How xylanase can enhance swine productivity

By Dr. Ajay Awati, Director of Enzymes, EW Nutrition

The use of by-products and high-fiber ingredients in feed formulations has increased in swine operations. Driven by both economic and sustainability goals, this shift has emphasized the importance of understanding the role of dietary fibers and carbohydrases in swine nutrition and health (Petry & Patience, 2020). These feeds rich in fiber are generally considered to have low nutritional value due to the lower digestive energy or amino acid levels when compared to concentrated feeds with high starch or proteins (Woyengo et al., 2014).

Dietary fiber is vital in pig nutrition, necessitating a baseline inclusion to support regular digestive tract functions (Wenk, 2001). Incorporating fiber into the diets of monogastric animals raises concerns due to its correlation with reduced nutrient utilization and diminished net energy levels (Noblet; Le Goof, 2001). High-fiber diets can present challenges for inclusion in monogastric animals' feeds, especially young animals, due to their bulky nature and restricted ability to ferment fiber, impacting nutrient uptake based on fiber type, the age of the pig, and diet composition (Bach Knudsen et al., 2012).

Moreover, the apparent ileal digestibility (AID) of nutrients is adversely affected by dietary fiber, attributed to the small intestine's deficiency in endogenous enzymes necessary for breaking down these bonds (Bach Knudsen et al., 2012).

This article aims to demonstrate how enzymatic degradation of arabinoxylans, particularly through xylanase enzymes, can mitigate anti-nutritional effects and enhance the nutritional value of high-fiber swine diets, thereby improving animal health and performance.

Into the World of Arabinoxylans

In plants classified as monocotyledonous, such as cereals, the main non-starch polysaccharides (NSP's) components of the cell wall are arabinoxylans, cellulose and β-glucan (Bach Knudsen, 1997). Arabinoxylans represent a complex group of dietary fibers with significant implications for swine nutrition and health. Their structural heterogeneity can influence physicochemical properties, biological activities, and affect pigs' gut microbiota and immune system. Present in both soluble and insoluble forms, it consists of a backbone of xylose residues with arabinose side chains, playing a crucial role in the nutritional dynamics within swine diets (Mudgil & Barak, 2013).

The fermentability of corn-based dietary fiber is limited by its insoluble fraction and complex branched structure; impacting the digesta transit rate and reducing the digestibility of nutrients (Gutierrez et al., 2013). Supplementing exogenous carbohydrases offers a viable approach to enhance the utilization of fiber that is otherwise difficult to ferment, potentially amplifying its positive effects.

Xylanase's Impact on Fiber and Gut Health

Non-digestible carbohydrates may be fermented by microbial populations along the gastrointestinal tract to synthesize short-chain fatty acids that may be absorbed and metabolized by the pig. Such indigestible carbohydrates consist of specific disaccharides, oligosaccharides, resistant starches, and non-starch polysaccharides. The presence and composition of these indigestible carbohydrates in pig diets vary based on the types of feed ingredients incorporated into their meals (Navarro et al., 2019). Xylanase works on the hydrolysis of the arabinoxylan fraction of NSPs. The NSPs present in the walls of plant cells encapsulate nutrients, making them unavailable for the action of the animal's own digestive enzymes. Moreover, NSPs exhibit a high affinity for water within the gastrointestinal lumen, leading to elevated digesta viscosity. This increased viscosity reduces gastrointestinal motility, facilitating an environment conducive to the proliferation of pathogenic microflora (Choct, 1998). The advantageous outcomes of enzyme supplementation arise from the enzymatic disruption of intact cellular membranes, leading to the release of sequestered nutrients, or are a consequence of modifying the physicochemical properties of non-starch polysaccharides, due to changes in viscosity and water-holding capacity and/or changes in the composition and content of bacteria in the intestine (Bedford, M. R., & Classen, 1992).

Arabinoxylans in Cereal Grains and Their By-products

Factors such as genetics, climate, maturity stage, fertilizer use, and post-harvest storage time influence the proportion of total cell wall polysaccharides in cereal grains. These factors vary across production systems and countries, depending on the availability of feed resources (Paloheimo et al., 2010).

Cereal grains and their by-products, including wheat bran, corn distillers dried grains with solubles (DDGS), and rice husks, serve as significant sources of arabinoxylans. Their incorporation into swine diets is growing due to economic advantages.

The ethanol industry's growth has increased the availability of distillery by-products. Brazil alone generates an estimated 366 million tons of DDGS annually (USDA, 2017). Among these by-products, distiller-dried grains are prevalent, especially in the U.S. pork industry as feed ingredients.

Corn, wheat, and barley, as staple ingredients in swine feed, exhibit significant variations in their NSP and arabinoxylans content. In grain form, corn contains 4.7% AX with a soluble component of 0.5%, while wheat has a higher arabinoxylans content at 7.3% with 1.8% being soluble. Barley stands out with the highest arabinoxylans content at 8.4%, of which 1.2% is soluble, reflecting its rich fiber composition. The processing into flour results in a reduction of arabinoxylans content across all three cereals, highlighting the impact of processing on dietary fiber availability (Knudsen, 2014).

Rice distillers' by-product is recognized as a valuable protein source, boasting high crude protein levels. Nonetheless, its high fiber content can restrict usage (Huang et al., 2017). Wheat bran is particularly rich in arabinoxylans, enhancing its dietary fiber content. DDGS also contain significant amounts of both soluble and insoluble arabinoxylans, resulting from the corn kernel's residual non-starch polysaccharides (Agyekum & Nyachoti, 2017).

It is essential to understand the specific levels of arabinoxylans in these components to create balanced diets that optimize nutritional benefits while minimizing potential anti-nutritional effects.

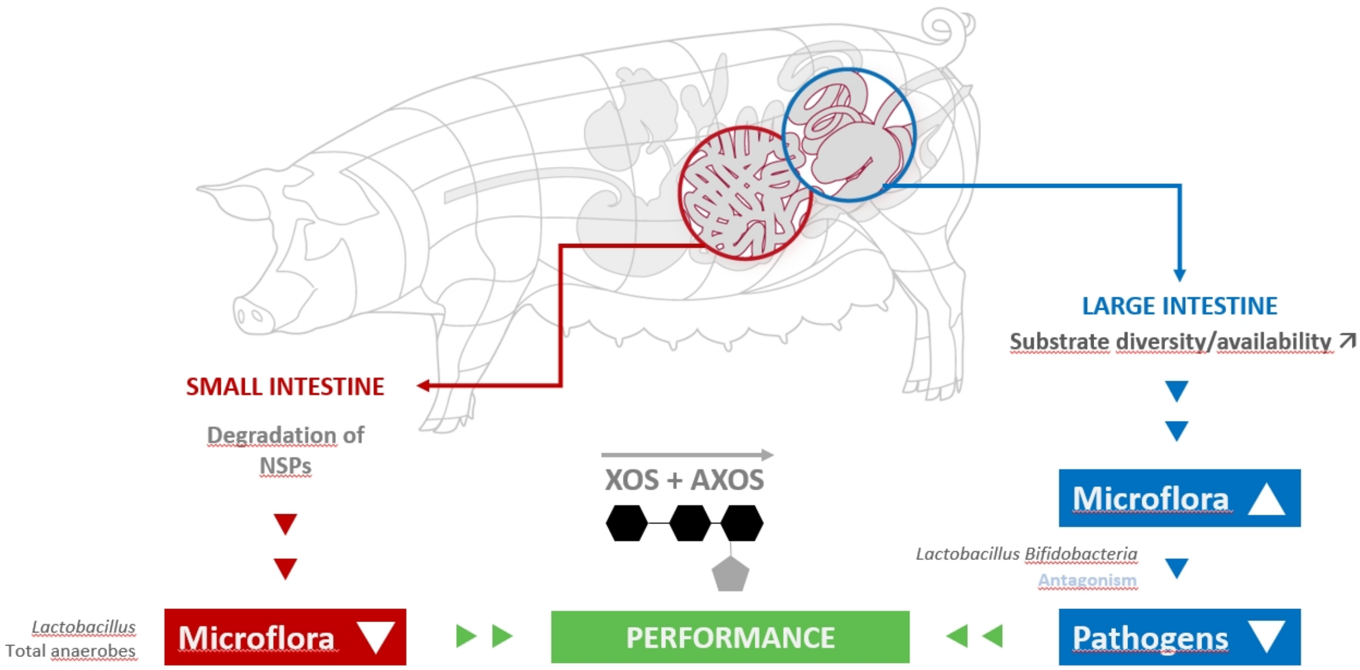
Addressing Arabinoxylan Degradation

Xylanases target specific substrates, necessitating the presence of arabinoxylans for their effective action. The complex structure of arabinoxylans makes them resistant to degradation by the swine's endogenous enzymes, presenting a dual challenge: how to harness the beneficial effects of soluble arabinoxylans while mitigating the negative impacts of their insoluble counterparts.

These enzymes specifically cleave the 1,4-β-D-xylosidic bonds in arabinoxylans, randomly targeting xylose linkages within the xylan structure. Each enzyme type has a unique pattern of degradation (Collins et al., 2005) and GH 10 xylanases specialize in breaking down arabinoxylans with high arabinose substitution into smaller oligosaccharides. These oligosaccharides are valuable for fermentation, serving as energy sources or prebiotics.

Also, this group of enzymes action not only reduces gut viscosity but can lead to enhanced feed efficiency, growth performance, and overall health of swine by improving the digestibility of fibrous components in feed (Lærke et al., 2015). GH 10 xylanases often have optimal activity at pH levels found in the animal gut, and their thermal stability ensures they retain activity under feed processing temperatures. Lei et al. (2016) highlighted the efficacy of xylanase in improving nutrient digestibility and overall feed efficiency. By targeting the arabinoxylans present in swine diets, xylanase enzymes facilitate a more efficient conversion of feed into energy, contributing to improved growth rates and performance metrics.

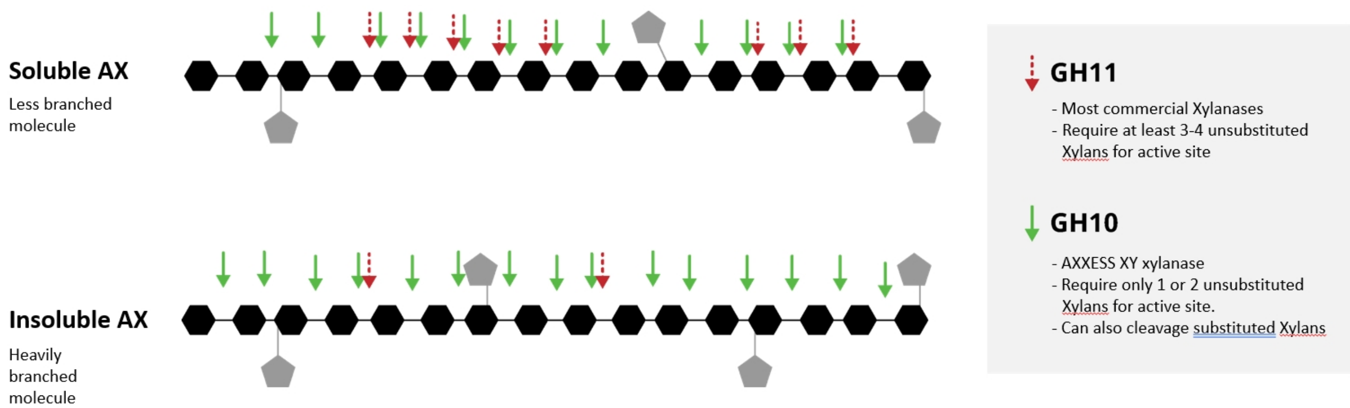
As detailed by Tiwari, Singh, & Jha (2019), arabinoxylans undergo fermentation in the gut, leading to the production of short-chain fatty acids (SCFAs) that beneficially alter the gut microbial ecology. The application of GH 10 xylanases has been highlighted for its potential to significantly enhance the degradation of arabinoxylans, thereby improving the fermentation process and increasing the yield of SCFAs. This enzymatic breakdown facilitates more efficient nutrient absorption and overall better gastrointestinal health, directly influencing swine growth and performance positively.



A study reveals that xylanase supplementation significantly reduces mortality rates in pigs in a dose-dependent manner. With mortality rates dropping from 4.16% in the control group to as low as 2.25% with the highest xylanase dosage, the results highlight xylanase's potential to improve gut health and increase survival rates. This suggests a promising approach for boosting pig well-being and reducing the reliance on enteric antibiotics, marking a significant stride in sustainable animal nutrition practices.(Zier-Rush et al., 2016).

The research conducted by Petry et al. (2020) demonstrated that xylanase increased the digestibility of non-starch polysaccharides, particularly arabinoxylan, in diets high in insoluble corn fiber. This improvement in nutrient absorption highlights xylanase's role in optimizing the use of high-fiber ingredients in swine diets, thereby enhancing animal health and performance. Due to its cost-effectiveness and nutrient profile, xylanase supplementation enhances the nutritional value of DDG in swine diets.

The strategic implementation of xylanase in swine diets represents a promising approach to the challenges posed by high-fiber feed ingredients. By improving the digestibility of arabinoxylans and other complex carbohydrates, xylanase supplementation can mitigate the anti-nutritional effects of insoluble fibers, enhance feed efficiency, and support optimal growth and health outcomes in swine.



Enhancing Swine Productivity with Enzyme Solutions

With the growing incorporation of co-products in swine feed, there arises a crucial need to transform the high fiber content into a beneficial asset for the animals. The strategic incorporation of enzyme solutions, particularly xylanase enzymes, into swine feed formulations emerges as a scientifically supported approach to significantly enhance the digestibility of high-fiber diets. This method effectively addresses the nutritional intricacies posed by arabinoxylans, facilitating improved feed utilization. Moreover, the action of xylanase enzymes extends beyond enhancement of nutrient absorption; it plays a pivotal role in promoting the health and performance of swine. Such targeted nutritional strategies are vital in the context of swine production systems, highlighting the necessity of integrating these enzymatic solutions to achieve optimal animal health, growth, and productivity.

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Overcoming Challenges of Xylanase Inhibitors in Animal Feeds

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In recent years, the scientific understanding of xylanase inhibitors (XIs) and their impact on animal nutrition has grown significantly. Xylanase, a crucial enzyme used to enhance nutrient availability in feed, can face challenges from XIs present in cereal grains. This article explores the evolution of plant protection mechanisms, the economic impact of XIs, and the development of a novel xylanase, Axxess XY, resistant to these inhibitors.

Xylanase inhibitors – an evolutionary protection mechanism of plants

Xylanase inhibitors (XI) are a classic example of the evolutionary development of protection mechanisms by cereal plants against pathogens. Microorganisms, such as fungal pathogens, involve the degradation of xylan as one of the mechanisms in pathogenesis (Choquer et al., 2007). There are also other mechanisms by which microorganism-produced xylanases affect plants.

To protect themselves, plants evolved xylanase inhibitors to prevent the activities of xylanases. XIs are plant cell wall proteins broadly distributed in monocots. There are three classes of XIs with different structures and inhibition specificities (Tundo et al., 2022):
1. Triticum aestivum xylanase inhibitors (TAXI)
2. Xylanase inhibitor proteins (XIP), and
3. Thaumatin-like xylanase inhibitors (TLXI).

Xylanase inhibitors have an economic

impact

In animal nutrition, xylanases are widely used in diets containing cereal grains and other plant materials to achieve a higher availability of nutrients. The inhibitory activity of XIs prevents this positive effect of the enzymes and, therefore, makes them economically relevant. Studies have reported that higher levels of XIs negatively impact broiler performance. For example, in one of the studies, broilers fed with grains of a cultivar with high inhibitory activity showed a 7% lower weight on day 14 than broilers fed with grains of a cultivar with less inhibitory activity (Madesen et al., 2018). Another study by Ponte et al. (2004) also concluded that durum wheat xylanase inhibitors reduced the activity of exogenous xylanase added to the broiler diets.

Xylanase inhibitors can withstand high temperatures

Even though XIs can impact the performance of exogenous xylanase in different ways, only minor attention was paid to the reduction of xylanase's susceptibility to xylanase inhibitors during the xylanase development in the last decades. Firstly, the issue was ignored mainly through the assumption that XIs are denatured or destroyed during pelleting processes. However, Smeets et al. (2014) showed that XIs could sustain significant temperature challenges. They demonstrated that after exposing wheat to pelleting temperatures of 80°C, 85°C, 92°C, and 95°C, the recovery of inhibitory activity was still 99%, 100%, 75%, and 54%, respectively. Furthermore, other studies also confirmed that conditioning feed at 70-90°C for 30 sec followed by pelleting had little effect on the XI activity in the tested feed, showing that xylanase inhibitors are very likely present in most xylanase-supplemented feeds fed to animals.

Do we only have the problem of xylanase inhibitors in wheat?

No. After first reports of the presence of xylanase inhibitors in wheat by Debyser et al. (1997, 1999), XIs were also found in other cereal grains (corn, rice, and sorghum, etc.), and their involvement in xylanase inhibition and plant defense has been established by several reports (Tundo et al., 2022).

In most of the countries outside Europe, exogenous xylanase is used not only in wheat but also in corn-based diets. Besides broiler feeds, also other animal feeds, such as layer or swine feed being part of more mixed-grain diets, are susceptible to the inhibitory activity of XIs. Nowadays, the situation is getting worse with all the raw material prices increasing and nutritionists tending to use other feed ingredients and locally produced cereals. They need a xylanase which is resistant to xylanase inhibitors.

Xylanases' resistance to XIs is crucial – Axxess XY shows it

To prevent xylanases from losing their effect due to the presence of xylanase inhibitors, the resistance of new-generation xylanases to these substances is paramount in the development process, including enzyme discovery and engineering.

In the past 25 years, scientists have learned much about XI-encoding genes and discovered how xylanase inhibitors can block microbial xylanases. Additionally, there has been a significant increase in understanding the structural aspects of the interaction between xylanases and XIs, mainly how xylanase inhibitors interact with specific xylanases from fungi or bacteria and those in the GH10 or GH11 family. With such understanding, a new generation xylanase, Axxess XY, was developed. Besides showing the essential characteristics of intrinsic thermostability and versatile activity on both soluble and insoluble arabinoxylan, it is resistant to xylanase inhibitors.

Axxess XY takes xylanase application in animal feeds to the next level.

Axxess XY outperforms other xylanases on the market

Recent scientific developments (Fierens, 2007; Flatman et al., 2002; Debyser, 1999; Tundo et al., 2022; Chmelova, 2019) *and* internal research can be summarized as follows:

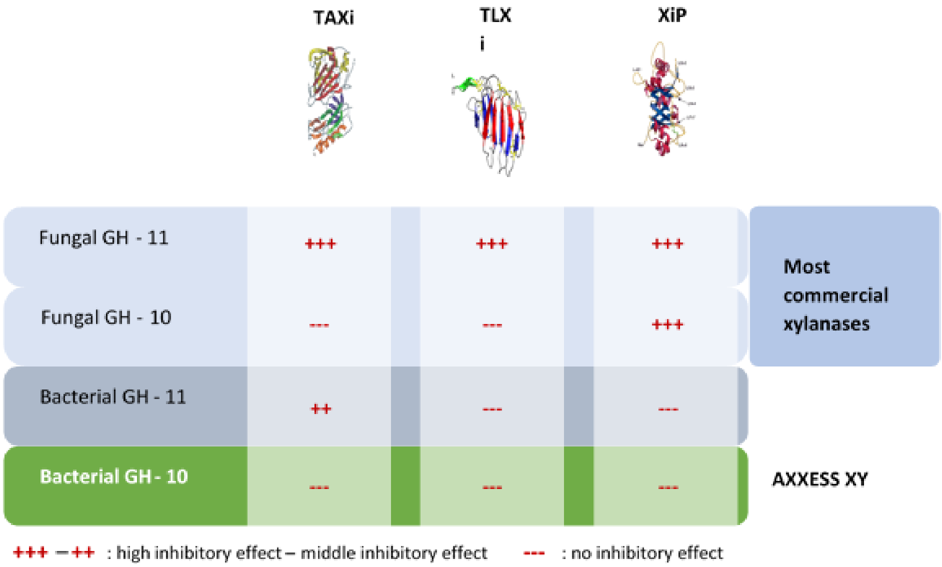

Figure 1: Schematic summary of the susceptibility of different xylanase to xylanase inhibitors from three main groups.

The high resistance to xylanase inhibitors is one of the reasons that a novel xylanase with bacterial origin and from the GH-10 family was chosen to be Axxess XY. EWN innovation, together with research partners, made an interesting benchmark comparison between xylanases that are commercially sold by different global suppliers and Axxess XY. For these trials, all xylanase inhibitors from wheat were extracted. The inhibitors, together with the respective xylanase, were incubated at 40^{0}C (to mimic birds' body temperature) for 30 mins. Then, the loss of xylanase activity was calculated by analyzing remaining activity after incubation. Results are shown below in Figure 2. There were varying levels of activity loss observed in the different commercially sold xylanases. In some xylanases, the losses were alarmingly high. However, Axxess XY was not inhibited at all.

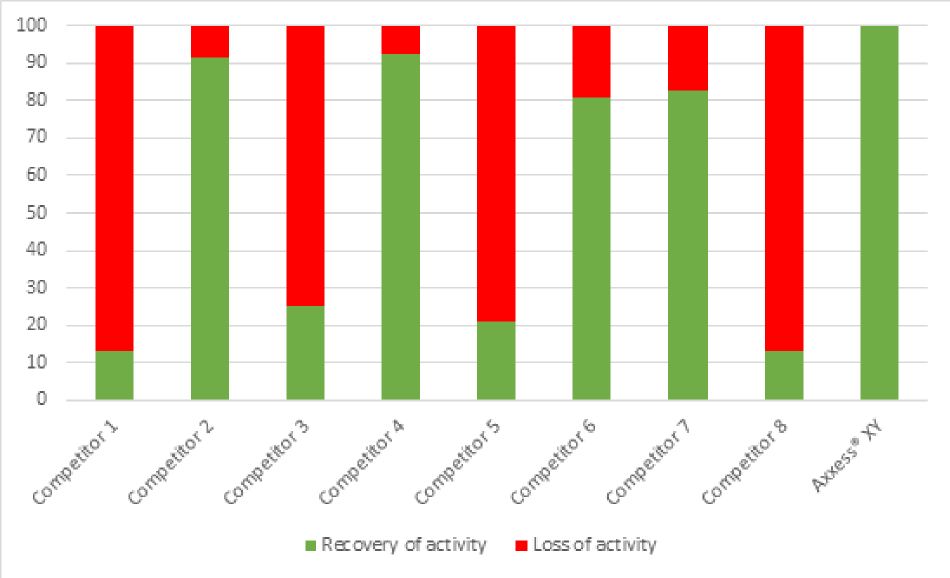

Fig. 2: Extracted total xylanase inhibitors from wheat incubated with the respective xylanase at 40°C for 30 mins. – Loss of activity after incubation with xylanase inhibitors

Conclusion:

Xylanase inhibitors are present in all cereal grains and, unfortunately, heat tolerant (up to 90^{0}C, still 75% of inhibition activity was retained). Regardless of the diets used, there is a possibility that the xylanase used may come across xylanase inhibitors, resulting in a loss of activity. More importantly, this can lead to inconsistent performance.

For effective, consistent, and higher performance of NSP enzyme application, it is a must to use xylanase that is resistant to xylanase inhibitors.

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