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Dietary fiber and animal health: A mini review

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ABSTRACT
This mini review describes dietary fibers, their source and compositions. It explores the importance of fiber in the animal diet, health benefit and how fiber contributes to the production of healthy animals in post antibiotics era. The review also discusses fiber fermentation, role in nutrient digestion, enzyme production and how the gut microbiota responds to a selection of fibers. And the components of fiber that increases microbiota which are commensal to the mucus and epithelium of gut. Lastly, recommendations are made on how dietary fiber could be used to achieve maximum advantages in terms of nutrient utilization, performance, and gut health in both monogastric and ruminant animals.

Keywords: dietary fiber, animal nutrition, gut bacteria, gut health

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Introduction

Dietary fiber and their compositions

The ban and regulation of using antibiotics as a growth promoter and to minimize the burden of sustainable feedstuffs for animals, several co-products and feed additives (probiotics, prebiotics, enzymes, phytogenic products, etc.) are considered (Jha et al., 2020). Among them, dietary fiber has received a considerable amount of attention in recent years as fiber components demonstrating beneficial effects in both monogastric (mainly swine and poultry) and ruminant animals. Most commonly fibers are added to the diet, however, fibers having prebiotic function can be delivered via in ovo technology (Das et al., 2021). Broadly, dietary fiber is categorized into two groups that are soluble and insoluble (figure 1)., Soluble fiber, which includes β-glucans (found in barley and oat), arabinoxylans (in wheat and, rye), and pectin (in fruits, and sugar beet pulp), increases intestinal viscosity and decreases the passage rate which helps in nutrient absorption, promote growth performance, and improve gut health which ultimately improves the animal's overall health (Jha & Mishra, 2021). On the other hand, insoluble dietary fiber is found in oat hulls and sunflower hulls which increases chyme retention time in the upper part of the gastrointestinal (GIT), and consecutively, stimulates gizzard development and improve the digestibility of starch and lipids (Jiménez-Moreno et al., 2019). The soluble fiber is fermented more efficiently than insoluble fiber however soluble and insoluble fiber fermentation vary depending on temperature, water content, buffer as the solvent, and fiber to the solvent ratio (Dhingra et al., 2012). Dietary fiber, by recent definition, includes non-starch polysaccharides (NSP), resistant starch (RS), non-digestible oligosaccharides (NDO), and non-carbohydrate polyphenolic ether lignin (Lunn & Buttriss, 2007). The main polysaccharides of non-starch polysaccharides are cellulose, and a wide

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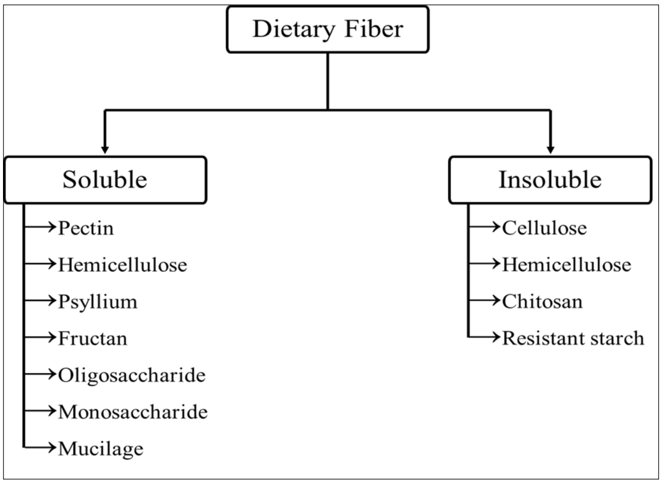

Figure 1. Classification of dietary fiber based on solubility in water . Modified from (Jha and Mishra, 2021).

variety of non-cellulosic polysaccharides (NCP); β-glucan, arabinoxylan, xylans, xyloglucans, and pectic substances to mention the major ones (Knudsen, 2014). The dietary fiber content of the feedstuffs varies widely among cereals generally having a lower concentration in cereals than in legumes and protein-rich crops, and generally, there is a higher concentration of dietary fiber in co-products from cereals and the agro and food industries (Knudsen, 2016). The fiber content of a diet is usually expressed in terms of neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Knudsen, 2016). Acid detergent fiber includes cellulose and lignin as the primary components and concentrations of ADF and lignin are correlated more with digestibility than intake (Van Soest et al., 1991). Neutral detergent fiber includes cellulose, hemicelluloses, and lignin fractions of feeds and is more highly correlated with feed volume and chewing activity than ADF or crude fiber (Jung et al., 1997).

Dietary fiber in poultry nutrition

The addition of fiber in the poultry diet is in trend to utilize non-conventional feedstuffs and contribute as an alternative to the antibiotic in the post-antibiotic era (Lillehoj et al., 2018). The antibiotic is a synthetic, microbial agent which is used widely in poultry to control and treat disease and infection. The researcher found that the inclusion of fiber in the poultry diet help to improve growth performance and overall health (Ali et al., 2021; Mehdi et al., 2018). The co-products of conventional feedstuffs namely wheat bran, sunflower meal, fuzzy cottonseed, oat hulls, soybean hulls, and pea hulls are rich in fiber, and adding these fibers to the poultry diet improves weight gain and feed efficiency (Jha & Mishra, 2021). Considering the laying bird feeding of alfalfa during molting may reduce the stress of egg production (Landers et al., 2005).

Dietary fiber has a great impact on the length and weight of the gastrointestinal tract which helps in the proper function of the gizzard, ultimately improves gut motility, and reduces the risk of gut pathogens and gut diseases like salmonellosis, coccidiosis, and so on (Jha & Mishra, 2021). It may influence epithelial morphology which depends on the type of dietary fiber and its level of inclusion, age of the bird, and site of the intestinal tract. Dietary fiber added to the diet increases the absorption of the mucosal surface of the small intestine by increasing villi height, and mucus secretion (Mtei et al., 2019). Fibers in diets also improve the diversity of the microbiota and stimulate intestinal activities whereas many soluble fibers function as prebiotics which promotes the beneficial bacteria in the gut and induce the production of short-chain fatty acid (SCFA) (Liu et al., 2021). While insoluble fiber shows the preventive method in cannibalism and feather pecking (Mens et al., 2020). Poultry has both innate and acquired immune systems, the dietary fiber can be used as a cost-effective nutrient to modulate the poultry immune system (Kheravii et al., 2018). With its high fiber content, alfa-alfa has been shown to have a very long transit time in the gastrointestinal tract of chickens (Jiang et al., 2012). Similarly, the inclusion of polysavone (Alfalfa extract) in the diet also increases serum Anti-Newcastle disease virus (Dong et al., 2007). The arabinoxylan from wheat bran increases the goblet cells which produce a protein barrier factor that protect intestinal epithelial cells (Jha & Mishra, 2021).

Dietary fiber in swine nutrition

Globally, a diverse range of fiber-rich feed ingredients is added to swine diets. They include wheat bran, wheat middling, oat husk, maize bran, rye bran, sugar beet pulp and fiber, corn cobs and bran, distillers grains, rapeseed, soya bean hulls, kiwi fruit, and chicory (Jarrett & Ashworth, 2018). Dietary fiber, usually defined as the indigestible portion of food derived from plants, forms a key component of many swine diets. Although not fully digested, dietary fiber can affect different physiological processes, both directly (e.g. by gut filling) and indirectly by the production of short chain fatty acid and physiologically active co-products through fermentation in the colon (Jarrett & Ashworth, 2018).

Although these diets do not always maximize swine performance but provide effective and economical use of locally grown feedstuffs and hence contribute to sustainable production. High fiber diets fed from the beginning of the estrous cycle could have a positive impact during this maturation process (Jiang et al., 2012). It is believed that this is because the high fiber-rich diets create endocrine profiles and ovarian follicular fluid content that enhance oocyte quality (Revelli et al., 2009). Such oocytes are then more likely to form viable embryos which, potentially through epigenetic mechanisms, are expected to survive throughout gestation and as piglets (Ashworth et al., 2009). A high fiber diet is most advantageous when fed before mating (Gianaroli et al., 2012). The most likely reasoning is that the high fiber diet affects the very early stages of development of the oocyte and embryo, more than factors such as ovulation and fertilization rates.

The inclusion of dietary fibers in the swine diet is sometimes limited because of their anti-nutritive properties (Jarrett & Ashworth, 2018). These include a reduction in the digestibility of dietary energy and protein which may lead to an inadequate amino acid, particularly threonine absorption (Jarrett & Ashworth, 2018). Fiber-rich diets can reduce the post-prandial activity of the pig, including the incidence of non-feeding oral and other stereotypic behaviors (Leeuw et al., 2008). It was also found that pigs fed a high lipid, high fiber diet had lower plasma concentrations of β-hydroxybutyrate, leptin, glucose, insulin, and urea (Yde et al., 2011).

A major concern when including dietary fiber for swine is that high dietary fiber content is associated with decreased nutrient utilization and low net energy values (Lindberg, 2014). Negative impacts of dietary fiber on nutrient utilization and net energy value will be determined by the fiber properties and may differ between fiber sources (Lindberg, 2014). Positive impacts are that it stimulates gut health, increases satiety, affects behavior, and overall improves animal well-being (Lindberg, 2014). Dietary fiber plays a major role in reducing ammonia emission by the growth of beneficial gut bacteria which shifts nitrogen excretion from urea in urine to feces (Jha & Berrocoso, 2016).

Dietary fiber in ruminants

Fiber plays an important role in ruminant nutrition. Fiber is essential to maintain animal health and is required to maintain an appropriate rumen function and physiology (Zebeli et al., 2012). In ruminants, fermentation of fiber occurs in the rumen. Thus, the microbial protein that is produced, as fiber is being digested, and is available for digestion to amino acids with subsequent absorption for use by the animal (Firkins et al., 1998).

Fiber is important in the diet of ruminants because it helps to make their stomach active. Fiber added to the diet 'tickles' the ruminant's stomach to get it to stay active and digest food. Fiber stimulates rumination, chewing, and salivation. It also maintains a normal fat test, normal rumen pH, and normal rumen mat (Ishler & Heinrichs, 2016). Simplistically, the fermentation of fiber (cellulose and hemicellulose) results in the production of acetic acid in liver which is used by the ruminant animal for energy and is the primary precursor of fat in the milk (Kung, Jr, 2014). The amount and size of fiber particles(NDF should be 35% of diet and eNDF) in the diets of lactating dairy cows are important to maintaining optimal rumen function (Zebeli et al., 2008).

Lignification of the plant cell wall generally increases with increasing plant maturity and within specific forage species; increased lignification is associated with reduced digestion by interfering the digestion of cell wall polysaccharides by acting as a physical barrier to microbial enzymes (Moore & Jung, 2001). White rot fungi i.e. Phanerochaeote chrysosporium-like fungi play a primary role in fiber digestion (Susmel & Stefanon, 1993). When ruminants are fed more starch and glucose and less fiber then rumen pH starts to fall causing acidosis (Beef Cattle Research Council, 2019). If rumen pH falls below 6.0-6.2, fiber digestion in the rumen begins to decline. As rumen pH decreases, fibrolytic bacteria in the rumen become less active and fiber digestion is decreased. When ruminal pH falls below 5.8-5.9, the rumen is mildly acidic and fiber digestion in the rumen ceases completely. When ruminal pH drops below 5.2 to 5.5, animals can succumb to acidosis (Kung, Jr, 2014).

Conclusion

Dietary fiber has an important role in the complex interaction between the diet, the endogenous enzymes, the mucosa, and the commensal microflora – all of which are considered important in the assimilation of nutrients and a key component for optimal intestinal health. These include enhanced welfare through increased satiety and reduced stereotypic behaviors (like wall licking, bar biting), a reduced environmental footprint, and improved reproductive efficiency. Studies described in this review have shown both positive and negative effects of feeding a diet high in fiber to poultry, pigs, and ruminants.

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