Review Article

Review on Impact of Dietary Fiber on Poultry Performance

Aklilu Getahun*, Nebiyu Yemane

Department of Animal Sciences, Arba Minch University, Arba Minch, Ethiopia.

Abstract | The impact of dietary fiber on poultry health and performance is multifaceted, influencing organ development, digestive efficiency, growth performance, gut microbiota, and immune function. Fiber inclusion in poultry diets promotes the development of digestive organs such as the crop, gizzard, and intestines, thereby enhancing feed utilization and digestion. Insoluble fiber contributes to gizzard muscle development, while soluble fiber supports fermentation in the ceca, improving nutrient absorption and gut health. Fiber also stimulates the production of short-chain fatty acids (SCFAs) that serve as energy sources and promote gut integrity. The passage rate of food through the digestive tract is also influenced by fiber, with increased gut motility and faster passage rates helping to prevent gastrointestinal blockages. Although dietary fiber can enhance digestibility and nutrient absorption, excessive fiber levels may reduce nutrient bioavailability, particularly in energy, protein, and lipids. The presence of fiber in the diet can reduce nutrient digestibility by forming a viscous environment that hinders the breakdown of feed components, yet fermentable fiber can promote protein utilization by supporting beneficial gut microbiota. Additionally, fiber supplementation has been shown to improve gut microbiota composition by increasing the growth of beneficial bacteria and reducing the proliferation of harmful pathogens, which enhances overall poultry health. Fiber's influence extends to growth performance, as moderate levels of fiber can improve feed conversion ratios (FCR), while excessive amounts may impair growth due to decreased energy density. Furthermore, fiber-rich diets support immune function by enhancing gut barrier integrity and modulating inflammatory responses through the production of SCFAs. Fiber's ability to foster a balanced microbiota and support immune health makes it a valuable component in poultry diets, promoting both productivity and disease resistance.

Keywords | Dietary fibers, Organ development, Passage rate, Gut microbiota, Growth performance, Immune system, Nutrient utilization

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***Correspondence** | Aklilu Getahun, Department of Animal Sciences, Arba Minch University, Arba Minch, Ethiopia; **Email:** aklilugetahun853@yahoo.com
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INTRODUCTION

Dietary fiber is an essential component of a well-balanced diet, widely recognized for its beneficial effects on gut health, metabolic regulation, and overall well-being (Slavin, 2013). Traditionally, dietary fiber has been primarily associated with digestive health, particularly in the prevention and management of conditions such as constipation, irritable bowel syndrome, and colorectal cancer (Anderson *et al*., 2009). However, recent advances in nutritional science have expanded our understanding of dietary fiber's influence beyond gut health, revealing its significant role in metabolic efficiency, energy utilization, and athletic performance (Rodriguez *et al*., 2015). The growing body of evidence suggests that dietary fiber intake can modulate various physiological processes, including glycemic control, lipid metabolism, and inflammatory responses, all of which are critical factors affecting physical performance and recovery (Nieman *et al*., 2019).

Athletes and physically active individuals require optimized nutrition to enhance performance, improve recovery, and prevent fatigue or injury (Jeukendrup and Gleeson, 2019). While carbohydrates, proteins, and fats have been extensively studied in the context of sports nutrition, the role of dietary fiber in performance optimization has

received comparatively less attention (Burke *et al*., 2017). One of the primary concerns surrounding dietary fiber intake in athletic populations is its potential to cause gastrointestinal distress, particularly during high-intensity or prolonged exercise (Costa *et al*., 2017). Despite these concerns, recent studies suggest that dietary fiber, when appropriately incorporated into an athlete's diet, can contribute to sustained energy release, improved microbiota composition, and enhanced immune function, all of which are critical for maintaining endurance and resilience in physically demanding activities (Mikulski et al., 2021).

Dietary fiber can be categorized into two main types: Soluble and insoluble fiber. Soluble fiber, found in foods such as oats, legumes, and fruits, forms a gel-like substance in the gut and has been shown to slow digestion, enhance satiety, and stabilize blood glucose levels (McRorie and McKeown, 2017). Insoluble fiber, prevalent in whole grains, nuts, and vegetables, adds bulk to stool and accelerates gastrointestinal transit time, supporting digestive efficiency (Stephen et al., 2017). These properties have important implications for athletes, particularly in relation to energy balance, nutrient absorption, and hydration status. Additionally, emerging research suggests that dietary fiber exerts significant effects on the gut microbiome, leading to enhanced production of short-chain fatty acids (SCFAs) such as butyrate, acetate, and propionate, which have been linked to improved metabolic health and reduced inflammation (Moran *et al*., 2020). Given the well-established connection between inflammation and exercise recovery, the potential for dietary fiber to modulate inflammatory responses presents a promising area of exploration in sports nutrition (Clarke *et al*., 2019).

Recent studies have also examined the influence of dietary fiber on glycogen replenishment and energy availability, particularly in endurance athletes. While high-fiber diets have historically been cautioned against due to concerns over delayed gastric emptying and reduced carbohydrate absorption, newer findings suggest that strategic incorporation of fiber-rich foods can support a steady supply of energy and promote gastrointestinal adaptability to exercise-related stress (Gaskell *et al*., 2022). Moreover, fiber's role in appetite regulation and body composition is gaining traction in the field of sports science, as it may help athletes maintain optimal weight and body fat percentages without compromising performance (Vitale and Getzin, 2019).

Despite these promising findings, several gaps in the literature remain regarding the optimal quantity, type, and timing of dietary fiber intake for athletes across different sports disciplines. Individual variability in fiber tolerance, training load, and dietary patterns further complicates the ability to make generalized recommendations (Gropper et al., 2022). As research in this area progresses, it is crucial to consider the interplay between fiber intake and other dietary components, as well as the potential need for personalized nutritional strategies based on an athlete's specific physiological demands and performance goals (Thomas et al., 2016).

This review aims to provide a comprehensive analysis of recent advances in the understanding of dietary fiber's impact on performance. It will explore the mechanisms through which dietary fiber influences metabolic health, gut microbiota, energy balance, and recovery. Additionally, the review will address potential challenges associated with fiber consumption in athletic populations and present evidence-based strategies for optimizing fiber intake to enhance physical performance. By synthesizing the latest research findings, this review seeks to contribute to the evolving discourse on the role of dietary fiber in sports nutrition and inform future dietary recommendations for athletes and active individuals.

DIETARY FIBER FOR POULTRY

Dietary fiber is an essential component of poultry diets, contributing to overall health and well-being. Fiber, a non-digestible carbohydrate, plays a crucial role in maintaining the digestive health of poultry by improving gut motility and preventing issues such as constipation, impaction, and gastrointestinal disorders. It also influences the microbiome of poultry, impacting immune system function, nutrient absorption, and the overall efficiency of feed utilization.

The primary function of fiber in poultry is to enhance digestive health. Fiber, particularly insoluble fiber, adds bulk to the diet, which aids in the movement of feed through the digestive tract. This can help prevent digestive disorders like gizzard impaction, which is common in poultry, particularly when a diet is low in fiber. In addition, fiber promotes the production of gastrointestinal fluids and enzymes, which improve the breakdown of feed and nutrient absorption (Huang *et al*., 2020). Furthermore, fiber influences the gastrointestinal microbiota, helping to maintain a balanced microbial population in the gut. This balance is crucial for poultry health, as beneficial gut bacteria can improve immunity and decrease the incidence of pathogenic bacteria such as Salmonella (Mastan *et al*., 2020). A healthy microbiome also supports the fermentation of fiber, resulting in the production of short-chain fatty acids (SCFAs), which provide energy to intestinal cells and promote overall gut health (Smith *et al*., 2021).

In poultry nutrition, fiber can be derived from both plant-based and animal-based sources. The most common sources of fiber include cereal grains, legumes, and by-products

from processing plants. For example, wheat bran, rice hulls, and soybean hulls are often used in poultry diets due to their high fiber content. These fibrous materials contain both soluble and insoluble fiber, each offering different benefits. Insoluble fiber is known to enhance gut motility, while soluble fiber can assist in stabilizing blood glucose levels by slowing down nutrient absorption (Anderson *et al.*, 2019). Other fiber-rich feed ingredients include alfalfa meal, oat bran, and various fruits and vegetables. These sources not only provide fiber but also contribute essential vitamins and minerals that support the overall health of poultry (Zhang *et al.*, 2022). Furthermore, some researchers are exploring alternative fiber sources, such as insect meals and processed agricultural waste, which may offer sustainable options for poultry feeding (Pereira *et al.*, 2021). The inclusion of dietary fiber in poultry diets has numerous benefits. First, it enhances digestive efficiency, ensuring that the poultry's gastrointestinal system operates optimally. It also improves the birds' ability to handle variations in feed quality and helps manage the effects of anti-nutritional factors commonly found in grains and oilseeds.

Additionally, fiber plays a role in improving nutrient utilization. When fiber is fermented by gut bacteria, it produces SCFAs, which are absorbed and used as an energy source by the poultry. This energy source can partially replace other forms of dietary energy, such as fats or carbohydrates, making the diet more efficient (Smith *et al.*, 2021). Lastly, increasing fiber in poultry diets can reduce the risk of obesity. Fiber contributes to satiety, helping birds feel fuller for longer, which can prevent overfeeding and promote healthy weight management (Anderson *et al.*, 2019). The major components of dietary fiber as part of the total carbohydrate are presented in Figure 1.

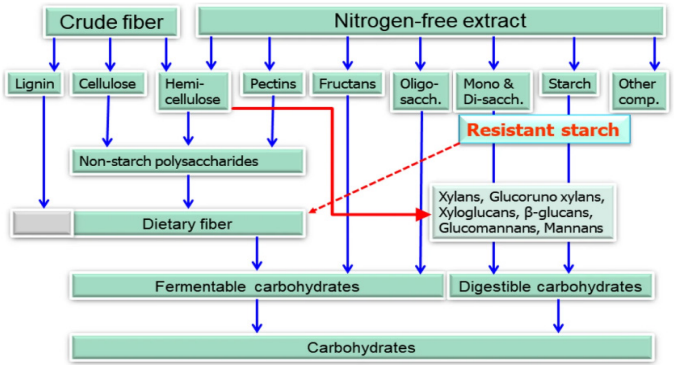

Figure 1: The major components of dietary fiber as part of the total carbohydrate.

IMPACT OF DIETARY FIBER IN POULTRY

Organ development and impact on passage rate

Organ development in poultry is influenced by dietary fiber in various ways, especially concerning the gastrointestinal tract. The inclusion of fiber in poultry diets promotes the development of the digestive organs, such as the crop, gizzard, and intestines. For instance, insoluble fiber, which resists fermentation, stimulates the gizzard's muscular development, improving the grinding and breakdown of food particles. This leads to enhanced feed utilization and improved digestion efficiency, as fiber also promotes the secretion of digestive enzymes (Wang *et al.*, 2021).

Moreover, fiber plays a role in the development of the ceca, which are responsible for fermentation processes in poultry. The ceca are pivotal in breaking down undigested fiber, thus providing additional nutrients and promoting overall health. Studies have shown that diets higher in fiber increase cecal size and enhance microbial fermentation, contributing to better nutrient absorption (Hernández *et al.*, 2022). This fermentation is crucial for producing short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate, which serve as an energy source and contribute to gut health by reducing pathogenic bacteria.

In addition to gastrointestinal organs, the liver and pancreas are also impacted by fiber intake. Fiber stimulates the pancreas to produce digestive enzymes, which helps in the breakdown of nutrients and their absorption. Furthermore, the liver benefits from fiber's role in reducing the absorption of harmful compounds and managing fat metabolism, which is particularly important for poultry reared in intensive systems (Alzahal *et al.*, 2020). Fiber's role in reducing fat deposition in the liver can prevent liver-related diseases, which are a significant concern in poultry production.

The passage rate refers to the speed at which food moves through the digestive tract. Fiber has a significant influence on the passage rate in poultry, as it increases gut motility and enhances the efficiency of feed digestion. Insoluble fiber, in particular, promotes faster passage rates by adding bulk to the digestive material, which encourages the movement of food through the gastrointestinal tract. This faster passage rate can help prevent gastrointestinal blockages and improve feed conversion ratios.

The effect of fiber on the passage rate is also linked to the gut microbiota. Higher fiber diets tend to support a more diverse and balanced microbial community, which aids in the fermentation of fiber and the production of SCFAs. These SCFAs not only provide energy for the bird but also influence gut motility. SCFAs have been shown to increase the frequency of contractions in the intestinal muscles, thereby promoting a quicker passage of feed material through the gut (Hajkowski *et al.*, 2021).

However, the effects of fiber on passage rate are complex and depend on factors such as the type and amount of fiber included in the diet, the age of the poultry, and environmental conditions. While a certain level of fiber is necessary to optimize gut health and passage rate, excessive fiber may lead to reduced nutrient absorption and decreased growth performance. This highlights the importance of formulating balanced diets that provide adequate fiber without compromising feed efficiency. The impact of fiber on poultry is not limited to its effect on organ development and passage rate but also extends to overall growth performance and health. Research has demonstrated that dietary fiber affects growth rates, with moderate levels of fiber often resulting in improved feed efficiency, better gut health, and reduced incidences of gastrointestinal disorders (Choct, 2015). Conversely, excessive fiber can lead to decreased growth rates due to its potential to bind with essential nutrients, thus reducing nutrient bioavailability.

The inclusion of fiber in poultry diets also plays a preventive role in metabolic disorders. For example, high-fiber diets have been associated with reduced risk of obesity, fatty liver disease, and intestinal diseases such as coccidiosis. Fiber can help regulate the absorption of glucose, improve lipid metabolism, and reduce the incidence of gut infections by acting as a prebiotic to stimulate beneficial gut bacteria (Zhang *et al*., 2019). This has made fiber an increasingly important component in the development of functional feeds for poultry.

Impact on digestibility and nutrient utilization

In poultry, the presence of fiber in the diet often reduces the digestibility of nutrients, particularly energy, protein, and lipids. Fiber interacts with digestive enzymes and gastrointestinal tract function, sometimes hindering the breakdown of feed components. This effect is particularly pronounced with high levels of insoluble fiber, which can reduce the efficiency of nutrient digestion due to its ability to absorb water and create a viscous environment (Swiatkiewicz *et al*., 2020).

Insoluble fibers, such as cellulose, lignin, and hemicellulose, are less fermentable and contribute to increased fecal excretion due to their bulk-forming properties. This can result in a reduction in the overall energy available to the poultry (Haug *et al*., 2020). On the other hand, soluble fibers, although still less digestible than starches, are fermentable and can be broken down by gut microbiota in the ceca, producing short-chain fatty acids (SCFAs) that provide an alternative energy source for the birds (Arocha *et al*., 2016). These SCFAs are particularly beneficial as they promote a healthier gut microbiota and can improve overall energy utilization.

The digestibility of protein can also be affected by fiber content. High fiber levels often increase the excretion of nitrogen, particularly from non-fermentable fiber types, leading to a loss of protein that otherwise could have been absorbed by the bird. However, certain fibers, especially those that are fermentable, can improve protein utilization by fostering a more balanced microbial ecosystem that supports amino acid synthesis in the gut (Yegani and Korver, 2008).

Fiber also impacts the absorption of key nutrients in poultry. The fermentation of fiber in the cecum produces SCFAs like acetic acid, propionic acid, and butyric acid. These acids can influence the absorption of nutrients, such as electrolytes, vitamins, and minerals, by enhancing the permeability of the gut lining (Swiatkiewicz *et al*., 2020). This can improve the overall efficiency of mineral absorption, especially with calcium and phosphorus, which are critical for skeletal development and eggshell formation in laying hens.

Moreover, fiber has been shown to modulate the secretion of digestive enzymes and bile acids, which in turn influences the availability of nutrients like lipids and fat-soluble vitamins. While fiber may reduce the digestibility of fat, it can also promote the secretion of bile acids, which enhances fat digestion in the small intestine (Liu *et al*., 2022). This is important in diets that include high-fat ingredients or those formulated for layers, as fiber can help ensure that fat-soluble vitamins are adequately utilized.

Additionally, fiber-rich diets improve the gut microbiome by promoting the growth of beneficial microorganisms, such as lactobacilli and bifidobacteria, while reducing the proliferation of harmful bacteria (Guo *et al*., 2018). This is essential for maintaining a balanced intestinal environment that supports optimal nutrient absorption and overall poultry health.

Beyond its influence on digestibility and nutrient utilization, fiber also offers significant health benefits for poultry. The addition of fiber to poultry diets has been shown to enhance gut health by improving intestinal motility, reducing the occurrence of digestive disorders, and increasing the diversity of gut microbiota (Singh *et al*., 2020). The increased fecal bulk and water retention associated with fiber can help in preventing issues such as constipation and gizzard erosion, which can be problematic in certain poultry farming systems.

Furthermore, fiber can act as a natural prebiotic, promoting the growth of beneficial gut bacteria. This microbial support not only aids in digesting fiber itself but also helps in the synthesis of essential nutrients like B vitamins and amino acids (Swaggerty *et al*., 2021). Fiber may also play a role

in reducing the incidence of certain metabolic diseases, such as obesity and fatty liver, by promoting satiety and regulating fat metabolism.

Impact of dietary fiber on growth performance

Dietary fiber plays an important role in the growth performance of poultry, influencing various physiological processes such as digestion, nutrient absorption, and gut health. The growth performance of poultry is typically measured through parameters like body weight gain, feed conversion ratio (FCR), and overall health, all of which are closely linked to nutrient intake and digestion. Research has shown that dietary fiber can have both positive and negative effects on these parameters, depending on factors such as fiber type, level of inclusion, and the specific needs of the poultry species. Understanding these factors can help optimize poultry diets for better growth performance.

The impact of fiber on poultry growth performance is primarily mediated through its effects on intestinal health and digestion. Studies suggest that fiber promotes the development of intestinal morphology, increasing the surface area available for nutrient absorption, which in turn enhances the overall digestion process (Sittiya *et al.*, 2020). A well-developed gut allows for more efficient nutrient uptake, leading to better growth outcomes. In particular, fiber has been shown to promote the growth of beneficial gut bacteria, which can further enhance digestion and nutrient absorption, supporting the overall health of the birds. This positive effect on gut health is one reason why moderate levels of fiber can enhance growth performance.

However, the relationship between fiber and growth performance is complex, as different types of fiber can affect birds differently. Soluble fibers, such as beta-glucans, are more easily fermentable and have been shown to improve gut health by promoting beneficial microorganisms. In contrast, insoluble fibers, such as cellulose and hemicellulose, are less fermentable but can still improve gut motility and reduce the incidence of gastrointestinal disorders (Tejeda and Kim, 2020). The fiber type, therefore, plays a key role in determining its impact on growth. Moreover, the particle size of fiber can influence its digestibility and the rate at which it passes through the digestive tract, further complicating its effects on poultry performance.

In terms of optimal inclusion, fiber is beneficial to a point, but excessive amounts can hinder growth. Studies have indicated that a moderate inclusion of fiber, typically around 5% of the diet, can improve feed conversion ratios (FCR) and overall body weight gain in broilers (Kim *et al.*, 2006). However, higher fiber levels (greater than 10%) may reduce growth performance by decreasing the energy density of the feed. This happens because fiber occupies space in the digestive system and competes with other nutrients, including carbohydrates, fats, and proteins, for absorption (Mekki *et al.*, 2015). As a result, high fiber levels can lead to reduced caloric intake and suboptimal growth rates.

The balance between fiber and energy is critical for maintaining optimal growth performance in poultry. High-fiber diets often require adjustments to the energy content of the feed to compensate for the reduced energy availability. This may involve increasing the energy density of the diet, such as through higher fat or protein levels, to offset the energy lost due to fiber inclusion. Additionally, the physiological status of the birds plays an important role in determining how fiber affects growth. For example, the nutritional needs of laying hens differ from those of broilers, and the fiber requirements for each may vary (Tejeda and Kim, 2020). Furthermore, the age of the birds can influence their ability to digest and utilize fiber, with younger birds generally being more sensitive to fiber levels than older ones.

Another critical aspect of fiber's impact on poultry growth is its role in preventing obesity and promoting lean meat production. Adequate fiber intake helps regulate feed intake by promoting satiety, which can lead to improved feed conversion efficiency (FCE). By controlling energy intake, fiber can prevent excessive fat accumulation in growing birds and encourage the development of lean muscle mass. This is especially important in commercial poultry production, where efficient feed utilization and lean meat production are key objectives.

Table 1: The influence of different types of dietary fiber on growth performance.

Fiber type	Effect on growth performance	Citation
Soluble fiber	Improves digestion and nutrient absorption, leading to enhanced growth rates. It can also help with weight gain in certain animal models.	Zhang *et al.* (2021). Effects of soluble dietary fiber on growth performance and gut health. Journal of Animal Science, 99(2): 120-131.
Insoluble fiber	Promotes gut motility and can improve overall gut health, but may not always enhance growth rates as effectively as soluble fiber.	Liu *et al.* (2020). Insoluble fiber's role in growth performance and gut function. Animal Feed Science and Technology, 267: 114-123.
Mixed fiber (Soluble + Insoluble)	A combination of soluble and insoluble fibers typically supports both gut health and growth performance by improving gut microbial balance.	Wang *et al.* (2019). Combined dietary fiber effects on growth and health in poultry. Poultry Science, 98(7): 2505-2513.

Impact of dietary fiber on gut microbiota

The addition of fiber to poultry diets has been shown to have several positive effects on gut microbiota composition, diversity, and function. Various studies have highlighted how different types of dietary fiber impact the microbial communities in the gastrointestinal tract of poultry. The fermentation of soluble fibers in the cecum produces SCFAs, which serve as a preferred energy source for beneficial bacteria. Studies have shown that dietary fiber supplementation promotes the growth of *Lactobacillus*, *Bifidobacterium*, and other beneficial bacteria in poultry. These bacteria help inhibit the growth of pathogenic microorganisms by producing lactic acid, which lowers gut pH and creates an unfavorable environment for harmful microbes (Yadav *et al*., 2018). A more diverse microbiota is often associated with better gut health and resilience against pathogens. Fiber inclusion in poultry diets can enhance microbial diversity, particularly in the cecum, where fiber fermentation is most active. A diverse microbiota has been linked to improved gut barrier function, nutrient absorption, and overall immune health in poultry (Zhao *et al*., 2019).

SCFAs, including acetate, propionate, and butyrate, are produced during the fermentation of fiber by gut bacteria. These SCFAs are critical for maintaining the health of intestinal cells, reducing inflammation, and supporting the immune system. Butyrate, in particular, is known to enhance the integrity of the gut barrier by promoting the proliferation of intestinal epithelial cells (Singh *et al*., 2014). Moreover, SCFAs may play a role in regulating gene expression related to metabolism and immune function in poultry (He *et al*., 2020). The competitive exclusion of pathogens is one of the main benefits of dietary fiber. By fostering the growth of beneficial bacteria, fiber supplementation helps to create a more competitive environment in the gut, reducing the chances of harmful pathogens like *Salmonella* or *Campylobacter* colonizing the gut. This can enhance poultry's resistance to infections and improve food safety (Gadde *et al*., 2017).

The benefits of fiber on gut microbiota have direct implications for poultry performance. Healthy gut microbiota are essential for nutrient digestion, absorption, and overall growth. Fiber supplementation can improve feed efficiency, weight gain, and overall performance by enhancing gut health and nutrient utilization (Liu *et al*., 2021). Furthermore, dietary fiber can reduce the incidence of gastrointestinal disorders, such as necrotic enteritis, which can be a significant issue in poultry production.

Impact of dietary fiber on the immune system

The gut microbiota plays a central role in the immune system. It contributes to the development of mucosal immunity and provides protection against pathogens. Fiber, particularly fermentable fiber, serves as a prebiotic, promoting the growth of beneficial gut microorganisms such as Lactobacilli and Bifidobacteria. These microorganisms produce SCFAs, which have direct and indirect effects on the immune system. SCFAs influence the production of immune cells, such as regulatory T cells, and enhance the gut barrier function by stimulating the production of mucus and tight junction proteins. This bolsters the intestinal lining's ability to resist pathogens and reduces systemic inflammation (Smith *et al*., 2013). Moreover, SCFAs can activate the G-protein-coupled receptors (GPR41 and GPR43) on immune cells, leading to the modulation of inflammatory responses (Liao *et al*., 2021).

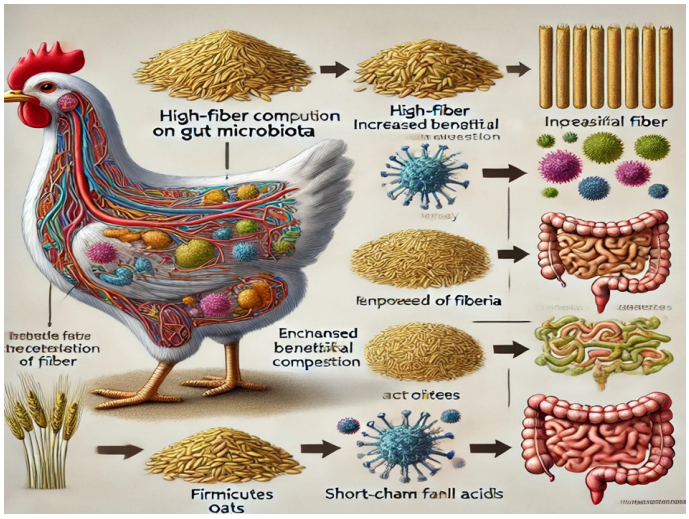

Figure 2: Impact of dietary fiber on gut microbiota in poultry.

The gut epithelium forms a crucial barrier to pathogens, and dietary fiber contributes to its integrity. Butyrate, a key SCFA produced from fiber fermentation, is particularly effective in enhancing gut barrier function. It has been shown to increase the expression of tight junction proteins such as occludin and claudins, which are essential for maintaining the intestinal epithelial integrity (Hamer *et al*., 2008). By strengthening the gut barrier, fiber helps prevent the translocation of harmful pathogens and endotoxins into the bloodstream, thus reducing systemic inflammation and preventing immune system overload. Chronic low-grade inflammation is a significant concern in poultry health, leading to reduced productivity and increased susceptibility to infections. Fiber intake has been found to reduce the secretion of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) and interleukins (IL-1β, IL-6), while simultaneously increasing the levels of anti-inflammatory cytokines such as IL-10 (Lee *et al*., 2018). This balance helps maintain homeostasis in the immune system and can enhance the bird's ability to resist infections.

Fiber's impact on the immune system also extends to the activation and function of specific immune cells, including macrophages, dendritic cells, and T lymphocytes. The production of SCFAs, particularly butyrate, has been linked to an increase in the activity of macrophages, which are essential for pathogen recognition and the initiation of immune responses (Singh *et al*., 2014). Additionally, butyrate has been shown to enhance the antigen-presenting capacity of dendritic cells, thereby improving adaptive immune responses. Another indirect way in which fiber influences immune function is through its antioxidant properties. Fiber-rich diets have been associated with increased production of antioxidants such as glutathione and superoxide dismutase in the gut (Mahan and Parrett, 2004). These antioxidants play a vital role in reducing oxidative stress, which can otherwise impair immune cell function and lead to chronic inflammation. By reducing oxidative damage, fiber helps maintain the integrity of immune cells and supports a more effective immune response.

Not all fibers exert the same effects on the immune system, and their impact can vary depending on their fermentability, solubility, and chemical composition. Soluble fibers, such as pectin and beta-glucans, are fermentable and can produce large amounts of SCFAs during digestion. Beta-glucans, in particular, are well-known for their immune modulatory effects. Studies have shown that beta-glucans can activate immune cells, such as macrophages and neutrophils, enhancing their ability to fight off infections (Brown and Gordon, 2003). In poultry, beta-glucans have been found to improve resistance to diseases like *Salmonella* and *E. coli* by boosting both the innate and adaptive immune responses (Vega *et al*., 2020). Insoluble fibers, such as cellulose and lignin, are less fermentable and contribute mainly to gut motility. While they may not directly produce SCFAs, they are still important for maintaining the overall health of the gut and preventing constipation. By ensuring a well-functioning gastrointestinal system, insoluble fibers indirectly support immune function by maintaining the integrity of the gut mucosa.

Summary of the Impact of Dietary Fiber in Poultry

Dietary fiber plays a significant role in poultry health and production by influencing various physiological processes. Fiber, particularly insoluble fiber, enhances the development of digestive organs like the crop, gizzard, and intestines, improving digestion and feed utilization. Insoluble fiber stimulates the muscular development of the gizzard, aiding in the breakdown of food particles, while soluble fiber promotes beneficial gut bacteria that enhance nutrient absorption. The inclusion of fiber also affects the development of the ceca, improving fermentation and nutrient absorption through the production of short-chain fatty acids (SCFAs). However, fiber's impact on nutrient digestibility can be complex. While soluble fibers aid in fermenting and producing SCFAs, which provide an energy source, insoluble fibers increase fecal excretion and decrease digestibility. Excessive fiber can also reduce nutrient bioavailability and lower growth performance by binding essential nutrients. Moderation is key, as moderate fiber levels can improve feed efficiency and gut health, preventing gastrointestinal issues.

Fiber also impacts growth performance by influencing gut health. Studies show that moderate fiber inclusion (around 5%) improves feed conversion and body weight gain, while excessive fiber (>10%) can decrease growth due to reduced energy density in the feed. Additionally, fiber regulates feed intake, preventing excessive fat accumulation and promoting lean meat production. Fiber's effects on the gut microbiota are also noteworthy. It encourages the growth of beneficial bacteria like Lactobacillus and Bifidobacterium, which enhance gut health, reduce pathogenic bacteria, and improve nutrient absorption. The fermentation of fiber produces SCFAs, which promote immune function, reduce inflammation, and strengthen the gut barrier. Finally, fiber plays a role in boosting poultry immunity by enhancing gut barrier integrity and promoting the production of anti-inflammatory cytokines. It also influences the immune system through the production of SCFAs like butyrate, which strengthens immune cell function and reduces oxidative stress.

Recommendations

- Moderate Fiber Levels: Aim for a balanced inclusion of fiber (around 5%) in poultry diets to enhance gut health and digestion without negatively impacting growth performance.
- Optimize Fiber Types: Use a combination of soluble and insoluble fibers to support both gut motility and microbial health, promoting better nutrient absorption.
- Adjust Diets for Growth Stages: Tailor fiber inclusion based on the age and species of poultry, as younger birds are more sensitive to high fiber levels.
- Monitor Fiber-Induced Effects: Regularly assess the impact of fiber on gut microbiota, feed efficiency, and overall health, adjusting fiber levels as needed to optimize performance.
- Utilize Prebiotic Fibers: Incorporate fermentable fibers such as beta-glucans to promote beneficial gut microbiota, which can help in disease prevention and improved immune response.

NOVELTY STATEMENT

This review explores the novel insights into how dietary fiber influences poultry performance, emphasizing its role beyond traditional nutrition. It unveils fiber's impact on

gut health, nutrient absorption, and overall productivity, challenging conventional feeding strategies. By synthesizing recent studies, this work highlights innovative approaches to optimize feed formulations, enhancing growth rates and health outcomes in poultry. The review pioneers understanding fiber's multifaceted benefits, offering ground breaking perspectives for advancing poultry farming practices through improved dietary interventions.

AUTHOR'S CONTRIBUTION

Both authors were contributed equally to this full-length review article.

Conflict of interest

The authors have declared no conflict of interest.

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