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Review article

Review of the prospects for the use of postbiotics in the growing of broiler chickens: from probiotics to postbiotics

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Abstract

Background and Aim. Systematization of current data on the impact of postbiotics on the health and productivity of poultry to justify their use in industrial poultry farming as an effective and safe alternative to antibiotic growth promoters.

Materials and Methods. This article examined review articles on the relevance and effectiveness of postbiotics in poultry farming, published between 2020 and 2026. The analysis was based on 106 review articles published in international and domestic scientific journals with varying impact factors.

Results. A review of scientific publications on the use of postbiotic preparations in poultry farming was conducted. The analysis of available sources demonstrated that postbiotics are considered a promising alternative to probiotics and antibiotic growth promoters due to their high stability, safety, and pronounced biological activity. The results of the review indicate that the use of postbiotic metabolites contributes to the improvement of gastrointestinal health in poultry, enhances feed digestibility, stimulates growth, and reduces the prevalence of pathogenic microorganisms. In addition, postbiotics have a positive effect on the formation of a balanced intestinal microbiota and the strengthening of the immune status of birds.

Conclusion. Thus, the findings of the literature analysis confirm the significant potential for the development and implementation of postbiotic preparations in poultry nutrition technologies, which may contribute to increased productivity and improved biosafety in poultry production.

Keywords: postbiotic; probiotic; eubiosis; microbiota; immune system; homeostasis.

Introduction

At the current stage of industrial poultry farming development, it is important not only to maintain the current level of poultry production but also to improve its quality and safety, including the creation of a domestic technological and breeding base, and, on this basis, to develop a healthy diet for the population.

Currently, there is a marked increase in global consumer demand for broiler meat produced without the use of antibiotic growth promoters. This trend has sparked growing interest in the microbial profiling of chickens raised under antibiotic-free protocols, although comprehensive research in this area remains limited [1]. Poultry meat is the most produced and consumed meat worldwide [2].

According to a report published by SAMMIT summarizing Professor O. Desouzart's presentation at the XIV European Conference on Poultry Farming (ECPP), global meat production is projected to reach 505.438 mln tons by 2050, while poultry production is expected to increase by 122.5% [3].

Analysis of the global poultry market shows that industrial poultry farming is the primary driver of global meat production, successfully maintaining its dominant position [4]. However, this expansion faces a critical economic bottleneck. Feed costs account for up to 80% of total production expenses, remaining the most pressing and persistent issue for the industry despite its intensive development [5].

Poultry farming in Kazakhstan is also one of the most progressive and dynamically developing sectors of agriculture, considered cost-effective and quickly profitable [6]. There are 70 large poultry farms operating in the country, including 34 egg and 36 meat farms, as well as 7 breeding farms. These enterprises not only supply the domestic market but also export. In this regard, it should be noted that today poultry farming in Kazakhstan is actively growing, striving for self-sufficiency in poultry meat (almost 80% by the end of 2025) and export to central Asian countries [7].

The dynamic growth in demand for poultry products is driven by global demographic and socioeconomic factors: population growth, urbanization, changing age structure, and rising affluence. These trends are leading to a significant increase in protein consumption, while poultry meat remains one of the most affordable and sought-after sources of high-quality animal protein [8, 9].

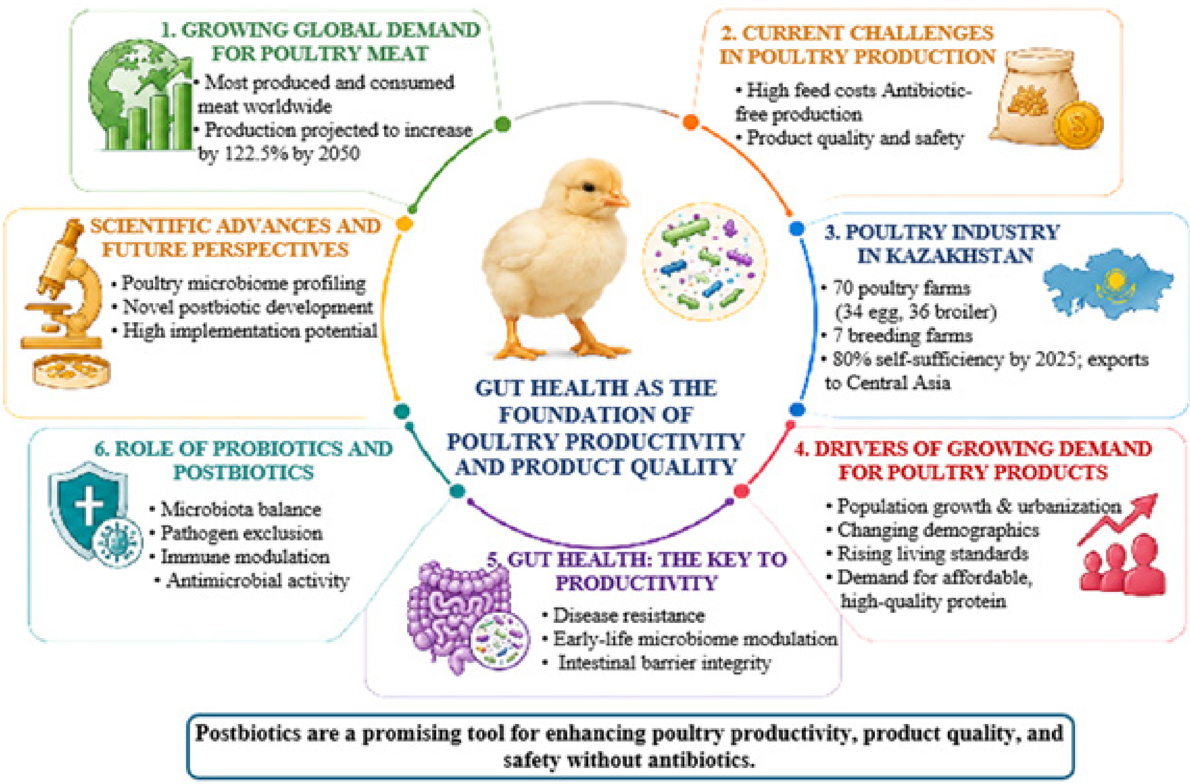

Figure 1. Role of Gut Health and Postbiotics in Enhancing Poultry Productivity, Product Quality, and Food Safety

Developing strategies to enhance poultry productivity in industrial settings remains a priority scientific and practical task. Gut health is a key factor here, determining the efficiency of nutrient absorption and the body's resistance. Targeted modulation of the microbiome during the early stages of development is particularly important, laying the foundation for long-term health and high productivity in chickens.

To solve this problem in industrial poultry farming, probiotics and postbiotics are used, which have a beneficial effect on the intestinal biocenosis by displacing pathogenic microorganisms, modulating immunity, producing antimicrobial compounds, and also maintaining the integrity of the intestinal barrier [10].

In this regard, we conducted an analytical review of the scientific literature dedicated to assessing the effectiveness of postbiotics in poultry farming. The data obtained formed the basis for the development of domestic postbiotic products with high potential for industrial implementation.

Materials and Methods

This study was conducted as a narrative literature review to summarize current knowledge on the use of postbiotics in poultry production. A total of 106 scientific publications published between 2020 and 2026 were identified and analyzed. The literature search was conducted using the scientific databases Scopus, Web of Science, PubMed, ScienceDirect, and Google Scholar.

The following keywords and their combinations were used: "postbiotics," "poultry," "broiler chickens," "layers," "gut health," "microbiota," "immune response," "growth performance," "antibiotic growth promoters," and "alternative feed additives." Publications that: (i) focused on postbiotics or postbiotic-derived compounds; (ii) assessed their impact on poultry health, performance, gut microbiota, immunity, or feed efficiency; and (iii) were published in peer-reviewed scientific journals. Studies not directly related to poultry production, duplicate publications, conference abstracts, and papers lacking sufficient methodological information were excluded.

The selected publications included review articles, original experimental studies, and research reports. Due to the heterogeneity of experimental designs, postbiotic formulations, dosages, and outcome measures, a quantitative meta-analysis was not conducted. Therefore, this work should be considered a narrative review with a qualitative synthesis of the available data. The collected information was grouped by postbiotic compound type, production methods, biological functions, mechanisms of action, and practical application in poultry production. Particular attention was paid to studies investigating growth performance, intestinal health, immunomodulation, feed conversion efficiency, and disease resistance in poultry.

Definition and classification of postbiotics

Postbiotics are preparations made from non-living beneficial microorganisms and their biologically active compounds that have therapeutic and functional potential. They consist primarily of microbial cell fractions, metabolites, enzymes, vitamins, polysaccharides, and short-chain fatty acids. These components can act directly or indirectly, but they all exert beneficial effects [11].

Postbiotics may contain intact, non-living microbial cells and/or microbial cell fragments/structures with or without metabolites/end products [12]. There are a number of microbial metabolites and/or microbial components that can be classified as postbiotics. Microbial metabolites can be very diverse, including enzymes, proteins/peptides, polysaccharides, organic acids, and lipids [13, 14].

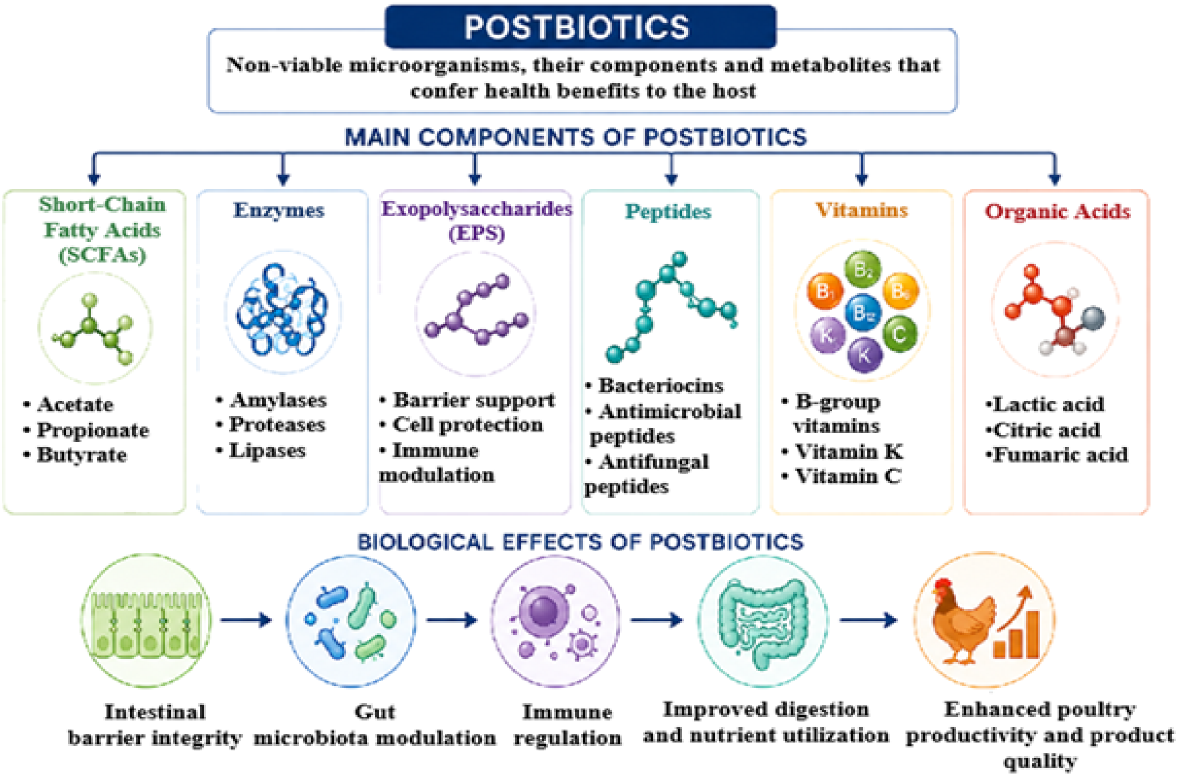

Figure 2. Main components of postbiotics and their biological functions

These low-molecular-weight biomolecules can provide a range of physiological health benefits and are the subject of revolutionary therapeutic strategies. Due to their diverse delivery methods and the ability to precisely dose, some postbiotics are promising therapeutic agents that can be used for both preventative and therapeutic purposes [15].

Short-chain fatty acids

Short-chain fatty acids (SCFAs) are produced by the intestinal microbiota as secondary metabolites during the fermentation of dietary fiber [16]. They serve as important chemical messengers in this axis, modulating hypothalamic feeding centers and systemic metabolism. The literature provides comprehensive data on the biosynthesis and kinetics of SCFAs in poultry and discusses their neural, humoral, and immune pathways to the brain [17].

Short-chain fatty acids are considered the most abundant postbiotic components formed during microbial fermentation and have been shown to be an important regulator of human gastrointestinal tract homeostasis [18].

Enzymes

Microbial enzymes, including lactase and antimicrobial proteins, can exert a positive impact on the body's health through their involvement in metabolic and protective processes. Depending on the nature of the reactions they catalyze, enzymes are divided into six main classes: oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases [19].

Enzymes such as peptidases, lipases, amylases, proteases, ureases, and antioxidants catalyze various biological processes. These are active proteins present in all living organisms. Enzymes derived from microorganisms break down components such as carbohydrates, fats, and proteins into monomers, thereby facilitating human digestion and bioavailability, as well as improving the taste and texture of food [20, 21].

Exopolysaccharides

Exopolysaccharides are biopolymers produced by microorganisms and secreted outside the cell wall [22]. They receive more attention than other polysaccharides because they play a key role in microbial adaptation to environmental conditions. They are involved in bacterial adhesion to various surfaces and help protect cells from adverse factors and pathogens [23, 24].

The role of exopolysaccharides is described in the works of *X. Zhou* et al. The authors identified the function of exopolysaccharides in intestinal barrier function. Their data showed that exopolysaccharides inhibit intestinal inflammation by regulating the function of the intestinal epithelial barrier [25]. Also, studies by *Bleau* et al. have shown that EPS obtained from several species of lactobacilli have the ability to modulate systemic and mucosal immune responses and have direct beneficial effects on health [26].

Peptides

Many bacterial species produce antimicrobial peptides called bacteriocins, which are antagonists of specific microbes. Bacteriocins are produced by ribosomes and exported into the extracellular environment [27]. They are capable of inhibiting pathogens from Gram-negative and/or Gram-positive groups [28].

There are three classes of bacteriocins from lactic acid bacteria. Classes I and II bacteriocins are stable to pH and temperature and, therefore, can retain their antimicrobial function after exposure to heat [29]. Class III is the only heat-labile class of bacteriocins derived from lactic acid bacteria, and therefore, class III bacteriocins remain active only if the postbiotic preparation process does not include a thermal inactivation step [30].

Vitamins

Microorganisms also produce vitamins, leading to the consideration of fermented foods (FPs) as a potential means of improving vitamin intake [31].

Among the microorganisms responsible for fermentation, a number of strains possess the ability to biosynthesize vitamins, which are successfully used to enhance the vitamin content of raw materials [32].

Vitamins are a chemically diverse group of organic compounds that are required in trace amounts but are essential for maintaining cellular and systemic physiology in all areas of life. Unlike macronutrients, which serve as structural components or energy sources, vitamins function primarily as cofactors or precursors of coenzymes, mediating a wide range of enzymatic reactions involved in central metabolism, biosynthesis, regulation of redox processes, and cellular signaling [33, 34, 35, 36].

Organic Acids

The production of organic acids through microbial fermentation using less expensive raw materials is also a major advancement in industrial microbiology. A number of studies have focused on the microbial sources and methods for producing various organic acids (citric, gluconic, fumaric, and lactic acids), used primarily in the food industry [37].

Research by *I.V. Rozhkova* et al. demonstrated that organic acids are a component of metabolic processes occurring in postbiotic substances obtained using the studied probiotic cultures L. paracasei ABK and L. helveticus H9 [38].

Organic acids are produced by beneficial intestinal bacteria through the fermentation of carbohydrates, which have long been added to feed to minimize contamination and the growth of harmful bacteria and fungi, reduce spoilage, and extend the shelf life of feed products. Moreover, they are most often added to poultry feed in the form of mixtures to achieve maximum positive effect [39].

The Role of Microbiota in Chicken Production

The gut health of farm animals and poultry is fundamental to profitability, as it significantly impacts growth performance, disease resistance, and product quality. With the restriction of antibiotic use in livestock production, probiotics, prebiotics, synbiotics, and postbiotics (PPSPs) have emerged as promising alternatives [40, 41].

The gut is known to play a vital role in the healthy growth and development of chickens, serving as a barrier to the immune system. Approximately 70–80% of immune cells are associated with the gastrointestinal tract, which together form a unified defense against pathogens while maintaining the body's homeostasis. This balance is disrupted by various stresses, which negatively impact the immune system and the microbiota, leading to health problems, as the microbiota is involved in the synthesis of neurotransmitters and regulates the stress response [42].

Research by *Teame* et al. has shown that lactobacilli postbiotics, including pili and p40/p75 protein, protect the intestinal barrier, stimulate the production of aggregation factors, bacteriocins, and S-layer proteins, and promote pathogen elimination [43]. It was found that adding carriers consisting of lactobacilli in the form of a probiotic (Pro) and a postbiotic (Post) to the diet of broiler chickens resulted in accelerated growth up to day 35 and up to day 21, respectively. The postbiotic increased feed conversion after day 22, while the probiotic had no effect compared to the control group [44].

The gastrointestinal tract (GIT) is a complex microecosystem where billions of microorganisms (microbiota) interact closely with the host organism. This interaction is critical for digestion, immunity, and overall health, as the microbiota influences food absorption, protects against pathogens, and affects the development of the immune system, forming a dynamic symbiosis [45, 46, 47]. This complex structure plays a crucial role in maintaining the health and well-being of animals. The use of postbiotics helps to optimize the morphofunctional state of the intestine and improve the quality characteristics of broiler meat, while ensuring the intensification of nutrient absorption [48]. Their mechanism of action includes support of local immunity of the mucosa and effective modulation of the composition of the microbiome [49]. Possessing biological effects comparable to those of probiotics, postbiotics demonstrate significantly higher technological and biological stability [50].

Despite the proven benefits, a number of researchers report no significant changes in the qualitative and quantitative composition of the microbiome when postbiotics are included in standard poultry diets. However, these studies did document a significant effect of the supplements on the metabolic activity of the microflora, particularly on the concentration of short-chain fatty acids (SCFAs). Notably, in some experiments, regardless of the dietary composition, the addition of postbiotics did not cause statistically significant changes in the assessed immune status parameters [51].

Thus, the poultry gut microbiome plays a key role in nutrient digestion, immune system function, and overall health. It acts as a link between the external environment and the body, modulating intestinal morphology, immune responses, and even behavior [52, 53].

The antibiotic-probiotic-postbiotic concept in poultry farming

The concept of a sequential transition from antibiotics to postbiotics, through the probiotic stage, is currently recognized as the most promising. Postbiotics are the logical conclusion of this chain, as they lack the disadvantages of live microorganisms, providing consistent results and safety without sacrificing effectiveness in maintaining poultry health.

An analysis of historical and current data revealed a clear global trend: the poultry industry is undergoing a forced evolution of feed strategies driven by the need to overcome the antibiotic resistance crisis. Historically, the high stocking density of broiler chickens has predetermined the widespread use of in-feed antibiotics. However, a summary of recent findings [54, 55, 56] shows that the eradication of pathogens (antibiotics) has been replaced by a paradigm of modulating the indigenous microbiota (pro-, pre-, post-, and phytobiotics).

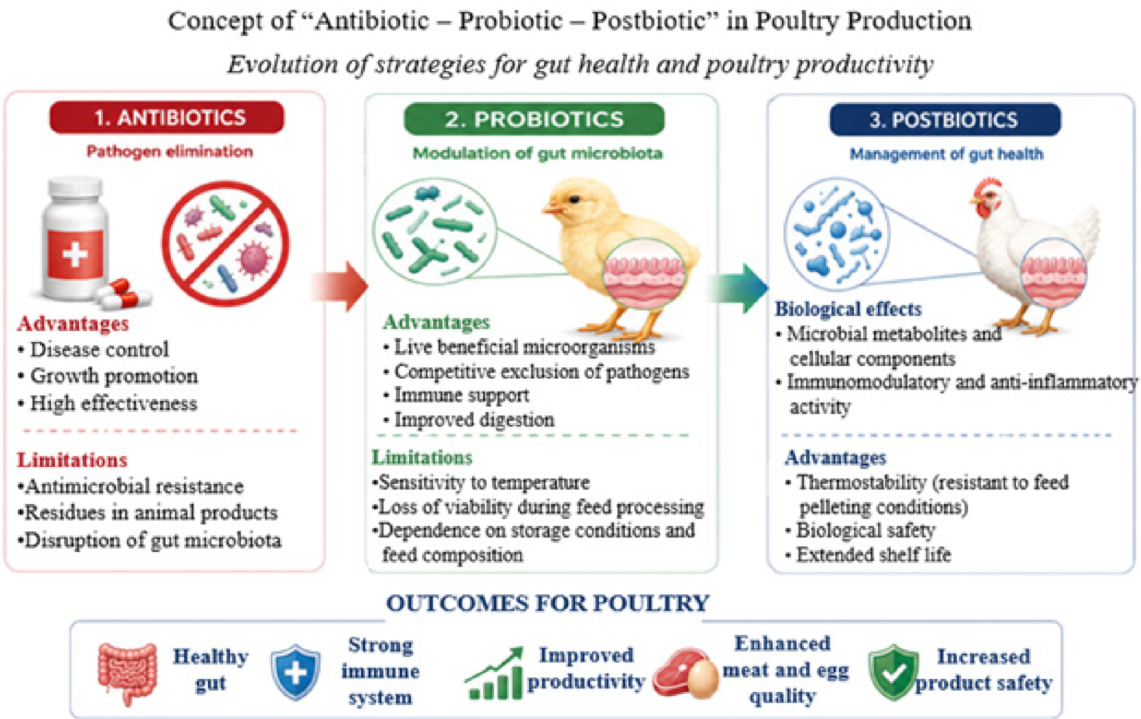

Figure 3. Evolution of nutritional strategies for gut health management in poultry: transition from antibiotics to probiotics and postbiotics

In 2001, a group of experts from the Food and Agriculture Organization of the United Nations and the World Health Organization officially defined probiotics as live bacteria that, when consumed in appropriate amounts, can confer a health benefit on consumers. However, despite the proven multifunctionality of live bacterial cultures, a detailed analysis of their use in industrial poultry farms revealed a systemic technological barrier associated with the viability of probiotics, which is critically dependent on feed pelleting conditions (high temperatures and pressure), as well as the pH of the poultry gastrointestinal tract [57].

The use of probiotics in poultry farms can ensure product safety and cost-effectiveness [58]. While the mechanisms of live probiotics for neutralizing mycotoxins [59, 60, 61] and removing heavy metals [62] have been well documented, the extrapolation of these properties to postbiotics remains controversial. There is virtually no data in the literature on whether inactivated cells (lysates, cell walls) are capable of maintaining similar enzymatic activity against toxins or whether their action is limited solely to passive physical sorption.

An analysis of accumulated data allows us to identify two key and complementary mechanisms of the protective effect of probiotics in broiler chickens. On the one hand, their biological role in the formation of a healthy microbiota is noted: lactic acid synthesized by lactic acid bacteria effectively suppresses pathogenic flora and stimulates early morphofunctional maturation of the poultry gastrointestinal tract during postnatal ontogenesis [63]. On the other hand, this effect is enhanced by chemical protection, expressed in the ability of probiotic cultures to reduce the overall toxic load on the chickens' bodies and accelerate the elimination of heavy metal salts [64].

The traditional paradigm for the use of probiotics is based on maintaining the target titer of viable microorganisms throughout the entire exposure period. However, in any native culture of the strain, a fraction of inactivated cells is inevitably present [65].

Scientific evidence indicates that these structural components and their metabolites possess independent biological activity and exert beneficial effects on the host organism, directly or indirectly [66]. The key advantage of postbiotics in industrial poultry farming is the combination of high technological resistance and guaranteed biological safety. Unlike live cultures, they maintain stable characteristics during aggressive feed processing and eliminate the risks associated with uncontrolled microbial behavior. Therefore, the use of inactivated microbial structures and their metabolites opens up broad prospects for the development of next-generation functional preparations with distinct competitive advantages over traditional live cultures.

Current trends in poultry farming indicate the high efficiency of postbiotics, both as standalone agents and as part of synergistic combinations. While postbiotics, when combined with prebiotics, are considered a direct alternative to feed antibiotics for stimulating the immune response and basic growth intensification in broiler chickens, their integration with phytobiotics provides a much more profound multifunctional effect. Complex diets based on post- and phytobiotic components enable targeted modulation of not only intestinal morphology but also macrostructural parameters: carcass characteristics, meat quality indicators, and tibia architecture in poultry.

Analysis of the available data revealed, postbiotics have been shown to have a predominant effect on innate immune mechanisms, possessing significant immunomodulatory potential. Under infectious stress, these drugs act to suppress proinflammatory reactions and promote a stable homeostatic response. In particular, studies by *C.N. Johnson* et al. confirmed the specific immunomodulatory effect of postbiotics directly on the lymphoid tissue of the small intestine of broilers [67].

A study of various dosages of a postbiotic based on Lactobacillus plantarum in broiler diets confirmed its pronounced multifunctional effectiveness. Including this feed supplement in the main diet has a comprehensive effect on the bird's body, optimizing the microbial profile and biodiversity of the cecum, activating the intestinal enzymatic system, which ultimately directly translates into improved growth and slaughter performance [68].

Analysis of efficacy data also shows that postbiotics improve intestinal villus health, increase lactic acid production, and reduce enterobacteria and fecal pH, which collectively leads to improved immune response and intestinal health, as well as increased growth performance. Postbiotics also reduce yolk and plasma cholesterol levels in laying hens and improve egg quality [69].

Postbiotic use has resulted in improved growth performance, meat quality, fecal lactic acid bacteria counts, villus height, and the ability to withstand heat stress in broilers, laying hens, and pigs [70]. Inclusion of postbiotics in feed and water has shown positive results in reducing the severity of nephrotic enteritis and improving liver and immune health in broiler chickens compared to commonly used probiotics and antibiotics [71].

In conclusion, it should be emphasized that the transition from antibiotics to probiotics and further to the use of postbiotics marks a fundamental evolution in poultry feeding strategies. This concept reflects a shift from attempts to quantitatively colonize the gut with live microflora to methods of targeted management of poultry health and homeostasis using heat-stable and technologically advanced biomolecules with predictable biological effects.

A comparative analysis of the data revealed a clear shift in research interest from probiotics to postbiotics. This is driven by a key technological trend: postbiotics, unlike live cultures, are heat-stable during feed pelleting and have a long shelf life, which solves the main problem with traditional probiotics.

Alternatives and the effectiveness of postbiotics in poultry farming

Postbiotics are the most rational alternative in poultry farming, as they combine the safety of antibiotics with the functional benefits of probiotics, while mitigating their production shortcomings.

Despite the steady growth in the number of publications on postbiotics, debate continues regarding their precise definition [72]. Over the past decade, probiotics have become the subject of intensive research due to their ability to improve gut health and modulate the microbiome, aiding in the treatment and prevention of disorders, strengthening the immune system, and participating in digestion, as confirmed by numerous clinical studies [73]. It should be noted, however, that preserving live, active bacteria with desired properties in probiotics is not always achievable. Therefore, the search for ways to utilize non-living probiotic bacterial cells, i.e., their metabolites-postbiotics-has become a pressing issue in the field of biotechnology.

The global literature contains extensive data confirming the effectiveness of postbiotics in poultry farming. Numerous publications attest to their positive impact on stimulating productivity and restoring the intestinal microbiome of poultry.

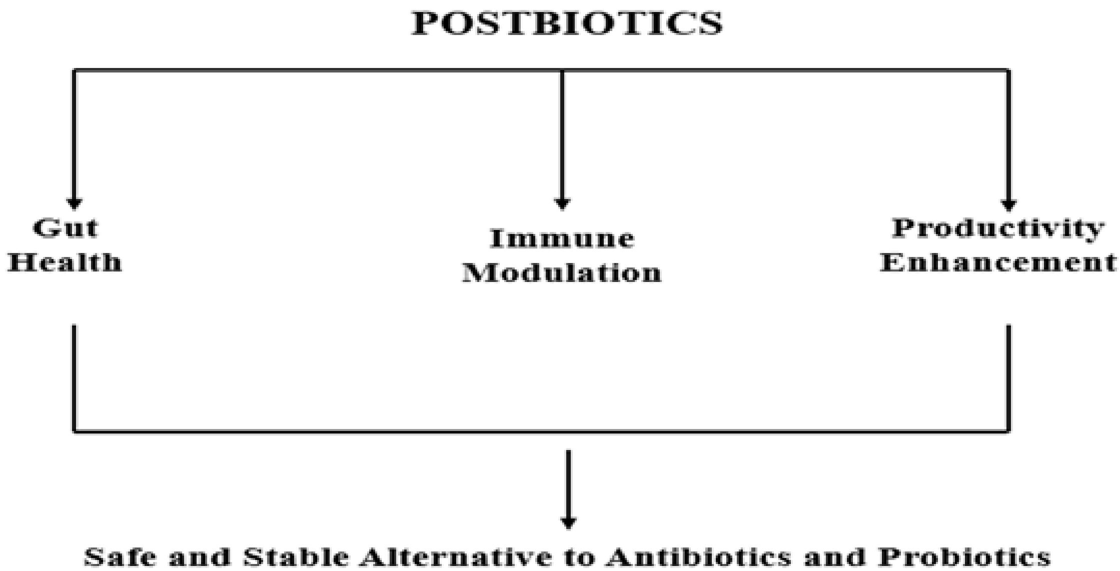

Figure 4. Postbiotics as a safe and stable alternative to antibiotics and probiotics in poultry production

In a study by *Kareem* et al. to determine the effect of postbiotics synthesized by Lactobacillus plantarum and inulin on the performance of broiler chickens, it was found that chickens fed a combination of postbiotics and inulin in starter and finisher diets demonstrated significantly higher body weight and weight gain compared to the control group. Postbiotics can reduce the number of pathogenic microorganisms in the intestine, improving intestinal health and growth efficiency [74].

Postbiotic use improves intestinal villi and intestinal barrier function, increases lactic acid production, and reduces enterobacteria and fecal pH, which contributes to improved immune response, intestinal health, and growth. Postbiotics also reduce plasma cholesterol and triglyceride levels in poultries [75].

Scientific studies by a number of authors confirm that introducing a 0.2% Lactobacillus acidophilus-based postbiotic into broiler diets effectively replaces feed-based antibiotic growth promoters. At this dosage, the preparation not only demonstrates high antibacterial activity but also eliminates the risks associated with the use of live probiotic cultures, such as excessive immune stimulation and competition between microflora and the host organism for nutrients [76].

Y. Chen et al. demonstrated the high therapeutic efficacy of Bifidobacterium bifidum (BbP)-based postbiotics as an alternative to antibacterial drugs for Salmonella Pullorum infection. The key mechanism of action of BbP is the suppression of pyroptosis, a specific form of programmed epithelial cell death induced by Salmonella. In parallel with this, the postbiotic ensures the regeneration of the intestinal barrier function through the expression of tight junction proteins and modulates the composition of the microbiota, creating unfavorable conditions for pathogen persistence [77].

The use of the postbiotic Culbac (a fermentation product of inactivated Lactobacillus acidophilus strains; TransAgra International Inc., USA) in chicken diets demonstrated its therapeutic potential, significantly reducing clinical morbidity and mortality, as well as minimizing pathological lesions of the intestinal mucosa, compared to an untreated infected control group [78].

All postbiotics available on the market represent a complex of biologically active metabolites of probiotic microorganisms that have significant potential for improving poultry productivity. Their effectiveness is due to their pronounced immunomodulatory effect, which is manifested by the activation of both innate and adaptive immune mechanisms in chickens [79].

A review by *R.C. Reuben,* et al. examined the concept, impact, and mechanisms of application of prebiotics, probiotics, and postbiotics in poultry farming and found that their use will undoubtedly lead to a more sustainable, safe, and cost-effective poultry industry, which will help feed the world [80].

The authors *Y. Danladi,* et al. investigated the effect of postbiotics and paraprobiotics from an active culture of *Lactiplantibacillus plantarum* instead of antibiotics and obtained positive effects on growth performance, small intestinal morphology, immune status, and liver growth gene expression in broiler chickens [81].

In the last decade, numerous scientific and clinical studies have been devoted to the study of the effect of probiotics, prebiotics, and symbiotics in diets, given their positive impact on microbial composition and normalization of intestinal balance [82].

The intestinal barrier is known to maintain intestinal integrity and provide protection against the penetration of intestinal pathogens [83]. The immune system can also influence the permeability of the intestinal barrier [84]. The literature reports the influence of pro- and postbiotics on immunity-related parameters [85].

Numerous studies examining postbiotics show that their effects on the immune system and intestinal barrier are comparable to those of probiotics, but they are also more stable and maintain their safety. This means that postbiotics are similar to probiotics in many ways and are more stable. However, optimal technologies for producing postbiotics, as well as their indications, have not yet been clearly developed. Therefore, this area requires in-depth and thorough research [86, 87].

Unlike probiotics, postbiotics do not require survival in the intestine, which makes them a promising option for poultry applications. Their mechanism of action is based on the direct interaction of bacterial metabolites with the intestinal epithelium and immunocompetent cells of the gastrointestinal tract. Postbiotics can modulate the immune response and enhance the integrity of the intestinal barrier. The latter, acting synergistically with the immune system and the microbiota, provides comprehensive protection against infections and helps maintain host homeostasis.

In this regard, Professor Mikhail Chikindas of Sechenov University noted in his presentation that postbiotics are unlikely to replace probiotics in the market, as probiotics can proliferate within the host and exert beneficial effects for a longer period than inactivated microorganisms. Despite the smaller size of the postbiotics market compared with the probiotics market, analysts report that the former is growing ten times faster than the latter; therefore, the health products market is expected to undergo significant changes in the near future.

Accordingly, an increase in the number of studies focused on postbiotics and the development of scientifically grounded approaches to their industrial production can be anticipated. Such advances may help mitigate the safety risks associated with live microbial cultures while ensuring high product stability and preserving biological activity.

Existing Limitations in the Standardization, Economic Aspects, and Prospects for the Application of Postbiotics

Despite the advantages of postbiotics highlighted in this review, further research is required to understand the more complex interactions between these compounds and their relationships within different poultry species and their immune systems [88].

Numerous studies have reported that, in addition to the positive effects of postbiotics on poultry health and growth performance, several challenges limit their large-scale implementation in production systems [89].

Studies evaluating the efficacy of postbiotics in broiler chickens have demonstrated no statistically significant improvements in feed conversion ratio (FCR) or average daily gain (ADG) compared with control groups. In this regard, strain specificity plays a significant role; that is, a postbiotic preparation derived from one particular bacterial strain may exhibit strong antimicrobial activity, whereas another strain of the same species may produce only negligible effects [90].

In most studies assessing the efficacy of postbiotics in animals, a specific dosage has not been established. In the study by *Y. Danladi,* et al. (2022), which investigated the use of postbiotics and paraprobiotics as alternatives to antibiotics in broiler chicken production, no statistically significant differences (($p > 0.05$)) were observed among the experimental groups with respect to final body weight, total body weight gain, or feed conversion ratio [81].

There are also reports indicating that the inclusion of various postbiotics in the diets of broiler chickens reared under heat stress conditions does not significantly affect carcass yield. This finding is consistent with the results reported by *Kareem* et al. (2016), who likewise observed that the combined administration of postbiotics and inulin had no effect on broiler dressing percentage [91].

The effects of postbiotics on growth performance and intestinal health remain inconsistent, despite their recognition as active growth-promoting agents. Therefore, researchers emphasize the need for additional studies to standardize postbiotic therapy and to investigate its long-term effects on poultry productivity [92].

The scientific literature describes numerous challenges associated with the standardization and industrial production of postbiotics, primarily due to the absence of a unified international regulatory framework and clearly defined quality control standards. *N. Piqué* et al. identified technological barriers, including the complexity of the chemical composition of postbiotic metabolites, which complicates the development of standardized quality control protocols for industrial production [93].

Consequently, postbiotics require a clearer classification system and nomenclature in both commercial and regulatory contexts [94].

It should also be noted that postbiotics present limitations for large-scale production from a commercial perspective. Their production costs remain substantially higher than those of traditional feed additives such as prebiotics and organic acids. This is attributable to the high costs associated with downstream processing required for cell inactivation, as well as spray-drying or freeze-drying procedures. Ultimately, these factors increase feed production costs, making the return on investment (ROI) unpredictable for large poultry enterprises.

The study by *T.H. Khayoon,* et al. (2024) experimentally confirmed that, despite significant improvements in feed conversion and the production index following postbiotic supplementation, the economic efficiency of feed expenditures declined compared with the unsupplemented control group due to the high cost of the postbiotic component itself [95].

In addition, the application of postbiotics in industrial poultry production presents operational challenges associated with high-temperature feed processing (80–90 °C) during pelleting. Although postbiotics are generally more thermostable than live probiotics, prolonged exposure to heat may still denature thermolabile enzymes and vitamins present within the matrix [96].

Thus, substantial heterogeneity in postbiotic characteristics, dosage regimens, and experimental designs limits the comparability of results across studies. Therefore, future research in this field should prioritize the standardization of postbiotic composition, evaluation of dose response relationships, and large-scale commercial validation to ensure consistent application under industrial production conditions.

Conclusion

This review demonstrated improvements in the productivity and economic efficiency of poultry production.

The results of this review demonstrate the feasibility of using postbiotics in industrial poultry production. The use of postbiotics helps stabilize homeostasis and correct the physiological status of poultry, which translates into enhanced growth processes and optimized meat production profitability.

It is known that the traditional practice of extensively using antibiotics in poultry production for the prevention and promotion of growth has become unsustainable. The key negative consequences include the spread of antibiotic resistance and intestinal dysbiosis in poultry, which poses risks to food security.

One of the key factors driving the transition from antibiotics to probiotics in poultry production was the ban on their use, which forced the industry to seek safe biological alternatives. Officially, on January 1, 2006, the European Union imposed a complete ban on the use of antibiotics as growth promoters in livestock feed. The decision followed a long-standing debate about the risks associated with the widespread use of antimicrobials in industrial livestock production and reflected growing concern in the EU about the problem of bacterial resistance to antibiotics [97].

In this regard, the transition to the use of probiotics has become an important step towards greening poultry farming. While live cultures have the ability to competitively displace pathogenic microflora and stimulate the immune response, they nevertheless face significant technological challenges. Key challenges include low thermal stability, leading to loss of viability during feed expansion and pelleting at temperatures above 75–80 °C, as well as the additional time required for adhesion and colonization of the intestinal epithelium.

The limitations inherent in live cultures have led to the emergence of a new category of bioactive compounds – postbiotics. According to the ISAPP definition (2021), which remains valid in 2025, postbiotics are preparations of non-living microorganisms or their components that provide a health benefit to the host.

Thus, despite the proven effectiveness of probiotics in maintaining the microbiome and optimizing digestive processes in chickens, their widespread use is limited by their low technological stability. The main challenge remains maintaining the viability of vegetative forms of microorganisms under aggressive production conditions and during transit through the gastrointestinal tract. Postbiotics-preparations based on inactivated microbiotic structures and their metabolites-are being considered as a promising alternative that offsets these shortcomings.

The conducted theoretical analysis confirms the high potential of postbiotics in chicken rearing and opens up new prospects for industrial poultry farming. In this regard, as part of a grant project funded by the Ministry of Healthcare and Education of the Republic of Kazakhstan, we are conducting research to identify probiotic microorganisms that produce postbiotics, such as exopolysaccharides, organic acids, and bacteriocins. In conclusion, postbiotics and sustainable poultry farming will ensure food safety and security worldwide.

Authors' Contributions

The authors jointly developed the concept and study design. Literary source search and selection, data analysis – GK and all others; Critical text editing, scientific content verification - Zh T. Scientific supervision, author coordination, approval of the final version of the article – MB.

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