An important anti-nutritional factor β-mannan in raw materials and β-mannanase application in feed

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Cereal grains, oil seeds and their co-products are commonly used feed ingredients. Their cell wall contains complex non-starch polysaccharides (NSP). It is well reported that all NSPs are indigestible for broilers, and some NSPs, especially soluble NSPs, may have anti-nutritional properties, and thus cause growth depression in poultry.

Mannan as a hemicellulosic polysaccharide is second to xylan in abundance in nature (McCleary, 1988). β-mannan is found in many feedstuffs including palm kernel meal, soybean meal, copra meal, and sesame meal and other leguminous feed raw materials. As an NSP, it is a highly anti-nutritional factor in poultry diets. Mannan consists of four subfamilies: glucomannans, galactomannans, galactoglucomannans, and pure (linear) mannans, and the structure is as Figure 1.

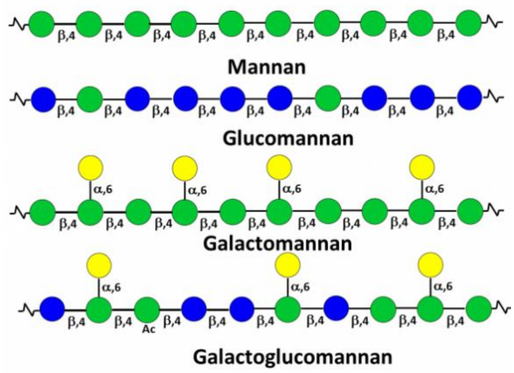

Figure 1: four subfamilies of mannan

Soybean meal (SBM) is a primary plant protein source and contains about 3% soluble NSP and 16% insoluble NSP. SBM's NPS consists mainly of mannans and galactomannans (Slominski, 2011). SBM is widely used as protein sources in feed, and therefore β-mannan is found in most of the poultry and swine feed.

Table 1. approximate content of β-mannan in some feedstuffs.

Feedstuffs	β-Mannan content, g/kg	Reference
Palm kernel meal	367	Sundu et al. (2006a)
Copra meal	250	Sundu et al. (2006b)
Guar meal	87	Lee et al. (2004)
SBM	13-16	Shastak et al(2015)
Rapeseed meal	4.5	Dierick (1989)
Rye	6.1	Dierick (1989)
Barley	4.3	Dierick (1989)

Wheat	0.9	Dierick (1989)
Maize	0.8	Dierick (1989)

Although galactomannan content in SBM is not high, it is still a concern for nutritionists because it has anti-nutritive effect. Dietary mannan is indigestible by poultry and swine, but it can be hydrolyzed by supplemental exogenous enzymes, therefore in this case it can be a potential energy source, and be prebiotics when it is degraded into manno-oligosaccharides (MOS). As such, dietary mannan and mannanase application in feed draw the attention of nutritionists.

Because of the abundance in nature and anti-nutrition effect of mannan, mannanase is commercially produced to supplement in feeds. Mannanases are perceived as the second most important enzymes after xylanases for the hydrolysis of hemicelluloses. Endo-β -mannanases are endohydrolases that cleave the internal glycosidic bonds of the mannan backbone and produce β-1,4-manno-oligosaccharides and D-mannose.

β-Mannanase supplementation has been reported to improve performance and nutrient digestibility in poultry fed corn-SBM-based diets in broiler (Li et al., 2010) and in layer (Wu et al., 2005), and other mannan-containing raw materials diets like guar meal (Odetallah et al., 2002), copra meal (Ibuki et al., 2013).

Modes of action of mannanase

Based on available research data, five modes of action may contribute to positive effects of ß-mannanase supplementation on performance and nutrient digestibility. These modes of action can be grouped as follows:

1). Reduce intestinal digesta viscosity.

High molecular weight soluble galactomannans can dissolve in the digestive tract forming highly viscous digesta, which is quite similar to soluble arabinoxylans and β-glucans. Thus, an increase in the digesta viscosity due to inclusion of feedstuffs containing high level of water-soluble galactomannan is understandable. High digesta viscosity may slow gastric emptying, affect the mixing of substrate with digestive enzymes and reduce the absorption due to less contact of nutrients with enterocytes. Lee (2003 et al) demonstrated that dietary digesta viscosity increased with the increase of mannan content from guar hull, and reduced with the addition of β-mannanase.

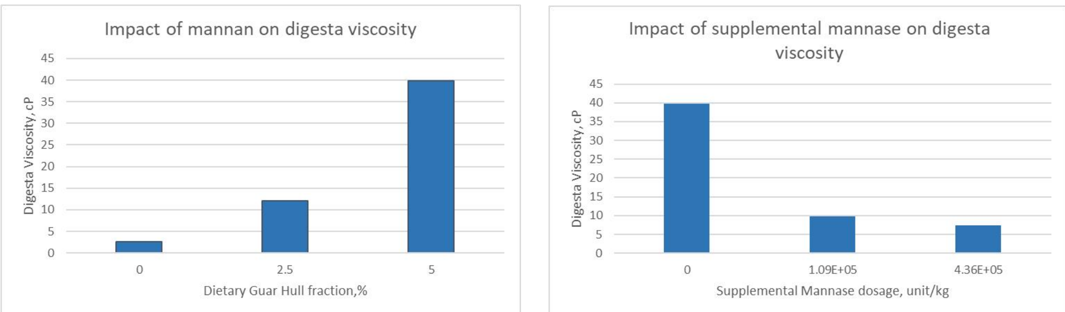

Figure 2: impact of mannan and mannanase supplementation on digesta viscosity

(Adapted from Lee et al, 2003)

Daskiran et al. (2004) observed water: feed ratio increased in broilers with the increase of dietary mannan content from guar gum, and tended to reduce with the mannanase supplementation. High viscous intestinal digesta stimulated more water drinking by broilers to keep proper mixing of digestive enzymes with substrate. However more water consumption leads to wet litter, which may cause birds health issues.

2). Suppression of the proliferation of pathogens in the gut.
β-Mannanase can degrade mannan to produce MOS, which is believed to prevent bacterial adhesion to the gut through saturation of binding sites. MOS was therefore observed to reduce the adhesion of pathogens to intestine epithelial cells in vitro (Kunz et al., 2001) and inhibited colonization of Salmonella in the intestine of broiler and layer chicks (Morikoshi and Yokomizo, 2004). Therefore β-Mannanase supplementation is believed to have the function of suppressing pathogens proliferation through its enzymatic hydrolysate MOS. Gutierrez et al. (2008), observed that exogenous β-mannanase supplementation to corn-SBM-guar meal-based diets significantly reduced Salmonella enteritidis colonization in late-phase laying hens challenged with this pathogenic bacterium.
Additionally, MOS has prebiotic effect on animals at low doses. MOS can be used as nutrients by Bifidobacteria and Lactobacilli but not pathogens such as Clostridium perfringens and Escherichia coli.

3). Impact on immune response.
Plant derived β-mannan is regarded as a pathogen associated molecular pattern analog for animals, which induce an over-stimulation of the innate immune system, and more portion of nutrients are divided to respond the “false” immune stimulation from growth purpose. β-Mannanase supplementation therefore can improve dietary energy utilization in corn-SBM-based diets in broilers (Li et al., 2010) and laying hens (Wu et al., 2005). The effect of β-mannanase on energy utilization was partly attributed to the reduced immune challenge caused by β-mannan in the diets (Li et al., 2010).

4) Release of trapped or bound nutrients.
NSPs could decrease nutrient digestibility through the encapsulation of the starch and protein inside the cereal endosperm (Bedford, 1993). As an NSP-degrading enzyme, Mannase may destroy the encapsulation effect and improve nutrient digestion. Li et al, (2010) reported that mannanase supplementation led to an increase in total tract apparent digestibility of crude protein and crude fiber, and improved AMEn value.

5). Release of D-mannose as an energy source.
β-Mannanase alone liberates short β-1,4-manno-oligomers, which can be further degraded to mannose by β-mannosidases and utilized by animals as energy source.

VTR mannanase trial in Sydney University

Exogenous β-mannanase supplementation to broiler diets is considered as an efficient nutritional strategy to overcome the adverse effect of galactomannan in broiler chickens. A trial was conducted in Sydney University to investigate the effect of VTR mannanase supplementation on broiler performance fed corn-SBM diet. The dietary treatment followed 2 × 4 factorial arrangements which consisted of four levels of β-mannanase inclusions and two dietary metabolizable energy levels. A total of 720 day-old male Ross 308 birds (parent line) were randomly assigned to 48 floor pens with 15 birds per pen and each treatment had 6 replicates.

A treatment interaction (P = 0.030) was observed for weight gain, largely because responses to β-mannanase were of a linear nature in birds offered standard energy density diets (Figure 3), which was not the case with low energy density diets. The linear impact of β-mannanase on weight gain in birds on standard energy density diets closely approached significance (P = 0.056) and the 300 mg/kg β-mannanase inclusion numerically improved weight gain by 3.75% (2887 versus 2773 g/bird). The energy density reduction increased feed intake by 3.28% (3784 versus 3664 g/bird; P = 0.027).

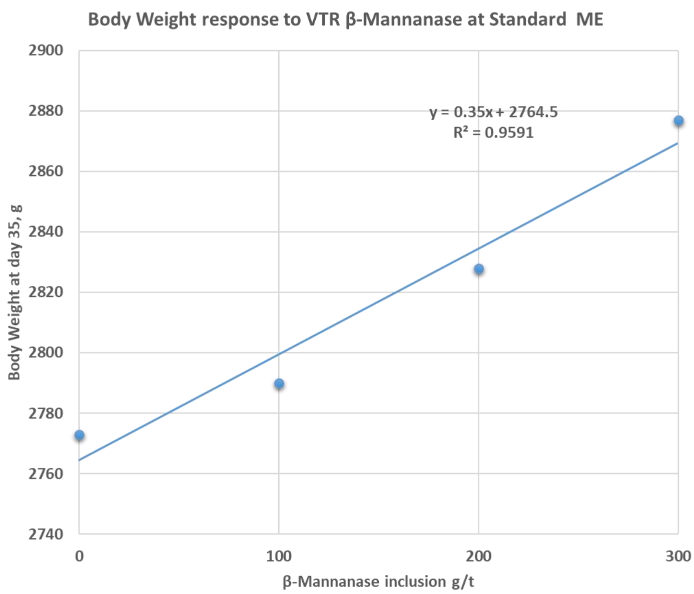

Figure 3: impact of VTR mannanase supplementation on broiler performance (unpublished data, 2022)

Conclusion

β-Mannan is an anti-nutritional factor, and is widely found in feed raw materials. It adversely affects digesta viscosity, nutrient digestibility, metabolism, animal health and overall performance. Supplementation of exogenous β-mannase can overcome the anti-nutritional effect. β-Mannanase may be a useful enzyme in monogastric animal nutrition which possesses a broad spectrum of different modes of action. β-Mannanase plays certain roles in a specific condition through single or combined mechanisms. Therefore, diet composition, β-mannanase source, age of birds, hygienic conditions are needed to consider when applying β-mannase to feed to optimize feed efficacy.

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