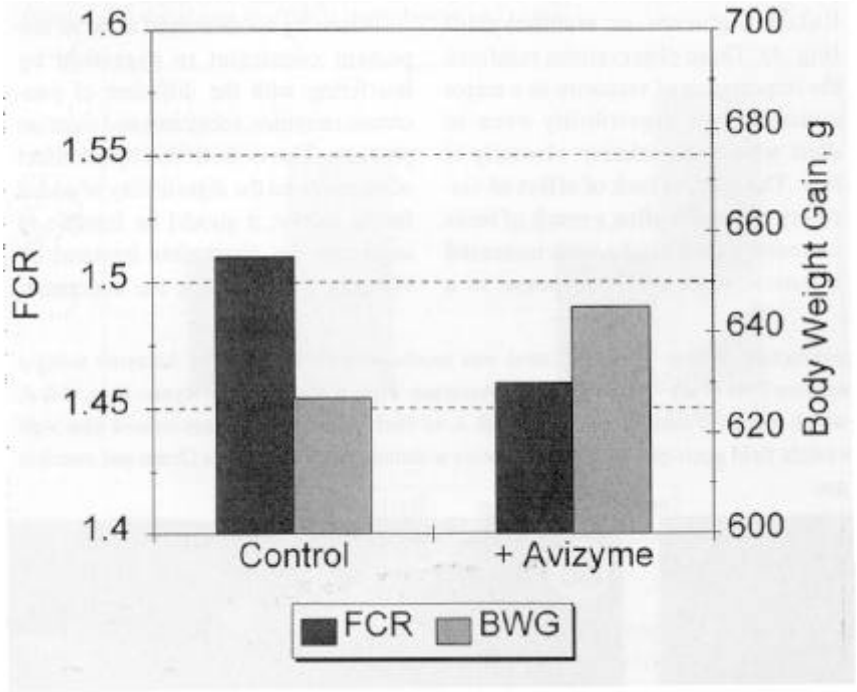
The relationship between variable wheat quality and digesta viscosity is currently a key focus of research. A range in broiler intestinal viscosity of 6.73 - 18.38 cP (mean = 10.41; s.d. = 4.20) has been reported from birds fed one of six wheat-based diets (60 - 67% wheat). Since a strong correlation exists between digesta viscosity and performance parameters in wheat-based diets for broilers, it can be concluded that digesta viscosity is likely to be one of the main determinants of wheat quality for feed use.

One of the most important advances in animal nutrition during the last decade has been the development of feed enzymes and, in particular, products for wheat-based diets for poultry and pigs. Figure 3 shows how feed enzymes improve performance in wheat-based diets for broilers.

Enzymes affect viscosity of digesta

In the study referred to above intestinal viscosity was reduced in all cases by the addition of Avizyme (Figure 2). The viscosity range was reduced to 2.66 - 6.85 cP (mean 4.08; s.d. = 1.62). It is clear that the addition of the enzyme can reduce viscosity of

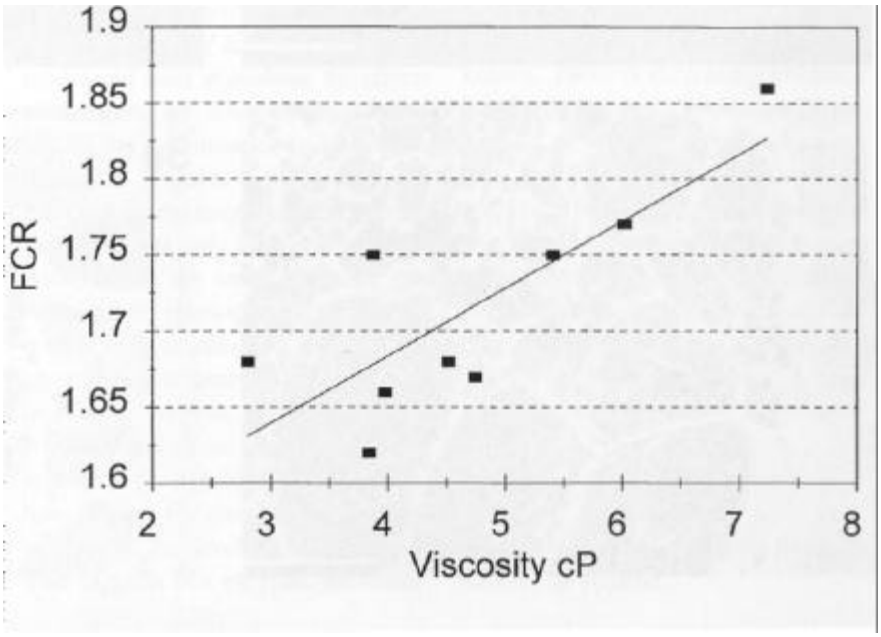
Figure 3. The effect of Avizyme 1300 on body weight gain and feed conversion in broiler chickens (0-21 days) fed a diet containing 60% wheat. Intestinal viscosity was 5.17 cP (Control) and 3.51 cP (+ Avizyme). Improvements due to enzyme were significant



wheats with relatively high viscosity to below that of wheats with relatively low viscosity. Furthermore, the viscosity of wheats with relatively low values can be reduced further by the addition of Avizyme. Therefore, the variability of wheats as measured by the digesta viscosity assay was reduced by the addition of Avizyme.

Annison (1991) has demonstrated a highly significant negative correlation ($r = -0.91$, $p < 0.0001$) between the AME values of 13 different Australian wheats and the water-soluble NSP content, which consisted mainly of arabinoxylan. Since AME and intestinal viscosity values are both reliable indicators of performance, evidence points to a relationship between all three of these factors. This strongly suggests that viscosity measured in the GI tract is related to the soluble arabinoxylan content of wheat. It should be noted that viscosity is related to the molecular weight profile of soluble arabinoxylans and that the relationship between AME, digesta viscosity and soluble arabinoxylan content might be more closely associated with a particular fraction of the total soluble arabinoxylan. Scott and Bedford (unpublished) have measured the AME of 5 different wheats with and without Avizyme supplementation. The AME values for the different wheats varied as expected (standard deviation = 347 kJ/kg) and enzyme treatment increased AME in all cases (standard deviation = 151 kJ/kg). The variability in wheat quality, as measured by the AME assay, was reduced by the addition of Avizyme. In line with this observation is the demonstration by Choct et al. (1944) that a low AME wheat (12.02 MJ/kg) had a relatively high intestinal viscosity (20.28 cP) compared to a normal AME wheat (14.52 MJ/kg; 9.65 cP) and that the increase in AME due to Avizyme was far greater for the low AME wheat (+ 24%) than for the normal wheat (+ 2%).

Figure 4. The effect of digesta viscosity on FCR in broilers fed diets based on wheat and barley with and without Avizyme. $R^2 = 0.645$, $p=0.009$



The importance of viscosity on feed conversion

In a trial involving the use of wheat, barley and wheat/barley diets with and without Avizyme, the maximum viscosity measured was less than 1OcP. Although the correlation between viscosity and liveweight gain was not strong (R^2 = 0.358, p=0.089), a very good correlation was observed between viscosity and FCR (R^2 = 0.645, p=0.009) regardless of the basis of intestinal viscosity - mixed - linked ß-glucans or arabinoxylans (Fig. 4). These observations reinforce the importance of viscosity as a major constraint on digestibility even in diets where the relative viscosity is low. The relative lack of effect of viscosity on gain is often a result of birds increasing feed intake with increased intestinal viscosity in response to a perceived drop in dietary energy. Gain is maintained somewhat, whilst FCR is a much more sensitive indicator of intestinal viscosity.

Viscosity is considered to be an important constraint to digestion by interfering with the diffusion of pancreatic enzymes, substrates and reaction products. This is illustrated by the effect of viscosity on the digestibility of added fat. In theory, it should be feasible to overcome the constraints imposed by viscosity by increasing the concentration of pancreatic type enzyme activities such as amylase, lipase and protease. Studies by Bedford and Classen (unpublished) have shown that supplemental lipase in a wheat-based diet can improve performance of broilers almost to the same extent as Avizyme, without a reduction in viscosity. In addition, adding pepsin to a wheat-based diet for broilers gives significant ($p < 0.05$) improvements in body weight gain. It appears, therefore, that the problems created by viscosity can, at least in part be resolved by mechanisms other than reducing viscosity of digesta. However, since viscosity in wheat-based diets interferes with

Figure 5. Effects of Avizyme on wheat microstructure. Wheat (ground, 3mm) was incubated with and without Avizyme using a crop/pepsin/pancreatin model (Model adapted from Zyla et al). Controls without Avizyme: Figs. a & c. With Avizyme: Figs. b & d. Figs. a & b are fluorescence micrographs in which protein is stained red/orange with Acid Fuchin and cell walls are stained blue with Calcafluor White-bar=250µm. Figs. c & d are bright field micrographs in which protein is stained green with Light Green and starch is stained violet with Lugol's solution-bar=100µm.

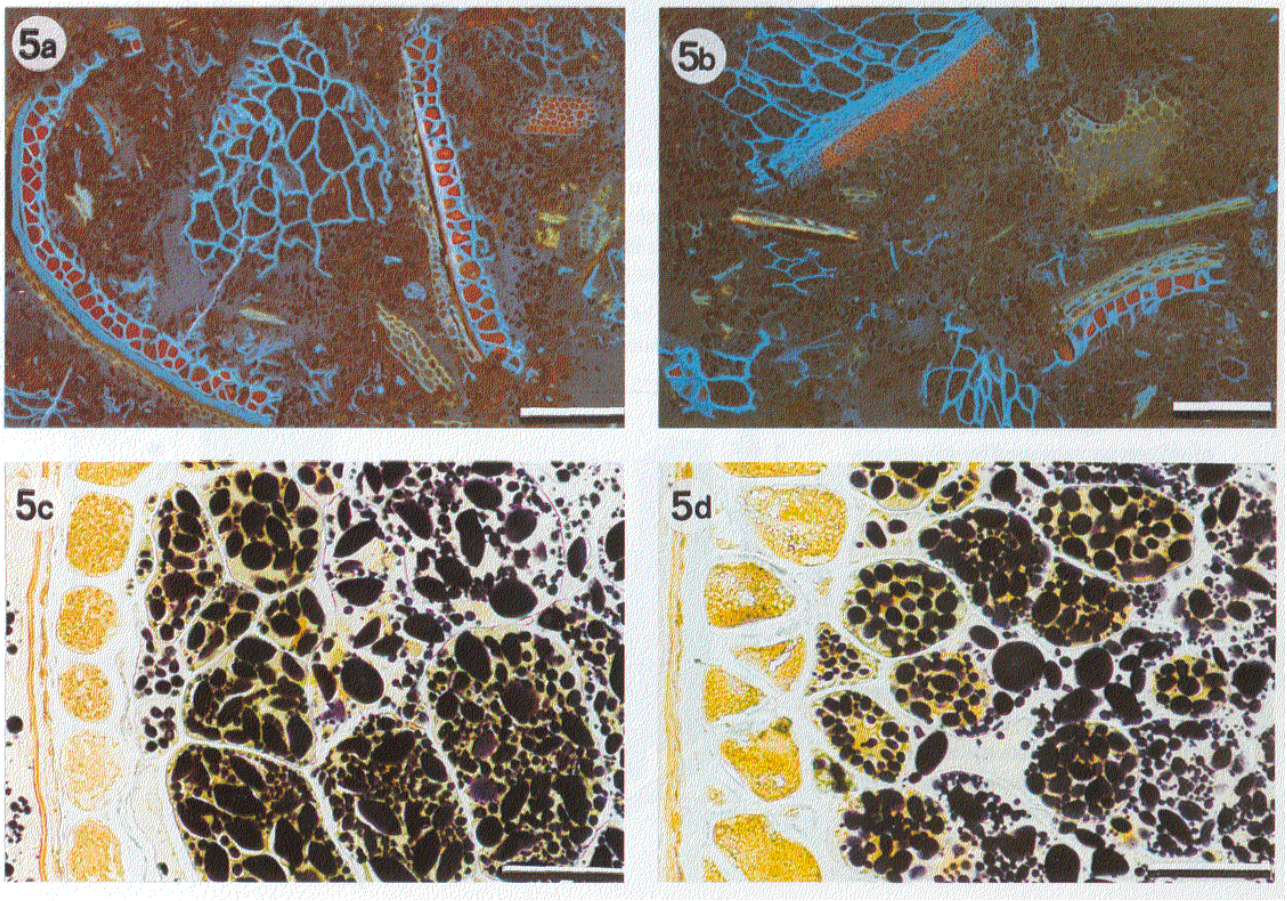
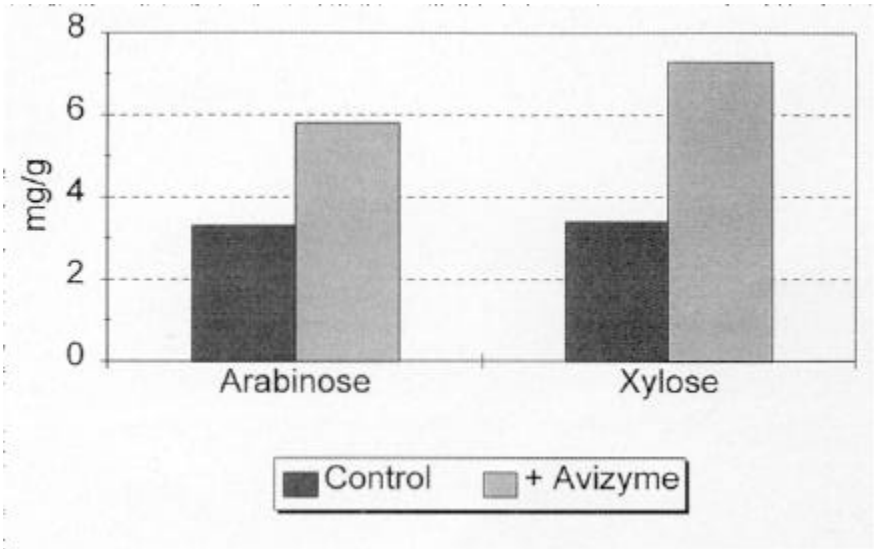


Figure 6. The effects of Avizyme on the solubilisation of arabinoxylans following *in vitro* digestion simulation. Sugars were analysed in supernatants using Dionex HPAEC following acid hydrolysis. The increase in supernatant carbohydrate concentration due to enzyme addition was significant ($p<0.005$) for arabinose and xylose.



the digestion of all nutrients, especially fat, enzymes that are highly effective in reducing viscosity *in vivo* are the most effective for wheat-based poultry diets.

The effect of enzymes on cell disruption?

Feed enzymes for wheat-based diets for poultry, work by reducing viscosity at the level of the intestine. Supplementation with gastric or pancreatic enzymes can overcome some of the effects of viscosity, but other mechanisms have a role in the process. Cell disruption has been advanced as one mechanism by which enzymes make more protein and starch available for digestion. A study was undertaken to evaluate the effects of enzymes on the microstructure of wheat. An *in vitro* broiler digestion simulation model was used to evaluate the effects of Avizyme on wheat microstructure and on the solubilisation of wheat arabinoxylan (Figures 5 and 6). It was evident from the microstructure analysis that there was only a limited effect of Avizyme on the integrity of the endosperm. In particular, there was no evidence of an effect on the aleurone layer. However, analysis of soluble arabinoxylan content, as measured by arabinose and xylose concentration after acid hydrolysis of the supernatant fraction (Figure 6), showed a significant increase in the level of solubilisation. This suggests that enzymes for wheat containing diets such as Avizyme, which contain high levels of endoxylanases, are able to degrade insoluble cell wall polysaccharides. Evidence for cell disruption due to feed enzyme addition is, however, limited. It is possible that the damage caused to wheat endosperm cell walls by feed enzymes results in cell disruption or increased permeability of cell walls to pancreatic enzymes *in vivo.*

There is increasing evidence that hydrolysis of arabinoxylans in wheat-based diets can affect microbial activity in the GI tract. A relationship with intestinal viscosity seems likely, though the effects of oligosaccharide and small molecular weight polymer reaction products as selective substrates for the microflora also need to be considered.

The evidence suggests that feed enzymes in wheat-based diets for broilers function optimally through reduction in viscosity improving the digestion of all nutrients. Although cell disruption is not clearly evident from *in vitro* digestion simulations with feed enzymes, it is possible that the permeability of cell walls to pancreatic enzymes is increased. The extent to which this contributes to improved nutrient digestion is not known. There is increasing evidence that feed enzymes can change the dynamics of the microflora, which, in turn, is likely to impact favourably on the availability of nutrients and the level of endogenous nitrogen losses. The extent to which this mechanism contributes to the improved utilization of nutrients in a wheat-based diet has not yet been established.

References are available from the authors on request.

KEY WORDS
Avizyme 1300, Wheat, broiler, digesta viscosity, viscosity, xylanase, arabinoxylan, AME, variability