Use of feed enzymes to realize the full potential of alternative feed ingredients

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The use of exogenous enzymes can markedly influence ingredient and diet digestibility. This suggests that digestive capacity of the bird is often compromised as in the case of younger birds where the production and activity of endogenous enzymes may be low and high intestinal viscosity can compromise the digestive efficiency of the gut. Complementation of the bird's own enzyme systems and hydrolysis of viscous polymers can enhance nutrient digestibility in the younger bird fed viscous cereal grains. The presence of lectins and trypsin inhibitors or non starch polysaccharides in the diet will greatly affect the digestive capability of the more adult bird. These dietary factors may decrease protein digestibility and increase endogenous enzyme production leading to a subsequent excess of energy expenditure further decreasing the efficiency of the bird. Also, alteration of the fermentation profiles in the bird's digestive tract after feeding enzymes can significantly benefit performance by more effective partitioning of nutrients between the bird and intestinal microbes. Feed enzymes acting directly of the feed substrate can shift fiber fermentation to the lower regions of the intestinal tract by providing short chain carbohydrates in the ceca altering the microbial population which may reduce immunological challenges.

Although feed enzymes have been developed to target specific cereals, the response to enzyme utilization may be variable even within one cereal grain. It is evident that enzyme addition significantly enhances the available dietary energy from the different wheats in the small intestine in all cases. Probably more important, this specific enzyme product also significantly reduced the variability between wheat samples with high viscous wheats responding more to enzyme addition than high quality wheats. Evidently nutrient digestion was more compromised in the former compared with the latter and is directly related to digesta viscosity. The ability of feed enzymes to reduce substrate viscosity and disrupt cell wall material also has a direct effect on the absorption of dietary nutrients especially amino acids and fat. The improvement in digestion was indeed reflected in the growth and F.C.R. results obtained in broilers fed the different wheat batches.

The increase in energy digestibility at the ileal level and the reduction in variability among barley samples were even more dramatic when feeding the appropriate enzyme than in the case of wheat. Hence a very important feature of enzymes in wheat-or barley-based diets is the more consistent nutritional value of different batches of the grain.

Based on a large number of growth and digestibility studies a nutritionist can take advantage of the nutritional benefits of xylanase used in wheat-based diets, and beta-glucanase used in barley-based diets by two alternative approaches. The

Table 1: Effect of a xylanase-based enzyme on ileal digestibility of nutrients in wheat-based diets in 21 days old broilers

Ileal apparent digestibility (%)	Control	Xylanase (+)	Improvement (%)	P value for xylanase effect
Energy	67.4	73.1	8%	0.02
Protein	72.1	77.3	7%	0.01
Lysine	80.8	87.1	8%	<0.00 1
Methionine	76.8	84.3	10%	0.03
Cysteine	48.2	65.6	36%	0.05
Threonine	65.8	74.4	13%	<0.001

first option is to add the enzyme "on top" of an existing formulation of wheat. Feeding enzymes to broilers on the average improved F.C.R. by 3.6% during the starter period, and 4.9% during the grower period in a survey of 14 trials reported by Bedford and Morgan. The alternative approach is to reduce diet formulation costs through adjustments in the nutritional value of the cereal in the computer matrix. For broilers, the AME value of wheat can be lifted by 6% (and the barley by 10%) to maximum levels of 3250kcal/kg, and the protein and amino acid values by 10% upon enzyme addition without negative effects on performance. This has been repeatedly tested and is now widely applied in countries where wheat and barley are available at a price competitive to corn.

Mode of action

Proper feed enzymes may increase overall diet digestibility and reduce variability within an ingredient of the diet through one or more of the following modes of action:

1) By disruption of cell walls and allowing better access of endogenous digestive enzymes to the encapsulated nutrients. Enzymes breaking down and punching holes into the cell walls may play an important role in increasing starch and amino acid digestion. On the other hand, early work with barley indicated that fat digestibility accounted for a large component of the energy uplift observed with enzyme addition. Since the majority of fat in the diet was not of barley origin, cell wall encapsulation could not explain all, if any of the response to addition of beta-glucanase. Similar effects have been noted in rye and wheat-based diets.

2) By inactivating anti-nutritional factors found in the cereal grains and vegetable protein sources. It has been repeatedly demonstrated that the problem elicited by barley and countered by use of beta-glucanase is due to a soluble, highly viscous beta-glucan component which dissolves from the endosperm cell walls and

Table 2: Fat digestibility and performance of birds fed tallow or soybean oil containing diets

Fat source Xylanase addition	Soy oil no	Soy oil yes	Tallow no	Tallow yes
Weight (21d)	681 [a]	761 [b]	128 [c]	665 [a]
FCR (0- 21d)	1392 [ab]	1266 [b]	2449 [c]	1474 [a]
Jejunal Viscosity (mPa.s)	438	32	311	139
Crude fat digestibility (%)	82.3 [a]	87.3 [a]	34.0 [b]	51.0[c]

Diets contained 60% rye, 10% added fat and a mixture of corn starch and cellulose to maintain each diet isocaloric ([a-c]P<0.05)

Table 3: Effect of fat type and xylanase supplementation on liver vitamin A and E content		
Diet	**Vitamin A (mg/kg liver)**	**Vitamin E A (mg/kg liver)**
Soybean oil, No enzyme	3150 ± 1108	0.109 ± 0.044
Soybean oil, Plus enzyme	6026 ± 1409	0.210 ± 0.121
Tallow, No enzyme	2250 ± 0.952	0.102 ± 0.029
Tallow, Plus enzyme	3904 ± 1227	0.125 ± 0.045

interferes with normal nutrient absorption from the lumen. The beneficial effect of xylanases in rye and indeed wheat-based diets was shown to be through a similar viscosity reducing mechanism but in this case it is arabinoxylans, not beta-glucans, which are primarily responsible for elevated digesta viscosity. Enzymatic reduction of intestinal viscosity improves nutrient digestion by reducing the constraints on diffusion of all components involved in the digestive process (table 1). The extent of improvement in protein and amino acid digestibility indicates that the enzyme used influences both the cereal and protein component of the diet.

The improvement in energy digestibility is largely due to better fat absorption. Viscosity reduction is known to have a much greater influence on digestion of saturated fat sources compared to unsaturated vegetable oils (table 2). The fact that digestion of tallow is more dependent upon good emulsification than that of the more soluble, liquid soy oil further suggest that the negative effects of viscosity on convection are considerable. Absorption of soluble components, such as vitamins A, D, E, and pigments, can also be expected to improve in the presence of enzymes (table 3).

Xylanases are added to wheat-based diets to address the problems created by arabinoxylans, the subsequent scale of response is dependent upon many non-wheat related dietary ingredients but in particular the source and inclusion level of fat. As digesta viscosity increases, the digestion of saturated fatty acids is more significantly impaired than that of long-chain unsaturated fatty acids. It is likely that this difference is due to a greater dependence upon emulsification of the saturated compared to unsaturated fat sources for

Table 4: Effect of enzyme supplementation on egg production and weight gain		
30-42 weeks of age	**Egg production (%)**	**Weight gain (g)**
Barley	82.8	12
Barley + enzyme	82	76
Wheat	86	32
Wheat + enzyme	89.7	129
Wheat/barley	82.1	56
Wheat/barley + enzyme	90.3	107

Table 5: Effects of enzyme[1] addition to wheat-based diets					
Age (week)	**Diet**	**Body weight ± std error (kg)**	**P value**	**Feed gain ± std error**	**P value**
8	Wheat	2.90 ± .08		1.58 ± .08	
	Wheat + enzyme	3.11 ± .07	0.23	1.49 ± .06	0.40
12	Wheat	7.10 ± .11		1.81 ± .05	
	Wheat + enzyme	7.35 ± .06	0.21	1.74 ± .02	0.12
16	Wheat	12.60 ± .20		2.05 ± .02	
	Wheat + enzyme	12.83 ± .09	0.02	1.97 ± .01	0.05
20	Wheat	17.92 ± .28		2.39 ± .04	
	Wheat + enzyme	18.03 ± .16	0.73	2.35 ± .06	0.69
[1] Avizyme 1300 (U.S. turkey integrator, 4 reps of 75 toms/treatment, 4-20 weeks of age)					

efficient absorption. Pasquier et al. clearly demonstrated that emulsification of triolein/phospholipid/cholesterol and subsequent rate of lipolysis was very much dependent upon solution viscosity and was independent of gum type used to generate different viscosities. Increasing solution viscosity from 1 to 4 mPa.s reduced the percent of emulsified triglycerides from 80% to 35% and cut emulsion surface area down by fourfold. These data suggest that even very low intestinal viscosity will have a large impact on digestibility of diets rich in fat, particularly if the fat source relies heavily on external forces for emulsification, e.g. saturated fat containing diets. In Vitamin A or E marginal diets this would result in a larger than expected response as determined by energy and protein digestibility enhancements. In many trials it has been demonstrated that the performance of birds fed viscous diets can be significantly improved by addition of bile salts and emulsifiers. Such observations suggest that the presence of these compounds will mitigate enzyme response in some circumstances.

3) By supplementing the bird's own digestive enzymes. Just after hatch, birds need to develop the ability to absorb and utilize dietary nutrients. To achieve that objective, the gastrointestinal tract of chickens needs to develop physically and functionally during the first few days after hatching. Katanbaf et al.

Table 6: Effects of enzyme[1] addition to wheat-based starter diets-summary of 3 trials						
Trial	**#1**		**#2**		**#3**	
Site	Scot. Agric.Coll Auchincruive, U.K.		Harper Adams Coll., Newport, U.K.		Roslin Institute, Edinburgh, U.K.	
Birds	BUT 8 hens		BUT 8 hens		BUT 8 toms	
Age	8-21 d		0-42d		0-35d	
	Control	Enzyme(+)	Control	Enzyme (+)	Control	Enzyme (+)
Weight gain, g	340	330	3297	3339	512	513
Feed:gain	2.14[a]	1.84[b]	1.69	1.65	1.73	1.68
Viscosity, cPs	3.9	2.7	4.6[a]	3.9[b]	4	3.2
[1] Avizyme 3300 - ([a-b] P<0.05)						

Table 7: Effects of enzyme addition to a commercial corn/soybean turkey starter diet (BUT poults, 0-42 days of age)

	Control	Enzyme[1] (+)
Digest viscosity, cPs (d 42)	3:24	2,8
Weight gain, g	3547	3702
Feed:gain	1769	1748
Feed gain, adj. to 3500g	1755	1687.

[1]Avizyme 1500 Stats pending

found that the relative weight of supply organs of young chickens increased during the first 10 days of life, whereas that of demand organs increased only after 10 days of age. Pancreatic amylase activity increases 3 fold between 1 and 10 days of age and trypsin and lipase activities increase 5 to 6-fold during the same period. Similarly, low maltase and sucrase activities in the intestine of hatching chickens have been reported. Thus, there seems to be a period after hatch when the digestive enzymes (pancreatic and intestinal) may not be fully functional and increase at a slow rate in young chickens.

4) By minimizing bacterial fermentation in the small intestine and encouraging beneficial bacterial fermentation in the cecum. Recent research indicated that feed enzymes alter microbial populations as indicated by microscopic, A.T.P. and V.F.A. data. The trend is that enzyme addition to wheat-based diets leads to reductions in ileal microbial populations while at the same time an increase in cecal fermentation has been noted. Several researchers have indicated that, particularly in rye-based diets, the negative effects of viscous grains can be overcome through the use of antibiotics. Demonstration of a synergy between a mixture of monensin and avoparcin with a xylanase in wheat-based diets again points to a microbial interaction with xylanase activity.

Enzymes in layer diets

Good early growth of young layers is essential to obtain the target body weights at the right time early in the lay cycle. It is now well established that both white and brown modern genotypes should be fed ad libitum through their cycle especially in hot areas. Low body weights at the beginning of lay will lead to mortality problems and poor persistence of production. However there are still pullet producers who are paid according to total bird feed intake thus these producers are still restricting the feed,

Many dietary factors such as

fiber content and its water holding capacity (W.H.C.) can have a direct impact on the feed consumption of these young pullets which will influence overall body weight uniformity at the time of lay. In vitro data has shown that the W.H.C. of fiber in alternative ingredients such as wheat midds and sunflower meal can be decreased by feeding specific enzymes. The ability to decrease the bulkiness of feed containing high levels of soluble fiber by supplementing enzymes will assist in increasing feed intake and thus body weights. As found in young broilers, feed enzymes will improve the digestion of dietary nutrients, through the mechanism of reducing intestinal viscosity and the water content which will minimize potential digestive disorders by altering the intestinal microflora population. Additional benefits of feeding enzymes will be a reduction in manure production and moisture content.

Trial work by Finnfeeds International and research institutes in Australia have shown that feed enzymes can increase egg production early in the lay cycle while allowing the hen to achieve a suitable body weight. Achieving a suitable body weight early in the lay cycle should ensure that the laying period is prolonged and egg size is adequate. Also, recently it was found that dietary nutrients could be enhanced in a wheat midds layer diet by supplementing enzymes. The histology of the villi in the jejunum of birds fed wheat midds were found to be shortened and thicker compared to birds fed midds with enzymes. These improvements in the intestinal environment and nutrient availability by feeding enzymes increased egg production and egg mass especially total albumen.

The improvement in fat and fat soluble nutrients observed in broilers with the use of enzymes has been reported as well in layers. A better absorption of the fat soluble vitamins (vitamin D in particular) may lead to better egg shell quality, and better chick liveability at hatch due to higher fatty acids and vitamin content in the yolk. Also, there is a clear effect of feeding enzymes on pigment absorption with improvements similar to levels seen in fat digestion. In Italy, where the level of natural pigment is very high, it is believed that pigments may be reduced in the diet by about 10 to 20% with the improvements from enzymes.

Enzymes in turkey diets

Commercial turkey production commonly suffers from incidences of digestive disorders, which again have negative consequences on litter conditions, leg quality and carcass downgrades. The ability of xylanases beta-glucanases to reduce viscosity in wheat and barley-based diets may again be beneficial to alleviate potential digestive problems similar to findings previously reported for broilers. This is supported by digesta viscosity measurements in turkey poults at various ages and correlates well with

practical experiences observed in European countries regularly formulating wheat-based turkey diets. A recent U.S. trial using wheat as the major cereal confirmed these positive effects of feeding enzymes. When fed from 4 weeks to market in diets containing amounts of wheat increasing form 40 to 75% xylanase addition improved growth and feed conversion throughout. Though body weight difference somewhat diminished during the last period, the enzyme effects towards better feed conversion as well as lower variability in body weights are apparent. Another incentive to use feed enzymes in turkey starter diets may be to support effective utilization of expensive dietary protein. It has been shown previously that the young poult may not always produce its endogenous enzymes in adequate amounts. While the young poult has a limited ability to digest fats, particularly saturated fats, less focus has been placed on possible limitations in protein and amino acid digestion. In fact, it was demonstrated a very low endogenous protease activity during the first 3 to 4 weeks of age, which then rapidly increased through 8 weeks. The age period with one of the highest dietary requirements for amino acids thus coincides with the lowest host enzyme production for protease. With soybean meal as the predominant source of protein and amino acids in these diets, its quality is of critical importance.

The focus of recent soybean quality in chicks and turkeys.

Soybean meal may contain fairly high residual levels of antinutritional factors such as trypsin inhibitors, lectins and antigenic proteins.

Trypsin inhibitors reduce protein digestibility through interaction with the birds own proteolytic capacity, which leads to excessive production of trypsin and chymotrypsin. Lectins are thought to bind to the intestinal surface, causing irritation, inflammation and even immune responses, inflammatory responses such as increased lumen cell turnover and mucin production may lead to depressed protein digestibility, mainly caused by a rise in endogenous losses.

This overview shows improvements in feed efficiency during the early growth of turkeys poults. Compared to typical viscosities recorded in broilers, the digesta in young poults was less viscous, however, digesta viscosity was reduced through enzyme addition.

The present concept was recently extended to corn/soybean meal starters in an effort to check if the enzyme was also effective in low viscous diets. Data give evidence that turkeys fed such a diet to 6 weeks of age responded to enzyme addition with an improvement in body weight and corrected feed conversion.

With further tests in corn-soybean diets independent of the cereal component used.

References are available on request.

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Avizyme 1300, Avizyme 1500, broiler, layer, turkey, xylanase, beta-glucanase, protease, amylase, wheat, barley, corn, soybean meal, tallow, soy oil, ileal DE, digestibility, amino acid, uplift, fat, egg production, viscosity