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Role of Synbiotic additive on Chicken Gut Microflora for Disease Control and Production Efficiency: A Narrative Review

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A B S T R A C T

The use of synbiotic additives in chicken feed improves gut microbiota and represents a promising approach to bolster protective immunity against infectious diseases and enhance production efficiency. These additives, which encompass probiotics, prebiotics, and synbiotics, are essential in modulating the microbiota of the chicken, thus promoting gut health. This narrative review aimed to explore the application of synbiotic feed additives to enhance gut microflora and mucosal immunity to disease control and improve production efficiency in chickens. In poultry production, infectious diseases are among the major challenges. Chickens may acquire these diseases either from external sources or from opportunistic pathogens that normally exist within their bodies. Most commensal bacteria reside in the gastrointestinal tract, where they form the gut microbiota. This microbiota, which begins to establish immediately after hatching, is essential for the health and well-being of chickens. The gut microbiota includes both beneficial and opportunistic pathogens. While medications are used to control infections and promote growth, excessive antibiotic use in poultry disrupts this balance, leading to negative health effects. To promote a balanced intestinal microbiota in chickens, beneficial microbes can be provided through synbiotic feed additives. This strategy can improve gut health for better nutrient absorption, strengthen mucosal-associated lymphoid tissue to enhance immunity, and potentially reduce reliance on antibiotics. Synbiotics generally have beneficial effects on host biological functions, acting as immunomodulators and promoting growth in chickens. They help limit pathogen colonization and enhance overall performance. Therefore, poultry producers should be encouraged to incorporate synbiotic-based feed supplements.

Keywords: *Chicken, Immunity, Infectious Disease, Feed additive, Gut Microbiota, Health, poultry, Synbiotic*

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1 Introduction

Poultry production is one of the fastest-growing livestock sectors worldwide; however, infectious and nutritional diseases remain major constraints to poultry health and productivity. Optimizing feed management, therefore, requires novel dietary additives that can enhance performance and sustain feed efficiency (1). The chicken gastrointestinal (GI) tract harbors a complex and diverse community of microorganisms, collectively known as the gut microbiota (2). In young birds, the gut microbiota is highly dynamic, with a stable core community typically established in mature chickens around 20 weeks of age (3). Several factors, including age, diet (broiler, layer, or grower rations), genetics, breed, and environmental conditions, significantly influence the composition and stability of the gut microbiota (4, 5)

The main phyla in the chicken gut microbiota are *Firmicutes*, *Bacteroidetes*, *Proteobacteria*, and *Actinobacteria*. The gut microbiota becomes steady around 7 days post-hatching, with unique communities developing in various gut sections (4, 6). The microbial populations and their types are different in the gut of the chicken according to the physiology of each organ of the digestive system, showing distinct patterns in the crop, gizzard, ileum, cecum, and colon. *Firmicutes* bacteria are commonly found and make up a large portion of the microbiota in different parts of the GIT organs, except the ceca (3). Excessive antibiotic application in poultry farming causes instability in the microbiota and decreases *Lactobacillus* numbers. Moreover, changes in climate and seasonal patterns can lead to differences in the microbiota makeup of the chicken intestine (7).

Synbiotics, a synergistic combination of probiotics (beneficial microbes such as lactic acid bacteria, yeasts, and Bacillus species) and prebiotics (non-digestible feed ingredients that stimulate beneficial microbes), have emerged as promising dietary additives in poultry production (8, 9). In chickens, synbiotics improve gut health by enhancing intestinal microflora balance and colon mucosa integrity, thereby reducing pathogenic bacteria such as Proteobacteria while increasing beneficial Firmicutes (10). They also boost immune modulation and overall health status, serving as natural alternatives to antibiotic growth promoters (11, 12). Furthermore, synbiotics improve feed efficiency by enhancing nutrient digestion, increasing body weight gain, and reducing lesions associated with necrotic enteritis (13, 14). Additional benefits include improved egg quality, meat yield, and pathogen resistance, making synbiotics a valuable strategy to optimize poultry productivity while safeguarding animal health (15).

Synbiotics are replacing antibiotic growth promoters in chicken due to concerns about antibiotic resistance (1). Research findings suggest that taking probiotics can reduce harmful bacteria such as *Salmonella* and *Clostridium perfringens*, while boosting beneficial *Lactobacillus* (15). In addition to this, Synbiotics also help lower blood cholesterol levels, which is vital for the health and physiological improvement of the chicken heart. Additionally, synbiotics can decrease the growth of harmful bacteria in broilers, particularly *Campylobacter jejuni*, enhancing the natural immunity of poultry to bacterial infections (14). Using antibiotics in poultry production hinders the growth of helpful bacteria and promotes the emergence of antibiotic-resistant bacteria, causing worries about the efficacy of antimicrobial treatment in chickens. In addition, factors like age, diet, genetics, and environmental conditions can impact the gut microbiota, causing potential instability and alterations in its composition There is still limited information and insufficient evidence on the effectiveness of synbiotics in broiler production, particularly regarding their role in shaping the gut microbiota to significantly enhance immunity, improve gut health, increase feed conversion efficiency, and optimize carcass quality. This review aimed to describe how synbiotics modulate the chicken gut microbiota to enhance immunity, improve gut health, and boost production efficiency.

1.1 Literature Search Strategy

A narrative review was conducted from December 2024 to July 2025, incorporating the published article from a previously indexed journal. The databases searched included PubMed, Web of Science, Scopus, and Google Scholar. The search was performed using keywords such as “gut microbiota,” “gut poultry health,” “synbiotic," "poultry nutrition," "poultry enteric disease," or "internal disease," and "poultry production." The review focused on studies investigating the use of synbiotics and feed additives aimed at enhancing gut microbiota for disease control and improving poultry production performance. After the article is retrieved from indexed journals, it is reviewed by three committee members to ensure quality.

1.2 Inclusion Criteria

This narrative review included studies conducted on poultry, specifically broilers, regardless of the geographical location. However, only articles published in peer-reviewed journals were considered. To ensure the quality and completeness of the data, only full-text articles were included that contained essential sections, such as abstract, methodology, results, discussion, and conclusion. The exclusion criteria were: articles not written in English, incomplete articles, publications from non-indexed journals, and studies not related to synbiotics or feed additives.

2 Composition of Chicken Gut Microbiota

The gut microbiota in chickens refers to the diverse community of microorganisms, including bacteria and fungi, that inhabit the gastrointestinal tract (2). The gastrointestinal tract of the chicken consists of the crop, proventriculus, gizzard, duodenum, jejunum, ileum, ceca, large intestine, and cloaca (3). Each section of the gastrointestinal tract has distinct metabolic functions that influence the microbial composition (Figure 1), making it crucial to consider the sampling location and study design. However, Choi *et al.* (2014) observed considerable variability in microbial composition among individual broilers fed the same diet, attributed to differences in the timing of feeding.

In the gizzard, bacterial concentrations are similar to those in the crop, but bacterial fermentation is limited primarily due to the low pH content of the gizzard. The gizzard predominantly contains lactobacilli, enterococci, Enterobacterales, and coliform bacteria. Among the small intestinal segments, the duodenum has the lowest bacterial density due to its short passage time and dilution of digesta by secreted bile. The bacterial community in the duodenum mainly comprises clostridia, streptococci, enterobacteria, and lactobacilli (16, 17). The ileum microbiota has been the most extensively studied among the small intestine segments. As Lu *et al.* (2003) analyzed the ileal bacterial community using 16S rRNA gene sequences and identified *Lactobacillus* as the major group (70%), followed by *Clostridiaceae* (11%), *Streptococcus* (6.5%), and *Enterococcus* (6.5%). In comparison, the cecum supports a more diverse, rich, and stable microbial community, including numerous anaerobes (18).

Shang et al (2) documented significant changes in cecal microbial communities from hatch to 6 weeks of age in commercial broilers and observed substantial differences between cecal and fecal samples from individual birds. Typically, cecal microbial richness and diversity increase over the first 6 weeks, with a shift in the taxonomic composition from Proteobacteria, Bacteroidetes, and Firmicutes to predominantly Firmicutes by 3 weeks of age (2, 13). Conversely, Kumar *et al.* (19) found that Firmicutes were the most abundant phylum in both the ceca and ileum at all ages (day 0 to day 42), except on day 42 in the ceca, where *Bacteroidetes* were more prevalent. Variations in bacterial composition can result from differences in nucleic acid extraction protocols, primers, sequencing methods, environmental factors, dietary treatments, breed, and environmental conditions. Greater individual variation in sample types, such as crop samples, necessitates a larger sample size compared to cecal samples to detect potential differences (16).

2.1 Factors affecting the composition of gut microbiota

The stability and diversity of the gut microbiota are critical for maintaining chicken health, as they influence nutrient absorption, immune modulation, and resistance to infectious diseases. Several factors affect the composition and development of the gut microbiota, including age, diet, genetics, breed, environmental conditions, and management practices (4, 5). Antibiotics are extensively used in poultry production systems, not only for therapeutic purposes but also as prophylaxis (4). Studies have shown that the indiscriminate use of antibiotics reduces the stability of the microbiota of chickens in their intestines. Most commonly used antibiotics are broad-spectrum and can disrupt the host microbiota by killing non-target and beneficial bacteria (5).

The composition of the microbiota can vary within a segment of the intestine and is influenced by climate and seasonal fluctuations of the environment where the chicken is found (20). Some studies (4, 20) reported that the composition of the cecal microbiota varies depending on the season, with species richness being highest in summer and doubling in winter. These variations are due to the influence of regional and seasonal climatic conditions on the microbiota surrounding the chicken and the chicken themselves. The husbandry system is another factor that affects the microbiota composition of the intestine, and this, in turn, impacts the production performance of the chicken (4). This is because different housing systems (cage, barn, free-range) create distinct environmental exposures that influence gut microbiota development. Commercial production systems disrupt natural microbiota colonization compared to traditional hen-chick rearing (21).

The composition of the microbiota within a segment of the intestine is also influenced by heat stress and diet (6, 20). Chickens require suitable environmental conditions, such as an appropriate temperature, to perform well. Heat stress has a greater effect on the bacterial population in the chicken gut, which reduces performance and compromises the integrity of the gastrointestinal tract (GIT). This also indirectly affects the metabolic function of the chicken (20). Diet is another factor that influences both intestinal physiology and microbiota composition (6). For example, when supplementing fat and soybean oil with medium-chain fatty acids (MCFAs; 0.3% C10 and 2.7% C12) for 34 days, broiler ileal microbiota, such as *Lactobacillus*, *Enterococcaceae*, and *Micrococcaceae*, are reduced, but *Enterobacteriaceae* are increased (17).

Dietary metabolisable energy and crude protein are important dietary components that affect the composition and diversity of the gut microbiota. When the ME and CP ratio is appropriate, broilers grow faster, have higher feed conversion and production (6). However, the inappropriate provision of a fat-containing diet and ME and CP for a longer time, heat stress, and the use of antibiotics (4, 20) can affect the composition of the microbiota. This side effect can often lead to dysbiosis or leaky gut syndrome, and the development of pathogenic bacteria, which further promotes the emergence of antibiotic-resistant bacteria and possibly leads to the horizontal transfer of corresponding resistance genes ((4) (6). In adult chickens, the phyla *Bacteroidetes*, *Firmicutes*, and *Proteobacteria* are the dominant phyla in the gut microbiota (6).

Chicken has the characteristic of being a source of energy, and there is a dynamic equilibrium between the energy conversion rate and protein conversion rate in the body. Increased metabolizable energy and crude protein levels have an impact on the gut microbiota. For example, higher protein intake increases the growth of *Proteobacteria* in the gut without changing other microbiota (6). Dietary crude protein (CP) levels play a significant role in regulating this microbial diversity, with higher CP levels increasing gut microbial diversity and relative abundance, while higher dietary metabolizable energy (ME) levels tend to decrease it (6).

In chickens, the gut microbiota richness, i.e., the number of different microbial taxa, increases during the first weeks of life, while the individual variation in microbiota composition decreases as the chickens age (21). Throughout the entire growth process, the gut microbiota continues to change, exerting a significant impact on the performance of broilers. A gene sequencing study conducted by various researchers (6, 22) aimed to determine the dynamics of the gut microbial community in broilers during the growth process. Some researchers reported that 93.5% of the total bacteria in the fecal sample from different age groups constitute mainly the phyla of *Firmicutes* (67.35%), *Fusobacteria* (9.85%), *Proteobacteria* (8.36%), and *Bacteroidetes* (8.09%). At the genus level, *Lactobacillus* accounts for the highest relative abundance in weeks 4, 5, 9, and 16 and maintains a high abundance during the entire growth process. Compared with other times, the relative abundance of *Romboutsia* is highest in week 14 (26.84%). *Fusobacterium* became the most abundant genus up to 4 weeks, but its abundance decreases with increased age (Yang *et al.*, 2022). This indicates that the gut microbiota in chickens is not static but rather undergoes continuous changes throughout their development, with specific genera becoming more or less abundant at different ages (6, 21).

The microbial community in the duodenum is highest at 7 days of age, which then decreases by 21 days. In contrast, the cecum's microbial diversity increases over time, peaking at 21 days before stabilizing. Notably, the cecum has higher community diversity compared to other parts of the gastrointestinal tract, highlighting its unique role (10). This suggests that microbiota composition varies with both the region of the gastrointestinal tract and age. The composition of microbiota in the same part of the gastrointestinal tract also varies with age. This variation indicates the evolving complexity of microbial ecosystems during early development, which is crucial for understanding gut health and the potential effects of synbiotic interventions (6).

2.2 Major Bacterial Taxa Colonizing Chicken Intestinal Tract

The chicken gut microbiota consists of hundreds of bacterial species, predominantly from the phyla Firmicutes, Bacteroidetes, Proteobacteria, and Actinobacteria. Microbial communities vary along the gastrointestinal tract, with distinct profiles observed in the crop, gizzard, ileum, cecum, and colon of broiler chickens (4, 6). Firmicutes are particularly abundant in the small intestine, comprising approximately 31 genera, with Eubacterium, Ruminococcus, and Clostridium each representing more than 5% of this phylum. Other identified genera include Riemerella, Paraprevotella, Tannerella, and Prevotella ((7, 23). As stated by Varmuzova et al. (2016, Bacteroidetes account for roughly 40% of the overall gut microbiota. Overall, the taxonomic composition of the gut microbiota varies throughout different segments of the gastrointestinal tract.

More than 90% of the microbiota in each segment of the GIT is represented by the top 3 to 4 dominant phyla found together. As indicated in Figure 1, more than 75% of the microbiota in the crop, proventriculus, gizzard, duodenum, jejunum, and ileum, and more than 50% in the esophagus and colon are represented by Firmicutes. The appendix is the only organ with a relative abundance of *Firmicutes* of less than 50%. The esophagus had the highest proportion of *Proteobacteria*, followed by the proventriculus, while the cecum had the highest proportion of *Bacteroidota*, followed by the colon. The composition of *Actinobacteria* is similar in all organs, except for the appendix and esophagus, which have the highest and lowest proportions, respectively (5, 16).

2.3 Acquisition and Development of Microbiota

To ensure a clear, sequential assessment of synbiotic effects throughout the broiler growth cycle, the experimental timeline was revised to progress chronologically. Sampling and data collection now occur at critical developmental stages: Day 0 establishes the baseline immediately post-hatch. Day 1 captures the initial response following synbiotic administration commencement. Progressing to Day 7, early shifts in gut microbiota composition and initial growth changes are evaluated. Day 12 targets mid-phase development, with a particular focus on immune system modulation. Day 21 assesses late-phase outcomes, including growth performance metrics and gut health status. The study culminates at Day 42, representing market age, for the final evaluation of overall growth outcomes (e.g., body weight, feed efficiency) and health parameters (Poultry Science Methods Guidelines, 2023); (24, 25). Beneficial microbiota can be introduced via inoculation, which increases the diversity of cecal microbiota and facilitates the colonization of specific bacteria, such as *Alistipes* and *Bacteroides*. These bacteria play a crucial role in establishing a stable gut environment (26).

From 3 to 42 days post-hatch, the cecal microbiota undergoes significant changes, which correlate with nutrient metabolism and intestinal health in the chicken (27). However, strict biosecurity measures in poultry production may limit the natural acquisition of beneficial microbiotas, indicating the need for strategies to enhance microbial diversity and functionality in broiler chickens (26). The gut microbiota of broiler chickens shows distinct patterns of microbial occurrence, characterized by colonization, disappearance, and core microbial communities (25). The "disappearance" pattern is observed with certain genera, such as *Clostridium sensu stricto*, which dominate early but decline as the chicken matures (25). Lastly, the core pattern includes stable microbial communities that persist across different gut segments, with Firmicutes remaining the dominant phylum throughout the gut (17). The development of gut microbiota in chickens starts right after hatching, as chicks are exposed to microbes from the air, feed, and their surroundings (28, 29).

Rapid colonization of gut microbiota is vital for the health and development of chickens, particularly in environments rich in pathogens. Since the gut microbiota undergoes significant changes during the early days of life, the microbial diversity and composition are evolving. For example, the cecal microbiota stabilizes around 12 days post-hatch, with notable shifts in microbial populations occurring as early as 1 day of age (6). By 21 days, the microbiota has achieved a more stable state, with specific genera, such as *Clostridium*, becoming predominant. The initial colonization phase is crucial as it lays the foundation for the gut microbiota's development and its subsequent impact on the host's physiology and health throughout the life of the chicken (8).

Applying microorganisms directly to chicks early in life can accelerate the establishment of a stable gut bacterial community, offering health benefits. Methods such as spraying eggs with adult cecal contents or probiotics have shown promise in establishing beneficial gut microbiota. Research indicates that applying dilute adult cecal content during incubation can successfully transplant spore-forming bacteria, thereby enhancing the early colonization of beneficial taxa, such as *Ruminococcaceae*, although it may not transfer all the important microbiota (14).

Additionally, per oral microbiota transplantation from healthy adult chicks significantly increases the abundance of beneficial bacteria in the gut, improving gut health and overall performance (30). Non-invasive probiotic applications before hatch in broiler chicken have also been linked to improved production performance and reduced mortality rates, suggesting that early microbial exposure can positively influence growth and health outcomes in broilers (31).

Microbiota being transplanted (MT) to day-old broiler chicks from the ceca of mature chickens has enhanced their gut microbiota diversity and improved health outcomes, such as reducing necrotic enteritis caused by *Clostridium perfringens* (30, 32). Various delivery methods, including oral gavage and spray, other than transplanting, have been shown to successfully introduce these beneficial microbes into the chicks' systems, promoting better gut health and pathogen resistance (26).

2.4 Functional Shifts in Gut Microbiota during Development

The gut microbiota is one of the most important defense components in the gastrointestinal tract against enteric pathogens (5). The gut microbiota maintains host health by regulating various physiological functions, including nutrition, metabolism, and immunity (33). Disruption of the gut microbiota-host interaction leads to the development of intestinal diseases (4, 10). *Lactobacilli* are widespread members of the gastrointestinal microflora that release enzymes into the intestinal lumen, preventing colonization by pathogenic microorganisms (5).

The functional effectiveness of gut microbiota in chickens varies significantly between early and later ages, influencing growth and health outcomes (33). From 4 to 16 weeks, the composition of gut microbiota changes significantly. The dominant phyla during this period are *Firmicutes* and *Bacteroides*. However, there is a decrease in alpha diversity, which means the variety of microbial species within the gut reduces over time. These changes in gut microbiota are linked to variations in body weight and growth performance (25). Specific microbial genera like *Bacteroides* seem to influence energy metabolism and immune function, which in turn affects body weight (33).

In the early stages of life, a higher abundance of *Bacteroides* is linked to increased production of short-chain fatty acids (SCFAs), which are beneficial for gut health. This is evidenced by reduced inflammatory markers in week-old chicks, indicating that *Bacteroides* play a crucial role in establishing a healthy gut environment shortly after hatching (25). As chickens mature into adults, the composition of their gut microbiota changes significantly and depends on their diet. *Firmicutes*, *Fusobacteria*, and *Proteobacteria* become the predominant phyla. Despite the overall decrease in microbial diversity over time, specific genera like *Bacteroides* continue to play significant roles (33). Even as the diversity of the gut microbiota decreases, it remains influential in metabolic functions related to weight gain and immune responses (26, 33). Firmicutes become functionally more effective in broilers during the later stages of development, typically after the first few weeks of age. As broilers mature, Firmicutes become one of the predominant phyla in the gut microbiota. The bacteria are supposed to increase energy metabolism and nutrient absorption, making them crucial for the growth and development of broilers as their age increases (10).

2.5 Synbiotics

The application of synbiotics in chicken feed helps mitigate the negative impacts of phasing out antibiotics on growth and health; several alternative feed additives have also been introduced in poultry production. These include exogenous enzymes, organic acids, probiotics, prebiotics, synbiotic herbs, and essential oils (34). Synbiotics, which combine probiotics and prebiotics, help promote the growth of beneficial microorganisms (9, 34). Prebiotics, specifically indigestible carbohydrates, selectively influence the intestinal bacteria and immunity of broiler chickens. Mannan oligosaccharide (MOS), the most commonly used prebiotic, inhibits the colonization of enteric pathogens, enhances immunity, alters microflora fermentation to improve nutrient availability, strengthens the mucin barrier at the brush border, reduces the turnover rate of enterocytes, and improves the integrity of the intestinal mucosa (19).

Probiotics are microorganisms that are used for and added as feed additives to generate small molecular metabolic by-products, which positively regulate the host's biological functions and act as immunomodulators (35). They primarily consist of lactic acid-producing bacteria, including various *lactobacilli* and *bifidobacteria* species, as well as yeasts like brewer's yeast and baker's yeast (17, 35). For probiotics to be effective, they must contain an adequate number of viable cells, provide health benefits to the host (such as growth stimulation), and enhance the function of the digestive tract (36).

Feed additive like probiotics is produced by isolating beneficial bacterial strains from sources like healthy chicken intestines. These strains of bacteria are cultivated in controlled environments to increase their numbers and then formulated into stable products, often mixed with excipients such as maltodextrin to ensure their survival during storage and administration (9). Although the exact mechanisms of probiotics as microbial feed additives are not fully understood, they are known to lodge in the digestive tract, endure harsh conditions, and stabilize the intestinal ecosystem. Those feed additives improve gut health by balancing gut microbiota, reducing pathogen growth, and enhancing nutrient absorption, which ultimately leads to better growth performance in poultry (23).

Synbiotics significantly improve the barrier function of the gastrointestinal mucosa in broiler chickens through various mechanisms. Probiotics, which are live microorganisms, attach to the intestinal mucosa, creating a physical barrier that prevents pathogenic bacteria from adhering to the gut lining. This process enhances the overall barrier function of the gastrointestinal tract (1, 18). Additionally, the antagonistic effects of probiotics further support the integrity of the intestinal mucosa, contributing to a healthier gut environment (19). Metabolite profiling of conditioned media from probiotics has revealed various metabolites that significantly enhance and advance transepithelial electrical resistance (TEER), a quantitative measurement of the integrity and permeability of the intestinal epithelial barrier. It reflects how tightly the intestinal epithelial cells (enterocytes) are connected through tight junctions (32). The epithelial cells in the gastrointestinal mucosa form a selectively permeable barrier acting as the first line of defense against harmful microbes. This intestinal barrier can be compromised by stress or disease, but certain probiotics can enhance its function by modulating the phosphorylation of cytoskeletal and tight junction proteins, thereby strengthening cell interactions and the stability of the intestinal lining. Probiotics have demonstrated the ability to restore the barrier function of the gastrointestinal mucosa in both in vitro and in vivo models (37).

2.6 Effect of Synbiotics on Chicken Intestinal Microflora

The use of synbiotics and probiotics has been shown to significantly impact the intestinal microflora of broilers, enhancing their health and performance (9). For example, *Bacillus subtilis* probiotics improve feed conversion ratios and reduce necrotic enteritis lesions, while enriching beneficial gut microbiota, such as *Streptococcus* and *Faecalibacterium*, which are crucial for gut health and the reduction of inflammation and disease occurrence (38). Similarly, compound probiotics containing *Lactobacillus* and *Bifidobacterium* are associated with improved growth performance and enhanced expression of intestinal barrier-related genes, indicating positive modulation of gut microbiota (32, 34). While supplementation with synbiotics at 21 days of age does not change the number of *Lactobacillus* colonies in the cecum (34), for instance, the addition of compound probiotics, including *Lactobacillus*, significantly increases the abundance of beneficial bacteria in the ceca, enhancing growth performance and reducing feed conversion ratios in broilers (38, 39).

Incorporating *Lactobacillus plantarum* in feed boosts short-chain fatty acid (SCFA) production in the intestine of the chicken and enhances cecal microbiota diversity, which is essential for improved growth performance and gut health in broiler chickens (38). Probiotics derived from Lactobacillus plantarum help reduce ammonia emissions, modulate immune responses, enhance antioxidant capacity, and improve cecal microflora composition, as well as regulate serum metabolites in broilers exposed to ammonia (3, 40). Additionally, *Enterococcus durans* combined with prebiotics has shown significant weight gain and reduced pathogen loads in broilers (31).

Probiotics and prebiotics work synergistically to maintain or enhance beneficial bacteria in the body of the chicken, with prebiotics fostering the growth of these bacteria and preventing harmful colonization (41). In synbiotic mixtures, prebiotics improve the survival and functionality of microbiota in the intestinal tract of broilers (42). Studies indicate that prebiotics like inulin and microbial polysaccharides promote the growth of beneficial bacteria, thereby enhancing gut health and performance metrics in chicken, as indicated in Table 1. For example, combining inulin with probiotics increased the abundance of beneficial strains such as *Faecalibacterium*, which is widely associated with improved immune function and enhanced resistance to pathogens (38, 42).

2.7 Effects of Dietary Supplementation of Synbiotics on Growth Performance of Chicken

Compared to taking prebiotics and probiotics separately, using synbiotics as a feed additive can improve feed efficiency (34). Synbiotics are known to increase feed conversion rates, as indicated in Table 3, meaning that chickens can convert feed into energy and body mass more efficiently (43). In addition to altering intestinal bacterial colonies and inhibiting the growth of pathogenic bacteria, probiotics and synbiotics also increase lactate and antibody production (24). The use of a combination of prebiotics and probiotics results in synergistic effects in broiler chickens, as prebiotics improve the survival and proliferation of probiotics by increasing their tolerance to high temperatures, oxygen, and low pH (43, 44).

Increased villi height in the gut, as indicated in Table 2, and improved gut health are two benefits of taking a synbiotic supplement (14). An increase in villi length, on the other hand, increases the surface area for nutrient absorption, thereby enhancing digestibility and nutrient utilization. This intervention enhances growth performance and feed conversion efficiency, leads to increased carcass yield, and reduces embryo mortality, as shown in Table 3 (14, 44).

2.8 Modulation and Monitoring of Gut Microbiota

Monitoring and modulation of gut microbiota are crucial for enhancing chicken production efficiency and its health management. Numerous investigations, as described by Dunislawska *et al.* (2017), have demonstrated that gut microbiota plays a critical role in the processes of feed digestion and resistance to pathogens, effectively diminishing the colonization of pathogens, including *Salmonella* and *E. coli*. This is achieved primarily through mechanisms of competitive exclusion and the modulation of microbial populations, as stated by (45). Moreover, interventions targeting gut microbiota have been shown to enhance thermoregulation in broilers subjected to elevated temperature conditions, thereby improving growth performance and feed conversion efficiencies (46). Studies indicate that incorporating synbiotics like *Enterococcus faecium* and *Bifidobacterium* significantly boosts growth performance and intestinal health by fostering beneficial bacteria and enhancing the production of short-chain fatty acids (SCFA). Short-chain fatty acids are essential for gut health and nutrient absorption (10). Moreover, precision glycan supplementation has been shown to enhance gut microbiota diversity and productivity, while improving disease resistance, particularly during outbreaks (24).

Synbiotic additives can further encourage fiber-degrading microbiota, resulting in improved fermentation efficiency and SCFA production, which additionally supports broiler performance (12). In addition, the application of synbiotics as substitutes for antibiotics has been associated with favorable alterations in the gut microbiota, fostering improved growth outcomes (10). The microbiota of the gastrointestinal tract can be modulated by bioactive substances such as synbiotics. These bioactive compounds can directly modulate the host microbiota, thereby having indirect effects on host organisms (14). Effective modulation of the GIT microbiota depends on the method and timing of delivery of bioactive compounds. Synbiotics are routinely added to food or water immediately after hatching. The effectiveness of early post-hatching supplementation with bioactive compounds is high because this is the period (from hatching to the second week) when the gastrointestinal tract is first colonized by microbiota and GALT becomes functionally mature (12). Alternatively, synbiotics can be delivered in ovo into the chick embryo, extending the effective duration of action to the period before hatching (10, 12).

To monitor the effectiveness of gut microbiota supplementation in chicken production, several methodologies can be employed based on recent research findings (46). Glycan supplementation has been shown to enhance gut microbiota diversity and improve performance metrics, such as weight gain and feed conversion ratios, alongside a reduction in pathogenic bacteria, including *Clostridium perfringens and Escherichia coli* (39). Additionally, the use of postbiotics and paraprobiotics has demonstrated positive modifications in the colon mucosa microbiota, promoting beneficial taxa such as Firmicutes while decreasing harmful Proteobacteria (18). Quantitative molecular assays, such as qPCR, can be utilized to evaluate specific bacterial populations linked to performance, providing a predictive tool for monitoring gut health (39).

2.9 Implications of Synbiotics in Disease Control

Antibiotic growth promoters (AGPs) are being replaced by probiotics in animals due to concerns about the development of antibiotic-resistant bacteria (44, 47). Among other things, probiotics help with digestion, lower cholesterol levels, improve lactose tolerance, strengthen immunity, reduce harmful intestinal bacteria, and maintain intestinal flora. Synbiotics contribute to these benefits by promoting the growth of beneficial bacteria and inhibiting the colonization of pathogenic bacteria in the digestive system (47). In some experimental studies, synbiotics supplementation has been shown to reduce pathogenic bacteria. For example, adding 0.05% fructone (which is a synthetic organic compound widely used in the fragrance and flavor of feed) to drinking water reduced the number of pathogenic bacteria in the gastrointestinal tract of broiler chickens, such as *Salmonella* and *Campylobacter jejuni*, *Clostridium perfringens*, but increased the amount of *Lactobacillus*, *Enterococcus faecium*, *Pediococcus acidilactici*, *Lactobacillus salivarius*, and *Lactobacillus reuteri* bacteria. These bacteria, used as probiotics, are useful in preventing the growth of harmful bacteria. Lower blood cholesterol levels are essential for cardiovascular health and can be achieved through probiotic supplementation (14, 43) Specifically, *Lactobacillus paracasei* and *L. rhamnosus*, probiotics can inhibit *C. jejuni* by competing for nutrients and binding sites in the gut, as well as producing inhibitory substances such as organic acids, hydrogen peroxide, and bacteriocins that directly affect pathogen viability (5).

The intestinal microflora of chickens contributes to controlling viral disease in addition to bacterial disease of chicken, particularly against viral infections where their infection site is at the GIT, such as nephropathogenic infectious bronchitis virus (IBV). Research indicates that the depletion of the chicken microbiota through antibiotics increases the pathogenicity and viral burden of IBV infections, highlighting the protective role of commensal bacteria in enhancing immune responses, such as type I interferon production(27). Furthermore, specific strains, such as *Lactobacillus*, can restore immune functions in microbiota-depleted chickens, suggesting potential therapeutic applications for probiotics in disease prevention (27, 45).

3 Conclusion

A comprehensive review of current research highlights synbiotics as a transformative strategy for enhancing poultry health and productivity by targeting the modulation of the gut microbiome. Formulations that combine probiotics such as *Lactobacillus*, *Enterococcus faecium*, and *Saccharomyces cerevisiae* with prebiotics like inulin, GOS, or FOS consistently demonstrate a dual effect: suppressing pathogenic bacteria (e.g., *E. coli*, *Salmonella*, *Clostridium perfringens*) while enriching beneficial microbiota. This leads to reduced disease incidence, necrotic enteritis lesions, and mortality. Such microbial optimization translates into measurable production gains, including improved feed conversion ratio, body weight gain, and carcass quality, even under stressors such as heat or disease challenges. Mechanistically, synbiotics strengthen intestinal barrier integrity, enhance short-chain fatty acid (SCFA) production, and modulate immune responses, particularly T-cell regulation and inflammatory cytokine balance, thereby improving nutrient absorption, metabolic efficiency, and reducing ammonia emissions and meat drip loss. Future research and adoption should prioritize precision formulations tailored to host genetics, delivery methods (e.g., in ovo supplementation), and optimized dosing to maximize sustainability and profitability in antibiotic-free poultry production.

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Conflict of Interest

We declare that no conflict of interest.

Author Contributions

AB write, editing, methodology, ZJ write, editing, methodology, BM write, editing, methodology, DJ write, editing, methodology, YD editing, methodology, supervise. All authors reviewed the manuscript. All authors checked and approved the final draft of the manuscript.

Data Availability Statement

All authors are ready to give the available data to the readers by requesting it via email or any communication platform.

Ethical Considerations

No ethical approval was required for this study because it is a narrative review of published studies and did not involve live animals, animal experimentation, or human participants.

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