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High-fiber diets for fattening pigs

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ABSTRACT

Objective: To establish the feasibility and benefits of implementing high-fiber diets for pigs.

Design/Methodology: A literature review of the practical application of pig diets with the inclusion of fibrous ingredients was carried out.

Results: The formulation of high-fiber diets for pigs maintains or improves productive performance and provides additional gut health benefits.

Study Limitations/Implications: Lack of information about the net energy and amino acid digestibility values of fibrous ingredients limits the proper formulation of pig diets.

Findings/Conclusions: The inclusion of high-fiber ingredients in pig diets can partially replace traditional ingredients, consequently reducing costs and providing health benefits.

Key words: forages, alternative ingredients, gut health.

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INTRODUCTION

The need to reduce pig feed costs and take advantage of special-priced ingredients has encouraged the use of high-fiber products and by-products from the agricultural industry (DDGs, hulls, bran, alfalfa, etc.). Overall, high-fiber ingredients are considered to have a low nutritional value in pig diets, given their lower energy and amino acid (AA) concentration in comparison with feeds with high starch or protein content and they have been attributed detrimental effects on the diet digestibility and productive performance (Agyekum and Nyachoti, 2017).

However, the use of dietary fiber in pig diets improves nutrient use and energy metabolism (Agyekum and Nyachoti, 2017), as well as the modulation of gut microbiota which leads to a reduction in antibiotic use, consequently improving productive performance and welfare (Han *et al.*, 2020).

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The effects of the source, type, and level of fiber inclusion on the gut health and productive performance of pigs must be identified (Agyekum and Nyachoti, 2017). Given the challenges involved in achieving predictable and profitable productive performance, the objective of this review was to establish the feasibility and benefits of implementing high-fiber pig diets.

Dietary fiber

Dietary fiber (DF) has attracted an increasing attention in pig nutrition. It is divided into soluble fiber (SF) and insoluble fiber (IF). Although it has traditionally been considered that DF can reduce nutrient digestibility and inhibit energy deposition, a higher amount of high-fiber feeds has begun to be used in pig diets (Li *et al.*, 2021), as a result of the potentially lower feed cost and DF nutritional assessment (Han *et al.*, 2020). The proper timing for the incorporation and inclusion of exogenous enzymes in the diet in order to reduce the anti-nutritional DF effects has also been assessed. However, the regulatory effect of DF in pigs is unclear; therefore, the wide range of fiber sources and diet composition must be taken into consideration (Li *et al.*, 2021).

In traditional studies about pig nutrition, DF was considered an antinutritional component, because it cannot be broken down by endogenous digestive enzymes and it can reduce nutrient digestibility (Jha and Berrocoso, 2015); these effects are associated with a detrimental effect on productive performance. Therefore, the DF ratio in commercial diets is minimal, resulting in the underuse and waste of high-DF ingredients.

Although pigs cannot digest DF, it can be fermented by gut microbes —mainly by bacteria in the large intestine. It can then be metabolized into volatile fatty acids (VFA: acetate, propionate, and butyrate), producing up to 30% of maintenance energy (Varel and Yen, 1997). VFA production and proportion varies according to the source and amount of fiber in the diet and the age/growth stage of the pig (Jha and Berrocoso, 2015).

Consequently, the sources and type of fiber must be identified and characterized, since soluble and insoluble components, viscosity, and other characteristics can modify the nutrients utilization and the development of the gastrointestinal tract (Hung *et al.*, 2020). Lyu *et al.* (2018) found a higher digestibility in diets with feeds whose SF concentration was higher than their IF. Feeds showing different SF/IF ratios could generate different productive responses. In addition, although the amount of IF leads to shorter digesta retention time, it may benefit the microbiota by reducing the adhesion of pathogenic bacteria to the mucosa (Molist *et al.*, 2014).

Overall, the risk posed by the inclusion of higher-DF content ingredients can be managed through formulations that take into consideration net energy and standardized ileal digestibility of amino acids (AA), exogenous enzymes addition, and feed processing.

Productive performance

High-fiber diets are commonly considered to cause a decrease in daily weight gain (DWG) and inhibit lean meat deposition in pigs (Wang *et al.*, 2016), mainly as a result of the decreased nutrient digestibility and energy deposition induced by the DF amount. Although Agyekum and Nyachoti (2017) mention that —whether the ingredients are rich in soluble or insoluble fiber or not— most studies show that DF does not impact productive performance (under certain assumptions).

The perceived impact of pig diets that include fibrous ingredients has changed and several authors point out that the said ingredients do not always have a negative response. Experiments conducted at the University of Alberta, Canada found that productive performance similar to that of pigs fed corn/soybean meal-based diets can be achieved with the inclusion of Distiller's Dried Grains with Solubles (DDGS) and canola meal (CM) in the diet of pigs at weaning (Landero *et al.*, 2013). In regards to finishing pig feeding, Jha *et al.* (2013) observed that similar productive performance of pigs fed lower fibrous ingredients can be obtained with the inclusion in the diet of up to 50% by-products (CM, flaxseed, and DDGS). It is important to note that in the abovementioned experiments, diets were formulated with an equal content of net energy and digestible AA. However, when Smit *et al.* (2014) assessed the CM inclusion (from 6% to 24%) in diets including 15% DDGS, they observed that increasing CM inclusion decreased gross energy digestibility, which could have reduced feed intake (FI), DWG, and feed efficiency.

Chen *et al.* (2013) attribute a decrease in nutrient digestibility as a result of the inclusion of alfalfa (one of the most commonly used forages in pig diets), mainly as a result of the presence of indigestible components. Chen *et al.* (2013) likewise assessed growing pigs whose diet included different levels of alfalfa (5%, 10%, and 20%) and wheat bran (5%) (13% NDF and 10% ADF; 15% NDF and 12% ADF and 19% DF and 14% ADF, respectively) and found that the inclusion of 5% alfalfa meal did not affect nutrient digestion and energy; meanwhile, acetate, propionate, and VFA concentration increased proportionally to the alfalfa concentration in the diet. Therefore, the authors inferred that alfalfa SF and IF play differential roles in nutrient digestion, which explains the variation in the intestinal flux of nutrients.

Chicory (*Cichorium intibus*) is a forage used in cattle production systems, with few reports about its use in pig feeding. The inclusion of chicory (4, 8, or 16%) in pig diets did not affect FI, DWG, or feed efficiency (Ivarsson *et al.*, 2011). The gradual inclusion (10 to 30%) of alfalfa and chicory in the diet, from the growing (40-60 kg) to finishing (80-100 kg) stages, obtained a similar DWG to that obtained with pigs fed grain-based diets. However, FI increased and feed efficiency decreased as the DF content increased (González *et al.*, 2020). It is worth mentioning that DF intake was similar in the chicory and alfalfa diet; nevertheless, the higher-SF intake in the alfalfa diet was associated with a negative decrease in productive parameters, since digestibility was higher in diets with ingredients whose concentration of SF was higher than IF (Lyu *et al.*, 2018). Likewise, Leivas (2017) reported that pigs fed alfalfa and chicory (20 and 30%) recorded a lower final weight; this difference was greater for alfalfa; although it did not have adverse effects on FI.

Wheat bran is one of the by-products commonly used in pig diets and it is characterized by its high fiber content. Therefore, it will be briefly addressed in this literature review, given the large amount of information available for this ingredient. Adding wheat bran to the feed of weaning pigs improves their gut health and modulates the activity and composition of their gut microbiota; however, its implementation in pig feeding shows that it is limited by its large amount of insoluble fiber, which is very resistant to natural degradation processes in the gut (Zhao *et al.*, 2018ab).

Sunflower meal is a fibrous by-product that can also be used as a good source of protein. On the one hand, Carellos *et al.* (2005) found that up to 16% sunflower meal can be included in the diet of finishing pigs without significant negative effects on productive performance. On the other hand, Cornescu *et al.* (2021) assessed different levels of crude fiber (3.5, 6.5, and 7.5%), adding alfalfa (4 and 6%) and sunflower meal (12 and 18%) to the diet of finishing pigs. Productive performance was not affected by either the source or content of the fiber; however, lean meat accumulation decreased.

High-fiber diets have also been used to reduce growth rate (and consequently energy density), in order to delay the market entry of pigs. Interestingly, research data show that the decrease in energy density in diets (from 3.32 to 2.86 Mcal of ME) did not result in a decrease in productive performance (Helm *et al.*, 2021a). Likewise, feeding finishing pigs with 12, 22, or 32% soybean hulls (SH) (15% NDF and 3.14 Mcal of ME; 20% NDF and 3 Mcal of ME; and 25% NDF and 2.86 Mcal of ME, respectively) caused a reduction in energy, without affecting productive parameters (Helm *et al.*, 2021a). Along with the reduction of energy, the inclusion of 20% SH (26% NDF and 2.99 Mcal of ME; Mauch *et al.*, 2018), 12 or 32% (13% NDF and 3.11 Mcal of ME; 23% NDF and 2.83 Mcal of ME, respectively; Helm *et al.*, 2021b) in the diets of finishing pigs limited the intake of diets with 20% and 32% SH, without negative effects on feed efficiency and DWG.

Carcass yield

High-NDF and ADF diets are generally associated with reductions in carcass yield (Mauch *et al.*, 2018). There is evidence that DF intake (10-30% chicory) increased digestive organ size and decreased carcass yield (Ivarsson *et al.*, 2011; Gonzalez *et al.*, 2020). Likewise, increasing the CM inclusion in the diet reduced carcass weight (Jha *et al.*, 2013).

When pigs are fed high-DF diets, the volume and weight of the viscera increase, resulting in higher energy and AA requirements for these organs. As a potential solution, high-DF diets that respect or increase the recommended net energy and digestible AA value could be formulated (Jha *et al.*, 2103). There is evidence that increasing DF does not impact carcass yield, as long as the AA concentration in the diet is not modified. Inclusion of up to 24% CM in diets including 15% DDGS affected neither carcass weight and yield, nor lean meat gain (Smit *et al.*, 2014). Likewise, adding up to 16% sunflower meal to the diet of finishing pigs did not modify carcass characteristics and performance (Carellos *et al.*, 2005).

Researchers agree that including more dietary fiber does not increase the thickness of subcutaneous fat, which is another important aspect to consider (Smit *et al.*, 2014; González *et al.*, 2020).

Gut health

One of the objectives of using high-DF in pig diets is to reduce the use of antibiotics and improve gut health (Helm *et al.*, 2021c). DF benefits the gastrointestinal system, improving the growth (DWG and feed efficiency) of pigs subjected to health challenges or stress

(Zhao *et al.*, 2018a). Including wheat bran in the diet of piglets positively modified their gut microbiota and butyrate production, consequently promoting gut health (Zhao *et al.*, 2018a). Likewise, piglets supplemented with lactoreplacer (0.2% pectin) had better health, DWG, and feed digestibility (Fleming *et al.*, 2020).

DF helps to decrease the incidence or severity of clinical pathological conditions, as a consequence of the relation of fiber with microbiota and the development of gastrointestinal diseases. Pigs fed diets containing low, medium (10% maize DDGS and 5% beet pulp) and high fermentation (10% beet pulp and 10% starch) fiber were subjected to a sanitary challenge with *Brachyspira hyodysenteria*. The percentage of pigs that developed clinical signs of dysentery was 85% (low fermentation fiber diet), 46% (medium fermentation diet), and 15% (high fermentation diet) (Helm *et al.*, 2021c). On the one hand, supplementing the diet of growing pigs with 0.5% inulin for 21 days increased cecal villi height and VFA production and decreased the apoptotic cell number and inflammatory cytokine secretion in the ileum and cecum. On the other hand, it also reduced the *Proteobacteria* concentration and increased the *Lactobacillus* concentration (He et al., 2021a). For their part, Wang *et al.* (2020) highlight that 2.5 g/kg of inulin reduced the *Echerichia coli* count in the colon, improving the functioning of the intestinal barrier (Wang *et al.*, 2020).

DF in pigs suppresses inflammatory response, improves morphology and intestinal barrier functions, and leads to beneficial changes in microbial fermentation (Wang *et al.*, 2020). According to Jarrett and Ashworth (2018), digesting fiber has beneficial effects on gut function and structure as a result of the VFA production. These changes include villus height and crypt depth (Liang *et al.*, 2014), as well as an increased antioxidant capacity of the intestine of pigs (Weber and Kerr, 2012). Hees *et al.* (2019) assessed the effect of supplying piglet diets with arabinoxylan and purified cellulose, observing that it led to an increase in the length and weight of the large intestine, as well as its VFA concentration.

Supplementation during gestation is another strategy to take advantage of the inclusion of DF, in order to improve gut health and, at the same time, obtain litter benefits. In contrast with a low-DF diet, providing a high-DF diet to pregnant sows led to a significant increase in the crypt depth of the ileum of newborn piglets. Similarly, the higher levels of acetate and isobutyrate that were found in the intestinal contents of the colon in piglets might be correlated with a better gut development (He *et al.*, 2021b). Finally, Li *et al.* (2020) point out that the incorporation of DF in the diet of pregnant sows improves the antioxidant capacity of piglets and reduces proinflammatory factors, which might be related to a positive modulation of the gut microbiota.

Adaptation

The progressive inclusion of DF enables a physical adaptation of the tract, through the enlargement of the stomach and the colon, but this adaptation period (AP) reduces carcass yield (Gonzalez *et al.*, 2020). The pig intestine needs a diet AP with different fiber types or levels, in order to gradually stabilize and increase DF digestibility (Zhao *et al.*, 2018b), since the AP duration affects the bacterial community and VFA profile in the pig caecum (Luo *et al.*, 2017). The AP to high-SF sugar beet was shorter than for pigs fed high-IF wheat bran, indicating that gut microbes adapted more readily to SF (Castillo *et al.*, 2007).

Growing pigs required more time to adapt to high-DF diets formulated with wheat bran, a phenomenon that is related to the gut microbiota activity (Zhao *et al.*, 2018ab), likely as a result of the 14-21-day period required to establish microecological homeostasis in the hindgut of pigs at weaning that were fed high concentrations of wheat bran (Castillo *et al.*, 2007).

CONCLUSIONS

General knowledge about the nutritional contribution and production benefits of including high levels of fiber in pig diets could help to predict production performance, meat quality, and health benefits, and to stop considering fiber as a negative aspect of diets, allowing the partial substitution of traditional ingredients with high-fiber feeds and consequently lowering their cost.

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