ENZYMES SUPPLEMENTATION OF DIETS CONTAINING HIGH LEVELS OF LEGUMES – A REVIEW

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Summary

Increased levels of indigestible carbohydrates, such as α-galactoside oligosaccharides and non-starch polysaccharides (NSPs), limit the inclusion rate of grain legumes in diets for pigs and poultry. There is contradictory information available on the anti-nutritive effects of legume NSPs and the effects of feed enzymes on legume NSPs. The addition of carbohydrases to diets containing high levels of soybean meal (SBM) as the main protein source has a significant effect on ileal protein digestibility and ileal NSP concentrations. However, the overall effect on broiler performance remains controversial. Similarly, the addition of carbohydrases to lupin-based diets has been shown to alter the intestinal NSP concentrations in comparison to unsupplemented diets. The overall effects on weight gain, feed intake and FCR, however, varied from study to study.

I. INTRODUCTION

Grain legumes are primarily grown for human consumption; however, soybean meal, whole seed or dehulled lupin, peas, faba bean or chickpeas are used as protein sources in diets for domestic livestock. The occurrence and amount of anti-nutritive factors (ANF) and their effect on protein and energy utilisation limits their inclusion in diets for pigs and poultry. Reduction of ANF through genetic selection or physical treatment such as dehulling or heat processing make grain legumes more suitable for inclusion in diets for pigs and poultry. Legumes included at a high level as the main protein source in broiler diets will result in poor growth and can cause excessive gas production from bacterial fermentation in the hindgut and osmotic diarrhoea. In cereal grains, such as wheat and barley, high levels of soluble NSPs raise digesta viscosity in the intestine of chickens leading to reduced starch, protein and lipid digestion (Choct and Annison, 1990). Although the mechanism by which viscosity affects digestion is not fully understood it is evident that the addition of feed enzymes can counteract these effects. This review will discuss the potential use of exogenous feed enzymes in broiler diets containing high levels of grain legumes. In view of the annual production and therefore economic importance of the various grain legumes, this paper is mainly limited to soybean meal and lupins with some reference to field peas and faba beans.

II. OLIGOSACCHARIDES AND NON-STARCH POLYSACCHARIDES IN LEGUMES

Legumes are rich in galactosyl-sucrose oligosaccharides (OS). These oligosaccharides are part of the raffinose family (raffinose, stachyose, verbascose and ajugose). The distribution and the quantity of OS vary widely among legume species as well as the variety within species. Due to a lack of endogenous α-galactosidase monogastric animals cannot digest α-galactosides. Bacterial degradation of α-galactosides in the hindgut can lead to increased fluid retention, increased hydrogen production, and can impair the utilisation of nutrients (Saini, 1989). However, the nutritive value of legume α-galactosides in broiler diets remains unclear. Coon et al. (1990) showed that OS from soybean using ethanol extraction increased nitrogen corrected true metabolisable energy (TME_{n}). On the other hand, Kocher et al. (1999a)
demonstrated that ethanol removal of OS from lupins (*L. angustifolius*) significantly decreased apparent metabolisable energy (AME). The addition of OS extracted from peas (Trevino *et al*., 1990) or lupins (Breñes *et al*., 1989) to an OS-free pea/lupin meal based diet had no effects on broiler performance or starch digestibility.

The NSP content of legumes used in poultry diets depends heavily on the degree of processing and subsequently on the hull proportion in the final product. The total NSP content in whole seed legumes ranges from 177g in faba beans to 350g/kg DM in some lupin varieties (Table 1). The predominant monosaccharide residues of legume NSPs are glucose and xylose in the hull fraction and galactose, arabinose, glucose and uronic acids in the cotyledon. The main NSP structures in legume seeds are cellulose (30-43% of polysaccharide component), and pectic polysaccharides such as rhamnogalacturonans, galactans and arabans (Arora, 1983).

**Table 1. Non-starch polysaccharides in grain legumes (g/kg DM).**

<table>
<thead>
<tr>
<th>Legume</th>
<th>OS</th>
<th>Soluble NSP</th>
<th>Insoluble NSP</th>
</tr>
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<tbody>
<tr>
<td>Beans (<em>V. faba</em>)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>59</td>
<td>50</td>
<td>140</td>
</tr>
<tr>
<td>L. <em>albus</em>&lt;sup&gt;2&lt;/sup&gt;</td>
<td>79</td>
<td>14</td>
<td>319</td>
</tr>
<tr>
<td>L. <em>angustifolius</em>&lt;sup&gt;2&lt;/sup&gt;</td>
<td>114</td>
<td>31</td>
<td>336</td>
</tr>
<tr>
<td>Pea (<em>P. sativum</em>)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>58</td>
<td>52</td>
<td>129</td>
</tr>
<tr>
<td>Soybean meal&lt;sup&gt;1&lt;/sup&gt;</td>
<td>60</td>
<td>63</td>
<td>154</td>
</tr>
</tbody>
</table>

<sup>1</sup>Bach Knudsen (1997), <sup>2</sup>Kocher *et al.* (1999b)

Although NSPs cannot be digested by the endogenous enzymes of chickens the water soluble fraction of the NSPs can be almost completely degraded through bacterial fermentation in the intestinal tract of birds (Carré *et al.*, 1990). The major site of bacterial fermentation is the caeca; however, it is known that increased levels of soluble NSPs will also increase fermentation in the upper gut which is detrimental to the overall performance as well as the bird’s health (Chocht *et al.*, 1996). Insoluble NSPs remain mostly intact through the intestine and will not be fermented, therefore it was suggested that they act as energy diluents and have little or no effect on overall nutrient utilisation.

### III. EFFECTS OF EXOGENOUS ENZYME ADDITION ON THE NUTRITIONAL VALUE OF GRAIN LEGUMES

It is well documented that in diets containing high levels of wheat, triticale or rye, added xylanases will degrade soluble arabinoxylans and in diets containing high levels of barley or oats added β-glucanases will depolymerise the soluble β-glucans present in these grains (Annison and Chocht, 1993). Recent studies with non-viscous grains such as corn and sorghum reported that the addition of commercial glycanases also improved the nutritive value of these grains (Creswell *et al*., 1998). Enzymes used in diets containing high levels of grain legumes contain increased levels of polygalacturonase (pectinase) designed to hydrolyse pectin present in legumes. However, enzyme products used in the feed industry contain a range of activities, and therefore will target a range of substrates. When discussing the effects of enzymes on the nutritive value of diets containing high levels of grain legumes, it has to be considered what other ingredients are present in the diet. An overall improvement in performance and energy availability could be the result of improved digestibility of an added cereal grain rather than actual improvement in the digestion of the tested legume.
Addition of enzymes to a corn-SBM broiler diet resulted in a significant improvement in weight gain and FCR as a result of increased ileal digestibility of crude protein (CP), starch and fat (Zanella et al., 1999). Similarly, Marsman et al. (1997) reported a significant improvement in ileal digestibility of CP and NSPs in broiler diets with corn-soybean meal. It was concluded from both studies that the added enzyme products not only had cell wall degrading activities but also exhibited protease activity, which explained the improved nutrient digestibility. The bacterial degradation of soluble NSPs from soybean is very high (80-90%) (Carré et al., 1990). It is possible that added enzymes solubilised parts of the insoluble NSPs, which resulted in the improved NSP digestibility. In addition, the release of proteins bound to carbohydrates could explain the improved protein digestibility. On the other hand, Irish and Balnave (1993), found that the addition of two multi-activity enzyme preparations to corn/wheat-SBM diets resulted in a significantly poorer growth compared to an unsupplemented control diet. It was concluded that NSPs were broken down into fragments. The presence of large amounts of indigestible low molecular weight NSPs results in fluid retention in the small intestine and can adversely affect the absorption of nutrients (Wiggins, 1984).

Several authors reported significant improvement in broiler performance and weight gain when commercial enzyme products were added to diets containing 45% dehulled L. albus (Brenes et al., 1993a; Roth Maier and Kirchgesner, 1994). A recent study by Kocher et al. (1999b) showed a significant improvement in ileal NSP digestibility of broiler chickens fed a diet containing 30% L. albus supplemented with an enzyme containing a high level of pectinase activity. The increased digestibility is directly related to increased digestibility of glucose, xylose and arabinose in the insoluble NSP portion. Although the sugar composition of various species of lupin are similar (Al-Kaisey and Wilkie, 1992), no such effects were observed when adding the same enzyme product to a different lupin species (L. angustifolius). AME, growth performance and digestibility of NSPs in the ileum and microbial fermentation in the ileum and caeca were not affected when adding the enzyme; however, a significant rise in digesta viscosity and increased concentration of soluble NSPs in all sections of the intestine were observed. Detailed analysis of monosaccharide composition in the ileum and jejunum showed increased concentration of soluble rhamnose and galactose, which indicated solubilisation of galactans and, possibly, rhamnogalacturonan also. The apparent lack of depressed nutrient absorption due to the increased viscosity may be explained by the fact that the addition of the enzyme degraded endosperm walls and subsequently released intracellular encapsulated nutrients, which helped to offset the reduced nutrient digestion.

Studies on the effects of enzyme addition to other grain legumes such as peas are very limited and give confusing results. Brenes et al. (1993b) reported that the addition of a pectinase to broiler diets containing 75% whole seed peas had no effect on broiler performance, although the authors reported a significant reduction in feed intake and weight gain. In contrast, Igbasan and Gunter (1996) showed a significant improvement in weight gain and a significant increase in feed intake of broilers fed a diet containing 80% peas supplemented with a pectinase. However, the addition of enzymes did not improve the overall feed conversion ratio.
IV. CONCLUSION

It is evident that commercial enzyme products have some effect in diets containing high levels of grain legumes. However, enzymes do not always affect growth and performance of broilers and therefore the consequences of enzyme addition can only be seen after detailed analyses of feed and digesta. In order to develop enzyme products which will improve the nutritive value of grain legumes, further in vivo studies of structural changes to cell walls are necessary.

REFERENCES