 DOI: 10.19601/j.cnki.issn1943 - 9903.2025.07.005

Research Review on Regulatory Effects of Garlic Polysaccharides on Poultry Intestinal Health

Zhiyan MENG

Shandong Agricultural University, Tai'an 271099, China

Abstract Through in-depth analysis of recent domestic research, this review elaborates on the mechanisms of garlic polysaccharides in regulating poultry gut microbiota balance, strengthening intestinal barrier function, and enhancing intestinal immunity. It also discusses their practical application effects in poultry farming, existing problems, and future research directions, aiming to provide comprehensive and in-depth theoretical support for promoting the widespread application of garlic polysaccharides in healthy poultry farming.

Key words Garlic polysaccharides, Poultry, Intestinal health, Regulatory effect

0 Introduction

The poultry farming industry holds a crucial position in China's agricultural economic system and is a vital source of high-quality animal protein such as meat and eggs. As a key organ for digestion, nutrient absorption, and defense against pathogen invasion in poultry, the health status of the intestine is directly linked to poultry growth performance, feed conversion efficiency, disease resistance, and farming economic benefits. A healthy intestine ensures efficient uptake of nutrients from feed, maintains good physiological function, enhances the body's immunity, and effectively resists various disease invasions. Once intestinal health is compromised, poultry are prone to problems such as slow growth, digestive disorders, diarrhea, and decreased immunity. This not only significantly increases farming costs but may also trigger disease transmission, causing severe economic losses to the poultry farming industry.

Garlic, as a plant with both edible and medicinal value, is rich in various bioactive components, among which garlic polysaccharides have received considerable attention. Garlic polysaccharides are widely available, relatively low-cost, natural, safe, and free from drug residues and resistance issues, giving them broad application prospects in poultry farming. In-depth research on the regulatory effects of garlic polysaccharides on poultry intestinal health will help develop novel, green, and safe feed additives, offering the possibility to replace or partially substitute traditional antibiotics. This will strongly advance the poultry farming industry towards sustainable and healthy development.

This article comprehensively reviews the research progress on the regulatory effects of garlic polysaccharides on poultry intestinal health. As an important active component of garlic, garlic polysaccharides exhibit great potential in the poultry farming field due to their natural, safe, and functionally diverse properties. This review aims to systematically organize and deeply analyze the regulatory mechanisms of garlic polysaccharides on poultry intestinal health and their practical application effects, analyze existing problems in current research, and provide prospects for future research directions. It is expected to offer comprehensive and in-depth theoretical reference for the scientific and rational application of garlic polysaccharides in poultry farming, promoting their widespread use in practical production.

Received: May 19, 2025 Accepted: July 2, 2025

1 Extraction and characteristics of garlic polysaccharides

1.1 Extraction methods Currently, the main extraction methods for garlic polysaccharides include hot water extraction, ultrasound-assisted extraction, and enzymatic hydrolysis. Hot water extraction is the most fundamental method. It utilizes the solubility of polysaccharides in hot water, dissolving polysaccharides from garlic through heating and soaking. This method is simple to operate and relatively low-cost, but it has problems such as long extraction times and low extraction yields. Furthermore, prolonged high-temperature treatment may damage the structure and bioactivity of the polysaccharides. Ultrasound-assisted extraction leverages the cavitation effects, mechanical vibration, and thermal effects of ultrasound to accelerate the dissolution of polysaccharides from garlic tissue. It effectively improves extraction efficiency, shortens extraction time, and can better preserve the structure and activity of the polysaccharides. However, this method requires specialized ultrasonic equipment, resulting in relatively higher equipment costs and energy consumption. Enzymatic hydrolysis utilizes the specificity of enzymes to degrade the garlic cell wall and other impurities, making polysaccharides easier to release. This method offers advantages such as mild conditions, minimal damage to polysaccharide structure, and relatively high extraction yield. However, enzyme costs are high, and the enzymatic hydrolysis process requires precise control of reaction conditions such as temperature, pH, enzyme dosage, and reaction time[1].

1.2 Structure and physicochemical properties Polysaccharides are a class of extremely important bioactive substances in garlic bulbs. Their structures are diverse, and their determination is influenced by various factors, including garlic variety, extraction process, and detection methods, making structural analysis research challenging. The monosaccharide composition of garlic

polysaccharides is diverse but primarily consists of fructose. They also contain galactose, glucose, arabinose, mannose, rhamnose, glucuronic acid, galacturonic acid, and others[2].

Garlic polysaccharides obtained using different extraction methods, from different garlic varieties, and different geographical origins exhibit variations in their monosaccharide composition and ratios. Garlic polysaccharides typically appear as white or light yellow powders. They are readily soluble in water but insoluble in organic solvents such as ethanol and acetone. They possess good stability; however, their structure and activity can be compromised under extreme conditions such as high temperature, strong acids, and strong alkalis. The physicochemical properties of garlic polysaccharides, such as solubility, viscosity, and optical rotation, are closely related to their structure and molecular weight. These properties influence their biological functions to a certain extent. For instance, a higher molecular weight and an appropriate structure may enable them to exhibit more significant effects in regulating gut microbiota and enhancing immune function.

2 Regulatory effects on poultry gut microbiota

2.1 Inhibition of harmful bacteria Numerous domestic studies indicate that in the antibacterial experiments conducted by Jia Weibin *et al.*[3] using extracted allicin, synthetic allicin, and iodinated modified allicin, the Minimum Inhibitory Concentrations (MICs) of these three types of allicin against *Escherichia coli*, *Salmonella enteritidis*, and *Staphylococcus aureus* were found to be 80, 40, and 80 μg/mL, respectively. Garlic polysaccharides exhibit significant inhibitory effects against common harmful bacteria in the poultry intestine, such as *E. coli* and *S. enteritidis*. Its mechanism of action mainly manifests in: altering the permeability of the bacterial cell membrane, causing leakage of intracellular substances and interfering with normal bacterial metabolism and growth; hindering the bacterial energy metabolism process; inhibiting the formation of bacterial biofilms; and reducing the adhesion ability of harmful bacteria to the intestinal mucosa. Consequently, this reduces the colonization and proliferation of harmful bacteria within the intestine. In the study by Wang Zheng *et al.*[4] on the effects of three Chinese herbal extracts on the *in vitro* fermentation characteristics of chicken cecal microorganisms, the addition of garlic polysaccharides resulted in significant inhibition of *E. coli* counts. This effect may be related to the antibacterial actions of allicin and garlic polysaccharides.

2.2 Promotion of beneficial bacteria Garlic polysaccharides can provide the carbon source required for the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*, promoting their proliferation. Simultaneously, garlic polysaccharides can regulate the intestinal environment, creating an acidic environment that is more conducive to the growth of beneficial bacteria and less favorable for the survival of harmful bacteria. After proliferating abundantly in the intestine, beneficial bacteria produce beneficial metabolites such as short-chain fatty acids (SCFAs). These metabolites not only provide energy for intestinal epithelial cells, promoting intestinal development and repair, but also regulate intestinal pH, inhibit the growth of harmful bacteria, and maintain intestinal microecological balance[5].

3 Effects on poultry intestinal immune regulation

3.1 Innate immunity Garlic polysaccharides can activate innate immune cells in the poultry intestine, such as macrophages and dendritic cells[6]. By regulating innate immune signaling pathways (such as the TLR signaling pathway), they prompt these immune cells to secrete cytokines (*e.g.*, TNF-α, IL-1β, IL-6) and chemokines, triggering an inflammatory response to promptly eliminate invading pathogens[7]. Simultaneously, garlic polysaccharides can enhance the phagocytic and bactericidal capabilities of innate immune cells, thereby improving the body's early defense capability against pathogens. This demonstrates the important role of garlic polysaccharides in activating innate immunity and resisting pathogen invasion.

3.2 Acquired immunity In terms of acquired immunity, garlic polysaccharides have a regulatory effect on the proliferation and differentiation of intestinal T cells and B cells. Research by Li Hui *et al.*[8] on the effect of allitridin on the immune function of mouse splenocytes and the expression of intracellular Toll-like receptor 4 (TLR4) and myeloid differentiation factor 88 (MyD-88) demonstrated that allitridin can enhance the innate and acquired immune capacity of splenocytes by upregulating the expression of TLR4 and MyD-88. It promotes the differentiation of T cells into different subsets such as Th1 and Th2, regulating the balance between cellular immunity and humoral immunity. Garlic can effectively enhance NK cell activity and IL-2 levels, as well as promote the division, proliferation, and activity of T lymphocytes[9]. These cytokines play crucial roles in the activation, proliferation, and differentiation of T and B cells, thereby enhancing the body's specific immune response[10].

4 Application effects in poultry farming

4.1 Growth performance Numerous domestic studies have shown that adding an appropriate quantity of garlic polysaccharides to feed can significantly improve the growth performance of poultry. Adding 300 mg/kg of allitridin increased the average daily gain and final body weight of "817" small white-feathered broilers. The final body weight of the group supplemented with 300 mg/kg allitridin was 133.75 g higher than that of the control group, and 135.25 g higher than that of the group supplemented with 150 mg/kg allitridin[11]. Its mechanism of action primarily involves improving intestinal health, enhancing the digestibility and absorption efficiency of feed, thereby providing ample nutrition for poultry growth. This fully demonstrates the significant value of garlic polysaccharides in promoting poultry growth and enhancing farming profitability.

4.2 Disease resistance ability Garlic polysaccharides can enhance the disease resistance of poultry, reducing the incidence and mortality rates of diseases. They exhibit good efficacy in pre-

venting and treating poultry intestinal diseases, such as reducing the occurrence of colibacillosis, coccidiosis, *etc.* In practical shrimp farming applications, mixing 80 g of polysaccharide with 20 g of garlic for 40 kg of feed improved issues like enteritis, white feces, empty intestines and stomach, and yellow/black liver in shrimp, reflecting to some extent the preventive and therapeutic effects of garlic polysaccharides on intestinal diseases. For poultry, garlic polysaccharides enhance the immunity of the poultry organism by modulating the intestinal microbiota, strengthening intestinal barrier function, and exerting immunomodulatory effects, enabling them to better resist pathogen invasion[11]. This indicates that garlic polysaccharides play an important role in safeguarding poultry health and reducing farming risks.

5 Problems and prospects in poultry farming application

5.1 Existing problems Currently, the application of garlic polysaccharides in poultry farming still faces several problems. Firstly, the extraction process for garlic polysaccharides is not yet sufficiently optimized, with problems such as low extraction yield and high cost, which limits its large-scale industrial production and application. Secondly, the stability of garlic polysaccharides during feed processing and storage needs improvement; they are prone to degradation under the influence of factors like temperature, humidity, and light, leading to a reduction in their activity. Furthermore, the optimal dosage and application methods of garlic polysaccharides in poultry feed require further research and determination, as the requirements may vary among different poultry breeds and growth stages. These problems constrain the widespread application of garlic polysaccharides in poultry farming and urgently need to be resolved.

5.2 Research prospects Future research can be conducted in the following aspects. First, it is necessary to deeply investigate the action targets and molecular mechanisms of garlic polysaccharides within the intestine to further reveal the essence of how they regulate poultry intestinal health, providing a more solid theoretical foundation for their rational application. Second, it is necessary to develop more efficient and low-cost extraction technologies and stable formulation forms to increase the extraction yield and stability of garlic polysaccharides, reduce production costs, and promote their widespread application in the farming industry. Third, it is necessary to conduct research on the combined application of garlic polysaccharides with other natural additives to explore their synergistic effects and develop more effective compound additives, providing a more comprehensive solution for healthy poultry farming. Through in-depth exploration of these research directions, it is expected to drive greater breakthroughs in the application of garlic polysaccharides in poultry farming and inject new vitality into the sustainable development of the poultry farming industry.

6 Conclusions

As a natural bioactive substance, garlic polysaccharides exert multifaceted regulatory effects on poultry intestinal health, including modulating intestinal microbiota balance, enhancing intestinal barrier function, and regulating intestinal immunity. In practical applications, garlic polysaccharides can improve the growth performance and disease resistance of poultry, demonstrating broad application prospects. However, there are still some problems that need to be resolved in areas such as extraction technology, stability, and application techniques. Future efforts need to further strengthen related research to promote the application of garlic polysaccharides in healthy poultry farming and contribute to the sustainable development of the poultry farming industry. Through continuous in-depth research and practical exploration, it is believed that garlic polysaccharides will play a greater role in the poultry farming sector, providing strong support for safeguarding poultry health and improving farming efficiency.

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