Feed enzyme and gut health of nursery pigs: beyond its traditional role

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Introduction

Upon weaning, the sudden change from sow milk to a plant-based diet, containing anti-nutritional factors is one of the biggest challenges faced by nursery pigs. It is well known that plant-based feedstuffs have a significant quantity of anti-nutritional factors that can affect the intestinal health and consequently affect the growth performance of the pigs (Kim et al., 2010; Taliercio and Kim, 2014; Berrocoso et al., 2015; Duarte et al., 2021) and these effects are even more pronounced in young animals due to their immature gastrointestinal tract (Lindberg, 2014).

The content of anti-nutritional factors limits the use of plant-based feedstuffs in the diet of pigs (Kerr and Shurson, 2013). The major NSP in the swine plant-based diets are arabinoxylan (Jaworski et al., 2015; Baker et al., 2021), mannan (Tiwari et al., 2020), and β-glucans (Sampson et al., 2015; Yu et al., 2018). Major anti-nutritional roles of NSP are related to their capacity to increase digesta viscosity causing encapsulation of nutrients, thus reducing nutrient digestibility in feeds (Passos et al., 2015, Duarte et al., 2019). In addition, plant-based feedstuffs contain proteins such as glycinin, β-conglycinin, and lectin, present in soybean meal (Krishnan et al., 2007), as well as kafirin in sorghum that are known to cause gut irritation and inflammation and to be resistant to hydrolysis by endogenous enzymes due to the presence of disulfide bond, especially in young animals (da Silva et al., 2011, Wang et al., 2011). Furthermore, around 61-

70% of the phosphorus (P) in cereal grains and oilseeds used in monogastric diet formulation are present in the form of phytic acid (Paiva et al., 2013). Phytate can bind to Ca, Zn, Cu, Mn, and amino acids reducing their digestibility and utilization (Adeola and Cowieson, 2011).

Feed enzymes have been used to aid the endogenous digestive enzymes and to digest NSP and phytate. Thus, the dietary supplementation with exogenous enzymes complements the activity of endogenous enzymes, mainly hydrolyzing those compounds that are resistant to digestion (Wang et al., 2011) and to reduces the anti-nutritional effects of NSP and phytate, consequently, enhancing the use of nutrients (Kim et al., 2003; Pedersen et al., 2012; Lærke et al., 2015). The increased nutrient digestibility can further reduce the nutrient excretion in the environment (Ferket et al., 2002), whereas the reduction of the anti-nutritional and toxic compounds in feeds can enhance the gut health and balance the gut microbiota (Duarte et al., 2019).

Proteases

Protease has been used in the swine industry individually or combined with other enzymes to improve protein digestibility and to reduce the deleterious effects of allergenic proteins (glycinin, β-conglycinin, lectin, kafirin). Glycinin, β-conglycinin, lectin, kafirin can cause intestinal irritation and inflammation (da Silva et al., 2011, Wang et al., 2011), consequently, increasing the oxidative stress status and impairing the epithelial barrier (Taliercio and Kim, 2013). It has been demonstrated that dietary protease supplementation reduced the concentration of tumor necrose factor-alpha (TNF-α), malondialdehyde (MDA), and protein carbonyl. The improvement on the inflammatory and oxidative stress status increased the villus heigh and the villus height to crypt depth ratio (VH:CD) enhancing the intestinal epithelial layer.

Furthermore, the use of protease reduces the availability of undigested protein for microbial fermentation reducing the abundance of pathogenic bacteria (Duarte and Kim, 2021).

Phytase

Phytate can bind to minerals, and amino acids reducing their availability and consequently affecting the growth performance of pigs (Adeola and Cowieson, 2011). The dietary supplementation of phytase has been used for monogastric animals to increase nutrient digestibility, enhancing bone parameters and growth performance (Cowieson et al., 2011; Adeola and Walk, 2013; McCormick et al., 2017; Babatunde et al., 2019). The change in the availability of P and Ca promoted the phytase supplementation can modulate the microbiota, increasing the abundance of beneficial bacteria and reducing potential pathogens counts (Metzler-Zebeli et al., 2013, Mann et al., 2014). According to Klinsoda et al. (2020), dietary phytase can shift the microbiota along the digesta mucosa-lymph node axis in the ileum of nursery pigs. Lee et al. (2016) reported that the dietary supplementation with corn-expressing phytase reduced the inflammatory and oxidative stress status increasing the VH:CD in jejunal mucosa and the growth performance of nursery pigs. Similarly, Moita et al. (2021) evaluating the effects of dietary phytase also reported an improvement in intestinal health of broiler chickens. The authors associated the enhanced intestinal health with the modulation of the mucosa-associated microbiota. The phytase supplementation increased the diversity of the microbiota and the abundance of *Lactobacillaceae*, whereas reduced the abundance of *Helicobacteraceae* in jejunal mucosa of broiler chickens.

NSPases

Major anti-nutritional roles of NSP are associated to their capacity to increase digesta viscosity reducing nutrient digestibility in feeds. Increased digesta viscosity can reduce the passage rate increasing the availability of undigested nutrients in the luminal environment for the proliferation microbiota (McDonald et al., 2001; Wellock et al. 2008; Metzler-Zebeli et al., 2010; Agyekum and Nyachoti, 2017). The proliferation of harmful bacteria resulted in intestinal immune response, oxidative stress, and eventually reduced growth performance (Chen et al., 2020; Duarte et al., 2020; Kim and Duarte, 2021). These effects can be even more pronounced in nursery pigs due to their inability to adapt to dietary challenges as well as their limited capability of handling NSP (Lindberg, 2014; Niu et al., 2015).

In pig production, NSPases have been largely adopted to handle anti-nutritional effects of NSP (Adeola and Cowieson, 2011). The main mode of action of NSPase, including xylanase, β-glucanase, and mannanase, is by reducing digesta viscosity which will in turn modulate the intestinal microbiota (Zhang et al., 2018; Petry et al., 2020, Duarte et al., 2021), increase nutrient digestibility and enhance the intestinal health and finally improve growth performance of pigs (Passos et al., 2015; Chen et al., 2020, Duarte et al., 2019). The oligosaccharides released by NSPases can also be utilized as prebiotics by the commensal microbiota and by probiotics (Duarte et al., 2020, Baker et al., 2021).

α-1,6-galactosidase can hydrolyze flatulence-producing carbohydrates in soybean meal improving nutrient digestibility and growth performance of nursery pigs fed diets containing soybean meal as a major protein ingredient (Kim et al., 2003). Glucose oxidase targets gut health by modulating the intestinal microbiota, reducing inflammation and oxidative stress (Tang et al., 2016). Furthermore, muramidase has been reported to enhance intestinal health and growth performance of broilers chickens and pigs by cleaving peptidoglycan present in bacterial cells (Schliffka et al., 2019; Vanrolleghem et al., 2019).

Conclusion

The use of feed enzymes should consider the optimal pH and temperature for the effective activity in the animal body. Considering the nutritional properties, the exogenous enzymes can aid endogenous digestive enzymes to improve nutrient digestion. Furthermore, selected enzymes can eliminate anti-nutritional compounds and toxins enhancing gut health and indirectly modulating gut microbiota, whereas NSPases release potential prebiotics modulating gut microbiota. Therefore, feed enzymes can target intestinal health beyond their traditional role.

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