Use of enzymes in pig diets
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INTRODUCTION
Traditionally, between 65 and 70% of the swine production cost are related to feed cost and efforts to improve nutrient digestibility can have significant effects on pork industry profitability (National Pork Board, 2012). Corn is the main ingredient and soybean meal is the main protein source in typical swine diets. Yellow dent corn (IFN 4-02-861, AAFCO, 1992) contains 9.7% of non-starch polysaccharides (NSP) (Knudsen, 1997) and 0.21% of phytate P (NRC, 2012). The arabinolxylans are the main NSP accounting for 4% of the corn composition (Ward et al., 2008). Soybean meal (IFN 5-04-612, AAFCO, 1992) contains 21.7% NSP (Knudsen, 1997) and 0.38% phytate P (NRC, 2012). Soybean meal also contains 3.8% raffinose and 7.3% stachyose (NRC, 2012), both considered as flatulence-producing factors (Liener et al., 1994). Feed enzymes aiming to degrade the indigestible components of swine diets have been studied (Pettet et al., 2002; Kim et al., 2003; Kim et al. 2006; Ji et al., 2008; Li et al., 2010; Wang et al., 2011a; Wang et al., 2011b; Jo et al., 2012, Almeida and Stein, 2012) in order to provide economic benefits to the swine industry.

The anti-nutritional effect of arabinolxylans (Choct and Annison, 1992) and flatulence-producing factors (Kim and Baker, 2003; van Kempen et al. 2006; Choct et al., 2010) were previously described. Pigs do not produce digestive enzymes to degrade NSP (Hartman et al., 1961; Lindemann et al., 1986; Huguet et al., 2006). Therefore there is growing interest in using supplemental enzymes to degrade NSP in order to mitigate their negative effect on nutrient digestibility (Choct and Annison, 1992, Choct et al., 2010).

Phytate P degradation by microorganisms in the large intestine (Schlemmer et al., 2001) does not enable pigs to utilize P from phytate. Therefore, there are several studies about phytase improving P digestibility in pigs (Almeida and Stein, 2010; Almeida and Stein, 2012; Akinmusire and Adeola, 2009; Yáñez et al 2011).

This literature review will focus on the primary enzymes available for feed supplementation in corn-soybean meal based diets. The objective is to analyze information regarding substrates, mode of action, and nutrient digestibility.
Non-starch polysaccharides and phytate

Xylanase
Xylan structure is composed of 1,4-β-linked D-xylopyranose and corn contains 3.0% of xylose (Knudsen, 1997). Arabinoxylans are composed of a xylan backbone with L-arabinose attached to xylose units (Subramaniyan and Prema, 2002). Arabinoyxylans are present in the endosperm and pericarp tissues of the grain (Ebringerova and Heinze, 2000). The arabinoyxylan of corn is characterized to be branched with L-arabinose, glucoronic acid (Huisman et al., 2000), and ferulates (Grabber et al., 1998). Under low pH, similar to that in the stomach, L-arabinose can be partially released from arabinoyxylans (Zhang et al., 2003; Craeyveld et al., 2009). Soybean meal contains xylose as xyl glucans and soybean contain xylose as xylans in its hulls (Karr-Lilienthal et al., 2005). Consequently, corn is the main source of xylans in a corn-soybean meal based diet. The non-ruminant animals do not produce enzymes to degrade the arabinoyxylan, therefore degradation of the arabinoyxylans in the cell wall would enable digestive enzymes to digest the nutrients inside the cell wall (Tervila-Wilo et al., 1996; Masey O’Neil et al., 2014).

The mode of action proposed for xylanases involves degradation of the arabinoyxylans in the cell wall enabling endogenous enzymes to digest the nutrients inside the cell wall (Tervila-Wilo et al., 1996; Masey O’Neil et al., 2014). Choct and Annison (1992) reported that dietary arabinoyxylans increased digesta viscosity and dietary supplementation of xylanase reduced the effect of arabinoyxylans on viscosity. The benefit of xylanase supplementation is related to NDF degradation. Passos and Kim (2014) observed that xylanase supplementation from 0 to 1,400 LXU/kg enhanced ileal NDF digestibility of a corn-soybean meal based diet fed to growing pigs. Zanotto et al. (2010) reported that combination of xylanase and amylase improved the digestible energy and metabolizable energy of a corn by 2.8 and 2.9 % respectively, whereas supplementation of amylase was not different than corn not supplemented with enzyme. The supplementation of xylanase also improved digestibility of a wheat-based diet fed to pigs (Woyengo et al., 2008; Moehn et al., 2007, Nortey et al., 2007). Therefore, there is evidence that xylanase can improve digestibility of feedstuffs by degrading arabinoyxylans of the cell wall.

Galactosides
Soybean meal contains 4.1% of galactose (Knudsen, 1997), 3.8% of raffinose, 7.3% of stachyose (NRC, 2012). It also contains mannose as 1% of β-mannans (Hsiao et al., 2006). Corn contains little amount of galactose (0.5%), raffinose (0.2%), stachyose (0.1%), and mannose (0.3%) compared to soybean meal (Knudsen, 1997). Reviewing the antinutritional factors of galactosides, Martinez-Villaluenga et al. (2008) mentioned about the osmotic changes that lead to diarrhea, microbial imbalance, abdominal pain, reduction of ME, and lower amino acids digestibility. Kim et al. (2003) and van Kempen et al. (2006) observed that the stachyose composition has a negative correlation with AID of dry matter and energy. Growth of pigs was also affected by galactosides and galactomannans (Kim et al., 2006). It was also reported that mannan forms viscous solutions and reduced the intestinal absorption of glucose (Rainbird et al., 1984; Nunes and Malmlof, 1992) and water (Rainbird et al., 1984).
The feed supplementation of enzymes targeting α-1,6-galactosides and β-galactomannans was reported in pigs. Kim et al. (2003 and 2006) studied galactosidase and mannanase in corn-soybean meal based diets fed to nursery, grower, and finishing pigs. It was reported improvements on AID of GE, lysine, threonine, and tryptophan due to enzyme supplementation. Moreover, the pigs fed diet supplemented with galactosidase and mannanase had a greater G:F ratio, and raffinose and stachyose concentration in the small intestine was reduced. Pettey et al. (2002) reported greater G:F ratio in nursery pigs fed a corn-soybean meal based diet supplemented with B-1,4-mannanase. Studying B-1,4-mannanase in corn-soybean meal-DDGS based diet fed to finisher pigs Yoon et al. (2010) observed greater ADG, ATTD of dry matter, GE, and protein.

Phytate
Phytic acid (myo-inositol 1, 2, 3, 4, 5, 6-hexakis phosphate) is the storage form of P in cereal grains and oil seeds (Cheryan, 1980). The corn grain will store P as phytin (phytic acid bound to Ca and Mg) mainly in the germ, but there is also phytin in the endosperm and in the hull (O’Dell et al., 1972). The soybean meal will have phytin stored together with protein (Erdman, 1979). Corn and soybean meal will have 0.21% and 0.36% of phytate P, respectively (NRC, 2012), thus limiting the phosphorus utilization of these feedstuffs by the pigs (Schlemmer et al., 2001). The dephosphorylation of myo-inositol hexakiphosphate (phytate) by phytases involves sequential removal of phosphate groups (Greiner et al., 2002). The removal of P from phytate and the further P absorption in the small intestine (Jones et al., 2010; Guggenbuhl et al., 2012; Rojas and Stein, 2012) is the main reason for phytase supplementation in swine diets.

Protease
Protease is the general term for enzymes that degrade proteins. The first use of protease in pig nutrition was reported by Cunningham and Brisson (1957) where they predigested feed ingredients with the enzymes, but no improvement of growth performance was observed. Recent studies reported supplementation of protease. Supplementation of protease improved AID of nitrogen in nursery (Guggenbuhl et al. 2012), growing (Wang et al. 2011b) and finishing pigs (Mc Alpine, 2012b). There is evidence that protease hydrolyze glycinin and B-conglycinin of soybean and improve growth performance of nursery pigs (Wang et al., 2011a).
Conclusion and Implications

Arabinoxylans and galactosides are the main indigested components of corn and soybean meal, respectively. Therefore, supplementation of xylanase and galactosidase can potentially improve nutrient digestibility of corn-soybean meal based diets. There is enough evidence to support phytase supplementation to improve phosphorus digestibility from corn-soybean meal based diets. However, more research is necessary to clarify the phytase effect on protein and energy digestibilities. The few reports about protease supplementation indicate the potential benefits on protein digestibility. However, more research is necessary to study the amino acid digestibility in order to adjust the diet formulation according to the nutritional requirement of pigs. Furthermore, little is known about combinations of enzymes and how protease could interact with other enzymes. The adequate supplementation of feed enzymes depends on the estimation of energy and protein digestibilities. Most of the studies demonstrated benefits of feed enzymes on complex diets and more information is necessary about supplementation of feed enzymes to specific feedstuffs.

Literature cited