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Future of NSP-degrading enzymes to improve nutrient utilization of co-products and gut health in pigs ☆

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ABSTRACT

Globally, the amount of co-products in swine diets is expected to continue to increase, resulting in the feeding of diets with a higher content of non-starch polysaccharides (NSP) than traditional cereal-based diets. Such diets may open up opportunities for NSP-degrading enzyme to improve nutrient digestibility and voluntary feed intake and thereby reduce the risk of feeding diets high in co-products. The link between supplemental enzymes and nutrient digestibility is understood; however, links to other underlying mechanisms in digestive physiology, e.g., intestinal microbial populations and physical characteristics of digesta to benefit gut health and voluntary feed intake are not well understood. Seven presenters highlighted unique components of these links between NSP, enzymes, and digestive physiology. Suggested critical gaps in knowledge were: a better understanding of the changes in enzyme substrates during processing, feedstuff components other than nutrients and NSP (antibiotic residues, mycotoxins), and the impact that co-products may play on altering gut health and feed intake. In conclusion, supplemental enzymes in the correct combination and proportions may play an important role in efficient and effective nutrient use of co-products in swine diets, but their effects on gut health warrant further investigation.

1. Introduction

The increasing pressure on grain markets within the last decade has resulted in a trend for swine diets with a reduced grain content and an increased co-product content. This trend has especially been noted in areas where grains produced are being used locally in value-added processing, such as flour milling and ethanol production. The resulting co-products such as millrun and distiller's dried grain with soluble (DDGS), respectively, were used initially solely in diets for ruminant species. However, due to recent increased production and reduced prices, co-products have become attractive in swine diets to reduce the cost of production.

Diets high in cereal grains were common in parts of the world with a large domestic grain production relative to the number of pigs such as North America. Generally, co-products are lower in starch and higher in crude protein and fibre (CVB, 2003; Sauvant et al., 2004) and have a larger range in nutrient quality; thus, inclusion of co-products introduces a risk for a lower growth performance. The risk of using co-products can be reduced by: 1) modern feed quality evaluation such as NE and SID or bioavailability of AA, 2) technology to rapidly measure feed quality such as NIRS, and 3) feed processing such as enzyme supplementation and extrusion. The objectives of the workshop were to present the current state of knowledge on the use of supplemental enzymes to enhance nutrient utilization of co-products, to explore new knowledge on the underlying mechanisms of fibre and supplemental enzymes on digestive physiology using presentations, and to discuss current gaps in knowledge to advance the use of supplemental enzymes for co-product utilization.

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2. Current state of knowledge

In the swine gut, a 3-way interaction occurs between diet, host, and bacteria. Overall, the 2-way relation between diet and pig has been described thoroughly. For example, the negative impact of fibre or NSP on energy utilization has been defined in grains (Zijlstra et al., 1999). The positive effects of enzymes on energy digestibility have also been defined, as long as the supplemental enzyme matches with a substrate that limits nutrient utilization. Thus not surprisingly, diets containing wheat co-products from flour milling have a drastically increased NSP and thus arabinoxylan content, and supplemental xylanase lifted up energy digestibility in swine (Nortey et al., 2007, 2008). Interestingly, the relationship between co-products from ethanol production, corn or wheat DDGS, and supplemental xylanase is less clear. The DDGS has been subjected to extensive periods in solution followed by drying, and supplemental xylanase does not always seem to improve energy digestibility of wheat DDGS (Widyaratne et al., 2009). Apart from nutrient digestibility, enzymes may also affect voluntary feed intake of diets high in NSP (Zijlstra et al., 2004). The underlying mechanisms for this phenomenon are not clear. The soluble NSP may alter gastric release of digesta, and obviously reduced digestibility may mean consequently an increased amount of digesta that may create alter digesta flow (Owusu-Asiedu et al., 2006).

The combined result of reduced nutrient digestibility and feed intake of diets containing co-products such as wheat DDGS and therefore higher in fibre might be a reduced energy intake (Widyaratne and Zijlstra, 2007) and perhaps a reduced feed efficiency. The main constraints for reduced feed intake of diets containing wheat DDGS are less understood, but increased retention time due to soluble fibre and reduced retention time due to insoluble fibre might play a role (Owusu-Asiedu et al., 2006). Indeed, wheat as a source of insoluble fibre reduced retention time (Wilfart et al., 2007). In summary, the interaction between the animal and feed is complex; a single study cannot provide an answer, but perhaps modelling can. Although the role of fibre overall is better understood, the role of the individual fibre fractions on the complexity of digesta flow, microbial populations, and gut health requires further investigation.

3. New knowledge

To provide further insight in underlying mechanisms that relate NSP to gut function and gut health, 7 abstracts were selected for an oral presentation. Presentations were selected based on containing a hypothesis test related to the topic of the workshop.

Solà-Oriol et al. (2010-this issue) tested diets containing 60% white rice or whole oats containing 0 and 14.6% NSP, respectively. Differences in kinetics of gastric and small intestine digesta flow appeared to be related to dietary fibre content. Martins et al. (2010-this issue) compared a low fibre diet to diets containing 15% wheat bran or brewers grain. Wheat bran increased content of volatile fatty acids and microbial digestive enzymes in the caecum, while brewer's grain affected intestinal morphology. Le Gall et al. (2010-this issue) studied degradation of arabinoxylans from wheat and rye in gastrointestinal tract. Arabinoxylans have a lower rate of degradation than β-glucans of oats. Hermes et al. (2010) compared diets based on rice or barley with or without extra fibre as wheat bran or sugarbeet pulp. Feed intake and intestinal protein fermentation were higher for rice diets, whereas extra fibre increased Enterococci counts. Perez et al. (2010) studied the effects of increasing levels of (corn) DDGS on small intestine morphology. Inclusion of DDGS did not prevent infection by *E. coli*. In summary, fibre clearly affects digestive physiology in pigs and plays a role in digesta flow and voluntary feed intake. However, the dietary fibre sources and diets were mostly poorly characterized for chemical composition and unique physico-chemical properties. So, underlying mechanisms that may explain the unique role of fibre fractions in the gut remain poorly explained.

Reilly et al. (2010-this issue) studied the effects of oat-based β-glucans or oat-derived β-glucans in a wheat-based diet with or without a β-glucanase cocktail. Intact β-glucans increased hindgut fermentation and Bifidobacteria and Lactobacilli populations in the colon; the supplementation of β-glucanase reduced these effects. Combined, these results indicate that intact β-glucans stimulate gut health. Smith et al. (2010-this issue) conducted a second study with similar design using barley and oat-based diets. Oat-based diets had a reduced nutrient digestibility and an increased population of Bifidobacteria and Lactobacilli. Willamil et al. (2009a) studied maize or wheat–barley–rye diets with or without a β-glucanase and xylanase cocktail. Enzyme increased feed intake and gain for the wheat-based but not the corn based diet, perhaps due to increased starch digestion in the caecum. Enzyme supplementation decreased Gram-negative bacteria overall, but only increased Lactobacilli, Bifidobacteria, and overall biodiversity for the wheat-based diet. Willamil et al. (2009b) used the same study design, indicating that enzyme tended to increase absorptive area and reduced cell proliferation and intra-epithelial lymphocytes in the gut. In summary, results confirmed that nutrient digestibility will differ among cereal grains, and that enzymes can enhance nutrient utilization in wheat-based diets. Both cereal grains and enzymes will affect components of gut health, including intestine morphology, bacteria populations, and microbial metabolites in the gut content.

Noteworthy, none of the presented studies would approach the dietary NSP content expected with diets high in grain-based co-products. New knowledge shared at the conference is thus more reflective of the interaction between NSP and enzymes in traditional grain-based diets.

4. Discussion

The presentation of new knowledge at the workshop added limited value to the current knowledge of the benefits of enzyme supplementation of co-products utilization of swine. However, the current and new knowledge combined provides clear evidence that the matching of substrate such as arabinoxylans with enzyme activity such as xylanase is just as essential for co-products as for cereal grains. A missing component in most presentations was a detailed analysis of substrate levels and enzyme activity in the diets. Inclusion of information from NSP analyses in these studies is essential. Also, the detailed reporting of NSP analyses from co-products using separation of sugar moieties, molecular weight analyses, and (electron) microscopic analyses will assist in the

understanding of the role that NSP play in limitations of nutrient utilization of co-products. Finally, evidence exist that in certain circumstances, NSP are not the most important factor limiting nutrient utilization of co-products, and other factors such as mycotoxins, NSP cross-linked with other molecules, and proper dietary nutrient balance might play a role.

5. Summary and conclusion

Generally, NSP-degrading enzymes improve energy digestibility and their effects on AA and P digestibility are variable depending on trial conditions. An expanded enzyme matrix containing complex xylanase and β-glucanase combinations might be required to effectively digest the increasing array of co-products. In conclusion, increased co-product use combined with application of enzyme technology, modern feed processing, and feed quality evaluation technologies may provide the pig with additional energy, AA, and P resulting in cost-effective, predictable growth performance and a more sustainable pork production system. Therefore, NSP-degrading enzymes do have a future to improve nutrient utilization of co-products in swine.

Conflict of interest

A. Owusu-Asiedu and P.H. Simmins are employees of Danisco Animal Nutrition.

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