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Effect of anti-nutritional factors of oilseed co-products on feed intake of pigs and poultry

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ABSTRACT

Soybean, canola, camelina and flaxseed co-products from the oilseed industry are used to formulate pig and poultry feeds. However, these co-products contain various anti-nutritional factors (ANF). The major ANF in soybean and potentially co-products is trypsin inhibitor (TI). Pigs and poultry can tolerate TI levels up to 3.00 and 4.00 TIU/mg in the diet, respectively. Solvent-extracted soybean meal has low TI activity (<14.0 TIU/mg); most TI is destroyed during the desolventising-toasting stage of oil extraction. Thus, inclusion of soybean meal in diets for pigs and poultry does not affect feed intake and nutrient utilization. However, soybean or expeller-pressed soybean co-products can contain considerable amounts of TI (>50.0 TIU/mg), implying that the raw soybean or expeller-pressed soybean co-products should be sufficiently heated to inactivate most of the TI before feeding. The major ANF in canola co-products are glucosinolates. Poultry and pigs can tolerate up to 2.00 and 2.50 μmol/g of glucosinolates in their diets. Total glucosinolate content in most canola co-products is moderate (<10 μmol/g). Thus, while co-products from modern canola cultivars do not affect feed intake, dietary inclusion of original canola co-products (with total glucosinolate content of ≤35 μmol/g) reduced feed intake of grow-finish pigs by 80 g/day and of broiler chickens in the starter phase by 4 g/day. Glucosinolates and TI are the major ANF in camelina co-products. In camelina co-products, total glucosinolate content ranged from 34.4 to 36.3 μmol/g and TI activity from 12 to 28 TIU/mg. Camelina co-products are not solvent-extracted and thus have high TI activity. Dietary inclusion of camelina co-products reduced feed intake of broiler chickens in the starter phase by 3.4 g/day. Cynogenic glucosides are the major ANF in flaxseed co-products. Flaxseed meal contained 127 mg cynogenic glucoside/kg. Dietary inclusion of flaxseed meal reduced feed intake by poultry by 3.4 g/day. In conclusion, soybean, canola, camelina and flaxseed co-products contain various ANF that reduce feed intake by pigs and poultry.

Abbreviations: AA, amino acids; AID, apparent ileal digestibility; ANF, anti nutritional factors; ATTD, apparent total tract digestibility; BW, body weight; CCK, cholecystokinin; EPCM, expeller pressed canola meal; NDF, neutral detergent fibre; NSP, non-starch polysaccharides; SBM, soybean meal; SECM, solvent extracted canola meal; TI, trypsin inhibitor; TIU, trypsin inhibitor units.

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1. Introduction

Co-products from oilseed crushing plants to obtain oil for food and biofuel industries are the most widely used amino acid (AA) sources in pig and poultry diets. Oil is obtained from oilseeds by solvent extraction, expeller pressing or cold pressing (Spragg and Mailer, 2007). The most used oilseed co-products for formulating pig and poultry diets are from soybean and rapeseed/canola (Woyengo et al., 2014a) with 200 and 40 million MT produced globally, respectively (USDA, 2015). Camelina and flaxseed co-products are also used to formulate pig and poultry diets in temperate regions.

Soybean, canola, camelina and flaxseed co-products contain anti-nutritional factors (ANF) that can limit dietary nutrient utilisation. Thus, the characterization of the ANF present in these co-products, and their effects and underlying mechanisms on nutrient utilisation is critical to optimise utilisation of these oilseed co-products in formulating pig and poultry diets. Understanding the mechanisms is important for developing targeted interventions. Oilseed co-product inclusion in pig and poultry diets can be cost effective, but ANF are the main deterrent to greater dietary oilseed co-product inclusion, and therefore, lower feed cost.

The major ANF present in the fore-mentioned oilseed co-products are: trypsin inhibitors (TI; in soybean and camelina co-products Budin et al., 1995; Jezierny et al., 2010), glucosinolates (in canola and camelina co-products Khajali and Slominski, 2012; Kahindi et al., 2014) and cynogenic glucosides (in flaxseed co-products Cressey et al., 2013). The nutritional value of soybean, canola and camelina co-products for pigs and poultry has been reviewed (Bell, 1993; Jezierny et al., 2010; Khajali and Slominski, 2012; Woyengo et al., 2014a). However, the specific effects and underlying mechanism of the ANF in the co-products on feed intake by pigs and poultry have not been reviewed. The objective of this paper is to review results from studies on the effects of TI, glucosinolates and cynogenic glucosides on feed intake by pigs and poultry, mechanisms by which they reduce the feed intake. Also, areas that need further research with regard to the effects of ANF on feed intake, and potential uses of ANF as nutraceuticals for pigs and poultry are suggested. The effects of the ANF on pig and poultry reproduction or egg production by laying hens were beyond the scope of this review.

2. Oilseed co-products

The soybean (*Glycine max*) co-product solvent extracted soybean meal (SBM) and full-fat soybean products are the most widely fed sources of protein in swine and poultry feeds. Rapeseed is an oilseed crop of *Brassica* family that is grown in temperate regions where soybean does not grow well. Canola is a crop that was developed from rapeseed; it contains low levels of glucosinolates, and is grown mainly in North America and Australia. The two most commonly grown species of canola include *Brassica napus* and *Brassica juncea*. The *B. napus* is conventional canola, whereas the *B. juncea* is a newly utilised species that is better adapted to the warmer and drier areas of the Great Plains of North America. To be termed "canola" the canola co-products must contain $\leq$35 μmol glucosinolates/g (Canola Council of Canada, 2009). Rapeseed and canola co-products are the second most widely fed sources of protein in swine and poultry feeds after soybean co-products.

Camelina (*Camelina sativa*) utilisation is relatively new among oilseed crop of the *Brassica* family. The production of camelina in temperate regions is projected to increase because it is more tolerant to frost and drought than canola (Wittkop et al., 2009) and its oil has a greater content of omega-3 fatty acids than canola oil (Karvonen et al., 2002). Camelina is an attractive feedstock for biodiesel, because biodiesel production from camelina is associated with lower GHG emissions than from soybean and canola (Li and Mupondwa, 2014). The availability of camelina co-products for livestock feeding is also projected to increase due to increased bio-industrial uses of its oil.

Flaxseed (*Linum usitatissimum*) is a temperate oilseed crop grown for human food, livestock feed and industrial fibre production (Singh et al., 2011). The seed yields oil, protein and dietary fibre, whereas the stem yields fibre for industrial purposes (Singh et al., 2011). Flaxseed oil, like camelina oil, has a greater content of omega-3 fatty acids than canola oil (54 vs. 9%; NRC, 2012). The omega-3 fatty acids that remain in co-products may have beneficial effects on immune function (Babu et al., 1997; Taranu et al., 2014). Flaxseed co-products from flaxseed crushing plants to obtain oil for food industry are feed to livestock.

3. Trypsin inhibitors

Trypsin inhibitors occur naturally in many plant seeds. Especially, leguminous seed (Table 1) contain appreciable amounts of TI. The TI can be classified into 2 major classes; Kunitz trypsin inhibitors and Bowman-Birk trypsin/chymotrypsin inhibitors (Pusztai et al., 2004). Kunitz trypsin inhibitors are the major TI found in soybean, whereas Bowman-Birk trypsin/chymotrypsin inhibitors are the major TI found in grain legumes such as field pea and lentil (Jezierny et al., 2010). Among the TI, Kunitz is thermo-sensitive, and hence it can be inactivated by heat treatment.

Dietary TI bind to pancreatic digestive enzymes trypsin and chymotrypsin in the gastrointestinal tract to form inactive complexes, leading to reduced AA digestibility (Jezierny et al., 2010). Inactivation of trypsin and chymotrypsin increases secretion of these enzymes into the gastrointestinal tract via a negative feedback mechanism (Hara et al., 2000; Morisset, 2008). Increased pancreatic enzyme secretion and required metabolic activity increases pancreas size (Pacheco et al., 2014). Increased metabolic activity in visceral organs such as the pancreas increases their energy expenditure at the expense of growth (skeletal tissue deposition; Ferrell, 1988). Thus, TI can reduce nutrient digestibility and growth rate of pigs and poultry by binding trypsin and chymotrypsin.

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