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Effect of fiber source and enzyme addition on the apparent digestibility of nutrients and physicochemical properties of digesta in cannulated growing pigs

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ABSTRACT

To evaluate the effect of fiber source and enzyme addition on the nutrient digestibility of cereal by-product based diets, wheat bran and soybean hull were used as sole fiber source to prepare 2 basal diets (wheat bran-based diet, WB and soybean hull-based diet, SH). After supplementing an enzyme mixture in the 2 basal diets, one of 4 test diets (WB and enzyme added WB, SH and enzyme added SH) was allotted to 2 of 8 male growing pigs that were surgically fitted with T-shape cannulas at proximal duodenum and distal ileum simultaneously, according to a 4×4 Latin square design. Duodenal and ileal digesta and feces were collected to measure the coefficient of apparent digestibility of crude protein (CP), ether extract (EE), starch, organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), non-starch polysaccharides (NSP) and its constituent sugar residues at proximal duodenum (CADD), distal ileum (CAID) and total digestive tract (CATTD) of pigs, and to evaluate their physicochemical properties as well. The result indicated that the digestion of most of nutrients including fiber and NSP fractions commenced with considerable extent prior to proximal duodenum in all diets. The wheat bran shown higher CAID of NDF ($P < 0.001$) and ADF ($P = 0.001$), and CATTD of CP ($P < 0.001$) and EE ($P = 0.005$) than soybean hull. Despite fiber source did not affect CATTD of NSP fractions, the total NSP ($P < 0.001$), arabinose ($P = 0.030$), xylose ($P < 0.001$) and glucose ($P = 0.001$), and insoluble NSP ($P < 0.001$), arabinose ($P < 0.001$) and glucose ($P = 0.003$) of wheat bran were more digestible at terminal ileum than that of soybean hull. Enzyme addition improved the CADD of OM ($P = 0.002$), ash ($P = 0.045$), NDF ($P = 0.004$) and ADF ($P < 0.001$); and the CAID of CP ($P = 0.006$), EE ($P = 0.001$), OM ($P = 0.029$), ash ($P = 0.003$), NDF ($P = 0.006$) and ADF ($P = 0.002$), but did not affect the CATTD of other gross nutrients. The CADD and CAID, but not CATTD, of most of NSP fractions and their constituent sugar residues were affected by enzyme addition. The fiber source and enzyme addition also showed influence on digesta viscosity, water binding capacity (WBC) and pH value of digesta and feces. In conclusion, dietary fiber source influenced the digestion of nutrients at different segments of pig digestive tract with higher CATTD of CP and EE of wheat bran than that of soybean hull.

Abbreviations: ADF, acid detergent fiber; CADD, coefficient of apparent duodenal digestibility; CAID, coefficient of apparent ileal digestibility; CATTD, coefficient of apparent total digestive tract digestibility; CP, crude protein; DE, digestible energy; DM, dry matter; EE, ether extract; INSP, insoluble non-starch polysaccharides; NDF, neutral detergent fiber; NSP, non-starch polysaccharides; OM, organic matter; SH, soybean hull-based diet; SHE, soybean hull-based diet with enzyme; SNSP, soluble non-starch polysaccharides; ST, ratio of solubilized NSP to TNSP; TNSP, total non-starch polysaccharides; WB, wheat bran-based diet; WBC, water binding capacity; WBE, wheat bran-based diet with enzyme.

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Exogenous NSP-degrading enzyme accelerated the degradation of fiber and NSP fractions, and promoted nutrient digestion in the fore-gut of pigs. It is of high potential to improve the efficiency of energy and nutrient utilization of fibrous cereal by-products.

1. Introduction

Increasing the inclusion of cereal by-product in pig feed can not only decrease the cost of pig production but also alleviate the tension between demand and supply in grain market, especially in parts of the world with large population and limited tillable land (OECD-FAO, 2015). However, cereal by-products, such as brans, hulls, and millers' offal, primarily consist of aleurone, testa and pericarp of grain kernel with high dietary fiber content (Sauvant et al., 2004). Although it has been suggested that pigs enable themselves moderately to adapt to high fiber diets, negative impact of fiber on nutrient digestibility and performance becomes apparent when high level of these by-products are used in pig diet (Reece, 2004; Wilfart et al., 2007). The dietary fiber itself cannot be hydrolyzed by pig digestive enzymes. In addition, it impedes the digestion and absorption of other nutrients, either in fibrous ingredient or in other dietary components, by means of physical restriction of cell wall and increasing the viscosity and water binding capacity (WBC) of digesta. However, with the help of gastrointestinal microflora which can degrade part of indigestible non-starch polysaccharides (NSP) and convert them into pig absorbable volatile fatty acids, dietary fiber can become one of key energy sources in pig feed, especially for adult pigs (Bach Knudsen, 2011).

To eliminate the negative effect of dietary fiber and improve the nutrient availability of fibrous diet, a number of strategies have been explored. It has been suggested that supplementation of NSP-degrading enzymes, whether in combination with other techniques or not, is of high potential (De Vries et al., 2012). The NSP-degrading enzymes were initially used in non-corn cereal based poultry diets with widely recognized success. However, the available published data on its application in pigs fed cereal by-product based diets are limited and varied in results (Högberg and Lindberg, 2004; Kiarie et al., 2007; Nortey et al., 2007; Jakobsen et al., 2015; Pedersen et al., 2015).

Dietary fiber in cereal is a collection of cell wall NSPs, including cellulose, hemicellulose, pectin, and lignin (Bach Knudsen, 2001a,b). It has been shown that fibers from various cereals differ in their constituent NSP fractions and chemical composition, and therefore would differ in their accessibilities to the added enzymes. The activity of exogenous NSP-degrading enzyme can be influenced by local pH value, and endogenous cation and enzyme secretion along pig digestive tract (Svihus, 2010). The retention time of chyme in different segments of pig digestive tract, which is affected by both the amount and the type of dietary fiber (Stanogias and Pearce, 1985; Wilfart et al., 2007), might play an important role in the degradation of fiber fractions and in the digestion and absorption of other nutrients of fibrous diet, either by added exogenous enzymes or by gastrointestinal flora. It is reasonable to postulate that the interactions between dietary fiber fractions and pig gastrointestinal conditions would impose crucial impacts on nutrient availability and effectiveness of exogenous enzyme in cereal by-product based diets. However, information on these interactions is limited, especially in the stomach, the harshest condition where both fiber and exogenous enzyme have to go through.

In present study, one of two by-products with distinct chemical composition, i.e., wheat bran (rich in arabinoxylan, representing gramineous grain by-products) and soybean hull (typical leguminous testa with high level of cellulose and pectin), were used as sole fiber source in test diets to eliminate any possible interference from other dietary ingredients. Pigs fitted with a T-shape cannula at anterior duodenum and at distal ileum enabled continuous collection of sample from the two digestive tract segments of the same pig, respectively. With the help of these techniques, it was expected that the results from current experiment would provide helpful quantitative information to improve our understanding of the effect of fiber source and enzyme supplementation on nutrient digestion of growing pigs fed fibrous diets.

2. Materials and methods

2.1. Experimental diets

Wheat bran and soybean hull were obtained commercially from local feed company (COFCO Eastocean Oil & Grains Industries (Zhangjiagang) Co. Ltd, Jiangsu, China) and their crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and essential mineral element content were analyzed prior to feed formulation. Two basal diets of similar NDF, digestible energy (DE) and other essential nutrient contents, i.e., wheat bran-based diet (WB) and soybean hull-based diet (SH), were formulated using either wheat bran or soybean hull as sole plant fiber sources and enriched by adding corn starch, fish meal, spray-dried plasma protein, soybean oil, crystalline amino acids, essential minerals and vitamins to meet the recommended nutrient requirements for 20–35 kg body weight lean-type growing pigs (Ministry of Agriculture of China, 2005). A premix of Cr_2O_3 (1:3 W/W of starch, providing 3.0 g Cr_2O_3/kg Feed, as-fed basis) was included in each diet as an inert marker for digestibility calculation. After pelletized through a 3.0 mm flat die (<85 °C, ZLDP-120S, Gemco Energy Machinery Ltd, Anyang, China), an enzyme cocktail which provided 1000 U cellulase, 5000 U xylanase and 1500 U phytase for per kilogram basal diets (as-fed basis) was sprayed onto half of each basal diet and air-dried, respectively. A total of 4 diets were used in this experiment, namely, WB, SH, and enzyme added contrasting diets (WBE and SHE). The enzyme cocktail

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