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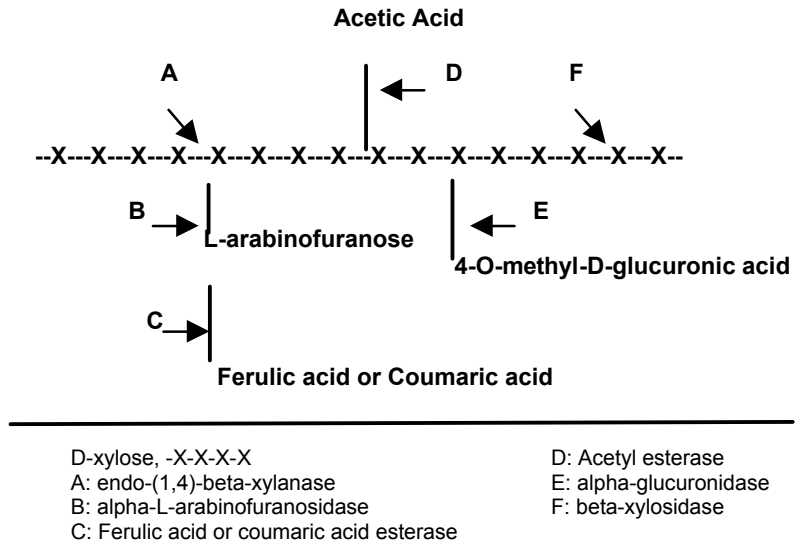
Enzyme use in viscous-inducing cereal diets examined

ABSTRACT

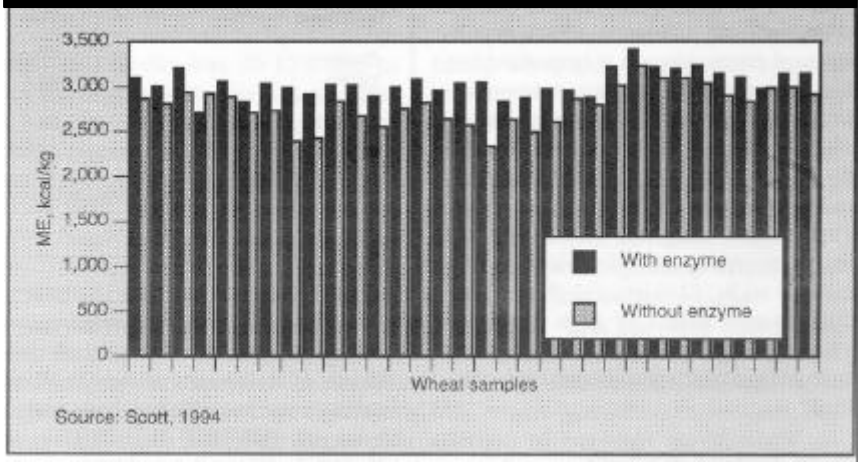
Wheat, barley, rye and other viscosity-inducing cereal grains are commonly associated with performance lower than experienced when corn is the major dietary cereal. Research has shown, however, that multi-enzyme mixtures developed for some cereal diets have increased amino acid digestibility, metabolizable energy and other live performance measurements, as well as decreased fecal moisture. This article specifically examines the use of enzymes in wheat and barley based diets.

FIGURE



1. Schematic representation of the structure of cereal xylans and sites of cleavage by xylanolytic enzymes

FIGURE



2. Effect of multi-enzyme on metabiolizable energy (ME) of wheat

By N.E. WARD

In the 1950s the feeding of some cereal grains (wheat, barley and rye) was recognised for producing poor performance, including wet litter in poultry. Eventually, the fibre or nonstarch polysaccharide (NSP) fraction was identified as the primary cause, as previously reviewed (Ward, 1995.)

Early on water soaking of the cereal was found to improve the feeding value of such grains (Fry et al., 1958; Lepkovsky and Furuta, 1960). In one study, 21-day poultry bodyweights were increased by 10, 24 and 40% for water-soaked wheat, rye and barley, respectively (Fry et al., 1958). Enzymes were assumed to be released within the kernels to improve the digestibility of the grain.

In chicks fed rye-based diets, there was a marked increase in anaerobes of the genus Clostridium (Wagner et al., 1978). Antimicrobials added to diets with high levels of rye (Moran et al., 1969) and other fibrous cereals were especially effective, with the greatest response usually being in diets with the highest level of NSPs.

Since these cereals prolong digesta passage rate, microbes have a better opportunity to multiply and proliferate in the moist, nutrient-rich digesta. This may explain the heightened efficacy of antimicrobials in these diets.

The beneficial effects of enzymes added to such diets have been known for many years (Jensen et al., 1957; Fry et al., 1958).Amylase and beta-glucanase were originally the focus of attention. Xylanases were later shown to be effective, and proteases and other enzymes may be of additional benefit.

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In short, this research has revealed that exogenous multi-enzymes can improve the feeding value of high-fibre cereals, and virtually eliminate the problem of wet faeces in poultry.

An optimal level of enzyme activity may exist, beyond which added enzymes could be counterproductive (Morgan and Bedford, 1993). In other words, complete hydrolysis of the NSP may be detrimental, possibly due to excess free xylose and arabinose, which can be anti-nutritive to chicks (Shulte, 1990). However, clarification is needed since low levels of these free sugars can be well tolerated (Choct and Annison, 1992).

The viscosity theory

The viscosity theory usually takes centre stage when rationalising how enzymes bring about improvements in performance. Here, enzymes partially degrade the soluble NSP arabinoxylans and mixed-link beta-glucans into smaller, short-chain polymers (De Silva et al., 1983; White et al., 1983). This hinders the formation of the highly viscous environment, which decreases nutrient digestion and absorption (Fengler and Marquardt, 1988). The main benefactor of lowered viscosity seems to be the fat added to the diet (Classen et al., 1985), evidence that impaired nutrient digestibility is not limited to the cereal itself.

It also has been argued that the poor digestibility of cereals such as barley is partly due to the encapsulation of its nutrients by the cell walls of the endosperm. Exogenous enzymes break down these cell walls and, in concert with the endogenous enzymes, increase starch and protein digestibility (Pettersson and Aman, 1988).

The viscosity theory explains a large portion of this poor performance (Bedford and Classen, 1992), while nutrient encapsulation is important but secondary. Also, enzyme supplementation improves wheat or barley-based diets to a degree greater than expected if the effect was limited solely to the degradation of the NSP (Bedford et al., 1992). Thus, enzymes may be: (1) releasing the encapsulated nutrients within the cell walls, (2) virtually eliminating the negative effect of high intestinal viscosity and (3) acting as a supplement to inadequate enzyme secretion by the bird.

Multi-enzyme mixtures

Beta-glucanase is the principle enzyme for reforming the feeding value of barley and oats. The soluble beta-glucan comprises 3-6% of these ingredients and is recognised as the primary anti-nutritive component. The addition of beta-glucanase to barley and oats-based diets can largely eliminate the depression in live performance and sticky droppings. Multi-enzyme products designed for high beta-glucan ingredients contain beta-glucanase as the primary constituent.

For wheat and rye, the soluble NSP of greatest importance is the arabinoxylan fraction, which can account for 10% of the dry matter (Antoniou et al., 1981). This component requires arabinoxy-lanases (pentosanases or xylanases). The addition of xylanases to wheat diets certainly improves dietary metabolizable energy (ME) and digestibility, as well as bird performance and litter quality. Commercial multi-enzyme products often contain endo-1,4-beta-xylanase as a major component, although not all xylanase sources are equal (Bedford, 1994a).

Historically, multi-enzyme products were developed with crude enzyme extracts and contained an assortment of enzyme activities. However, with advanced technology, today's products may be designed to contain specifically selected enzymes. These may include debranching activities that act synergistically to reduce the NSP polymers into smaller fragments, thereby reducing intestinal viscosity (Figure 1). Typically, such enzymes are produced by various fungal species. In addition, proteases can be instrumental in these products (Morgan and Bedford, 1995).

These feed enzymes must be stable and effective at the pH, temperature, substrate concentration and other conditions during feed processing and within the intestinal tract of the target animal. Dry and liquid enzyme preparations are available.

Enzyme effects

Increased intestinal viscosity is largely responsible for reduced nutrient digestibility when feeding cereals such as

TABLES

1. Effect of enzyme addition to six barley-based and six oats-based broiler diets

	---- Diet 80% barley ----		---- Diet 80% oats ----	
	Control	Control + enzyme	Control	Control + enzyme
21-day bodyweight, g	255[b]	308[a]	253[b]	303[a]
Bodyweight coeff. var., %	34.3	23.5	20.9	11.6
Feed:gain	1.34[b]	1.24[a]	1.28[ab]	1.23[a]
Digesta viscosity, cps	57.9[b]	8.4[a]	62.8[b]	12.0[a]
Excreta dry matter, %	40.1[c]	46.5[b]	46.1[b]	51.0[a]

Dr. T. Scott, Agriculture Canada, Agassiz, B.C., 1995
[abc]P<0.05 within rows
Multi-enzyme product from Finnfeeds International, U.K

2. Effect of enzyme supplementation on broiler ileal digestibility(%) of amino acids in a barley-based diet

	------Three weeks of age ----			------Six weeks of age ------		
Amino acid	Control diet	With enzymes	P value	Control diet	With enzymes	P value
Lysine	70.69	79.89	0.012	76.14	80.78	0.015
Methionine	66.77	77.97	0.007	77.23	80.02	0.306
Cysteine	48.04	66.10	0.011	61.46	67.35	0.351
Arginine	68.61	79.43	0.013	72.92	81.02	0.001
Threonine	52.06	65.33	0.037	58.1	64.48	0.051
Valine	61.17	73.56	0.016	64.57	73.33	0.025
Isoleucine	62.09	74.37	0.019	66.64	74.63	0.021

Bedford et al., 1992

3. Effect of rnulti-enzyme supplementation on the nutrient digestibility (ileal and fecal) of broilers fed a wheat-based diet

	Wheat control	Wheat + enzyme	P value
	----------Ileal digestibility, %----------		
Energy	67.4	73.1	0.03
Protein	72.1	77.3	0.007
Lysine	80.8	87.1	0.001
Methionine	76.8	84.3	0.03
Cysteine	48.2	65.6	0.05
Threonine	65.8	74.4	0.001
	----------Fecal digestibility, %----------		
Energy	67.1	72.7	0.001
Lysine	81.7	85.9	0.007
Methionine	82.7	86.9	0.02
Cysteine	65.8	69.3	>0.10
Threonine	73.6	79.1	0.008

SAC, U.K., 1994
Multi-enzyme product from Finnfeeds International, U.K
Diets contained 63% wheat

TABLES

4. Wheat-based diets relative to a corn/soybean meal diet for commercial broilers

	48-day bodyweight, lb.	Feed/gain	Digesta viscosity, cps
Corn/soybean meal control	5.390[b]	1.86[b]	2.5[d]
20% wheat diet			
no enzyme	5.434[b]	1.88[b]	3.5[c]
with enzyme	5.412[b]	1.84[b c]	2.3[d]
40% wheat diet			
no enzyme	5.478[b]	1.88[b]	5.2[b]
with enzyme	5.412[b]	1.83[c]	2.7[cd]
60% wheat diet			
no enzyme	5.500[a b]	1.91[a]	7.2[a]
with enzyme	5.588[a]	1.82[c]	2.9[cd]

[abcd]P<0.05 within rows
Multi-enzyme product from Finnfeeds International, U.K.
Trial conducted on location at U.S. commercial broiler integrator, 1994

5. Proposed matrix values of a wheat and barley with appropriate enzyme supplementation

Nutrient	No adjustment	+6%ME +10% CP	+6%ME +20% CP
	----------Wheat ----------		
CP, %	12.50	13.75	15.00
ME, kcal/kg	3,080	3,265	3,265
Methionine, %	0.18	0.20	0.22
Cystine, %	0.28	0.31	0.33
TSAA, %	0.46	0.51	0.55
Lysine, %	0.35	0.38	0.42
	----------Barley ----------		
CP, %	12.00	13.2	14.4
ME, kcal/kg	2,700	2,862	2,862
Methionine, %	0.17	0.187	0.20
Cystine, %	0.19	0.21	0.23
TSAA, %	0.36	0.39	0.43
Lysine, %	0.40	0.44	0.48

Bedford (1994)
Multi-enzyme product from Finnfeeds International, U.K.

barley, wheat or rye. As the viscosity increases, the rate of diffusion or movement through this gel-like mass declines (Fengler and Marquardt, 1988). Not only is the nutrient digestibility of the cereal adversely affected, but similar negative effects occur for nutrients in the other ingredients of this diet.

The addition of a feed enzyme is expected to reduce intestinal viscosity. In a recent study, an enzyme preparation decreased viscosity from 57.9 to 8.4 centipose units (cps) for barley, and from 62.8 to 12.0 cps for oats (Table 1). Such reductions in viscosity are usually associated with improved performance and/or increased nutrient digestibility. In this trial, significant improvements occurred with bodyweights, feed/gain ratio and excreta dry matter.

Protein and amino acids

One of the more widely recognised benefits of multi-enzyme supplementation is a general increase in amino acid digestibility. An improved viscosity would help explain this effect, as well as the breakdown of the cell walls.

In a recent study (Bedford et al., 1992), enzyme addition to a diet with 60% barley improved (P<0.05) bodyweight, feed/gain and intestinal viscosity of broilers. Apparent amino acid digestibility at the terminal ileum was improved at 3 and 6 weeks of age (Table 2). The increase in amino acid digestibility at 3 weeks was 10-15% due to enzyme supplementation, but was less at 6 weeks of age, suggesting an age related response. Similarly, an enzyme preparation in a diet with high glucan barley (60% of diet) increased the apparent digestibilities of lysine, methionine, cystine, threonine and arginine by 3-9% (P<0.05; Almirall et al., 1995) for broiler chicks.

In a study with wheat making up 63% of the diet, supplementation with a multi-enzyme product decreased intestinal viscosity (P<0.004; Table 3). Improvements in ileal and faecal digestibilities occurred (P<0.05) with all amino acids with the exception of faecal cystine. Demonstrating a similar effect, a study from the Scottish Agricultural College found the addition of an enzyme to increase the apparent amino acid digestibility by 22.4% for lysine (P<0.03), 21.3% for cystine (P<0.07) and 27.4% for methionine (P>O. 1 0). This diet contained 63.8% wheat and also recorded a 9% (P<0.01) increase in apparent metabolizable energy.

Metabolisable energy

Metabolisable energy (ME) is virtually always increased in the wheat or barley-based diets with enzyme supplementation. Starch digestibility is improved with enzymes, particularly, fat digestibility (Classen et al., 1985). The net effect would be an increased ME.

In a recent trial by Dr. T. Scott, Agriculture Canada, the supplementation of five different wheat-based broiler diets (80% of the diet) resulted in a decrease (P<0.001) in gut viscosity, a 7% increase (P<0.001) in ME and a 4% increase (P<0.001) in nitrogen retention. Nitrogen excretion was calculated to be decreased by 19% due to enzyme addition. The ME coefficient of variation was decreased by 56% with enzyme addition, thus decreasing the variability often associated with this ingredient.

In another trial, Scott (1994) reported a study with 32 different samples of wheat. Each was supplemented with a commercial multi-enzyme preparation and fed at 80% of the diet to determine effects on ME (Figure 2). An average improvement of 9% in ME was due to enzyme supplementation. As found in the above study, enzyme addition to these wheats sharply decreased the variability, and in this case, decreased the coefficient of variation from 7.7 to 4.4%. In many trials, enzyme supplementation has decreased bodyweight variability (Table 1,) presumably by decreasing wheat variability.

A similar increase in ME was also found when the commercial enzyme mixture was added to early frost-damaged wheat (Scott, 1994). In this trial, a large sample of frost-damaged wheat was separated into five different bushel weights. Although the enzyme mixture was effective for all bushel weight categories, it was especially effective in wheat with low bushel weight.

In a trial with the "low ME wheat phenomenon," Choct et al. (1994) tested feed enzymes in "normal ME" and "low ME" wheat-based diets for broilers. The addition of enzymes significantly increased the ME of both wheats, but was more effective in the low ME wheat. The energy level of the low ME wheat was brought up to that of the normal ME wheat when enzymes were fed with the former. This is an important finding since about 25% of Australian wheats are characterised by the low ME scenario.

Comparison of grains plus enzymes

When formulated properly (i.e., equal nutrient levels), wheat or barley-based diets with multi-enzymes are comparable to typical corn/soybean meal diets. Within the past 1-2 years, three trials with commercial U.S. broiler integrators have

made this finding. In one trial, light or heavy-weight barley at 40% of the diet with enzyme supplementation was equivalent to a corn/soybean meal diet for body weight, feed/gain and mortality. Without the multi-enzyme, a loss ($P<0.05$) in feed conversion was experienced with either barley diet.

In another, wheat was fed at 20,40 or 60% of the diet (Table 4). The birds fed 60% wheat with added feed enzymes experienced improved ($P<0.05$) feed/gain and body weight relative those fed the corn/soybean meal diet. Without the enzymes, feed/gain was worsened ($P<0.05$) for birds fed the 40 and 60% wheat diets. Clearly, the multi-enzyme mixture improved the utilization of the wheat diets.

Formulating with multi-enzymes

Since enzyme products improve nutrient digestibility, particularly that of energy and amino acids, it is logical that the ME and protein values for wheat could be "increased" in the computer matrix for least-cost formulations. This will allow diet costs to be reduced without any adverse effect on broiler performance.

6/10 matrix adjustment

Extensive trials initiated by Finnfeeds International have shown that ME and amino acid levels of wheat can be adjusted by 6 and 10%, respectively, in enzyme-supplemented diets (Avizyme 1300). Table 5 lists a partial nutrient profile of how wheat ME and amino acid values would be inflated (Bedford, 1994b). ME and protein "increases" actually could be higher than the 6/10 adjustment since multi-enzymes usually improve these values to a greater extent. However, a safety margin is advisable due to the large variability that exists in wheat.

A total of 13 trials has been conducted to test this concept (Table 6). For each trial, a control was compared to a diet with (1) added multi-enzyme, (2) inflated ME and (3) inflated protein values for the cereal tested. In some cases, modifications were greater than the 6/10 adjustment. In none of the trials was any of the measurements (i.e., body weight, feed/gain, litter condition, etc.) worsened due to the dietary adjustments. In some cases, performance was significantly improved with the adjustments, evidence that the feed enzyme products remained undervalued. Similar data show that with suitable enzymes, barley ME can be increased by 10% and amino acids increased by 15% in the feed formulation matrix.

Reformulated diets of this nature contain less soybean meal or other protein sources, as well as less added fat. The cost savings certainly can be substantial. Matrix adjustments of ME and amino acid values are needed to maximise the benefits of feed enzymes unless the objective of enzyme supplementation is simply to avoid wet litter problems.

Conclusions

Wheat, barley, rye and other viscosity-inducing cereal grains are commonly associated with performance lower than experienced when corn is the major dietary cereal. Most researchers agree that the viscosity theory explains a large portion of this poor performance, while nutrient encapsulation is important but secondary. Multi-enzyme mixtures developed for fibrous cereal diets have substantially increased amino acid digestibility, ME and other live performance measurements, and decreased faecal moisture. The 6/10 adjustment to the wheat in the diet (i.e., the inflation of the ME by 6% and amino acid digestibility by 10%) in combination with the inclusion of a suitable enzyme product is suggested. In this way, the true value of feed enzymes can be better realised.

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Key Words

Avizyme 1100, Avizyme 1200, Aviyme 1300, broiler, wheat, barley, oats, xylanase, betaglucanase, protease, digesta viscosity, viscosity, excreta moisture, ileal, digestibility, variability, uniformity, uplift.