Review Article

Journal of Advanced Veterinary Research
(2025) Volume 15, Issue 5, 740-745

Phytobiotic feed additive as a new strategy to replace synthetic antibiotics: A Review

Binti Ma'rifah, Luthfi D. Mahfudz*, Rina Muryani, Nur M. Wahyuni, Edjeng Suprijatna, Dwi Sunarti, Sri Kismiati, Teysar A. Sarjana, Hanna D. Shihah

Department of Animal Science, Faculty of Animal and Agricultural Sciences Universitas Diponegoro, Semarang 50275, Central Java, Indonesia.

ARTICLE INFO

Recieved: 15 September 2025

Accepted: 10 October 2025

*Correspondence:

Corresponding author: Luthfi D. Mahfudz
E-mail: luthfidjauharimahfud@lecturer.undip.ac.id

Keywords:

Phytobiotic, Antibiotic growth promotor, Herbal plants, Broiler, Pig.

ABSTRACT

The ban on synthetic antibiotics is the starting point for the discovery of other materials to replace them, one of which is materials of natural origin which are safer and easier to obtain is feed additive. Feed additives are additional ingredients that are mixed into animal feed to increase productivity, increase growth and improve animal health. Several feed additives that can be added to animal feed include probiotics, prebiotics, organic acids, enzymes and phytobiotics. Phytobiotic feed additives have been widely researched and developed as natural growth promoters for poultry. Phytobiotic feed additives can improve digestion and absorption of nutrients, increase enzyme secretion in the digestive tract, reduce oxidative processes, and reduce the growth of pathogenic bacteria. This mechanism has an impact on improving the health status of livestock, increasing feed intake and ration efficiency, improving carcass quality, and increasing the quality and shelf life of the meat produced. This review focused on alternatives to replace synthetic antibiotic that provide more safety to broiler production.

Introduction

Feed additives are supplementary components incorporated into animal feed to enhance productivity, promote growth, and improve livestock health (Valenzuela-Grijalva *et al*., 2017). These additives include probiotics, prebiotics, organic acids, enzymes, and phytobiotics (Gadde *et al*. 2017). Phytobiotics, in particular, has gained prominence as a subject of scholarly inquiry. Recent research and development efforts have focused on phytobiotic feed additives as natural growth enhancers for poultry (Franz *et al*. 2010). These additives can improve nutrient digestion and absorption, stimulate enzyme secretion within the digestive system, reduce oxidative processes, and inhibit proliferation of harmful bacteria. Such actions contribute to enhanced livestock health, increased feed consumption and efficiency, improved carcass quality, and extended quality and shelf life of meat (Valenzuela-Grijalva *et al*., 2017).

Phytobiotics derived from plant sources contain bioactive compounds that can enhance animal performance and health. These natural additives have shown promising results in improving gut health, immune function, and overall productivity in livestock. As consumer demand for antibiotic-free animal products continues to grow, phytobiotics represent a sustainable and safe alternative to traditional growth promoters in animal feed. Although phytobiotics offer numerous benefits as natural feed additives for livestock, their effectiveness may vary depending on factors such as plant source, extraction method, and dosage. Additionally, the complex nature of plant-derived compounds poses challenges in standardizing their composition and ensuring consistent results across different production systems. Bioavailability and bioaccessibility are crucial factors that significantly affect the efficacy of bioactive compound combinations. Bioavailability refers to the proportion of a nutrient or bioactive compound that is absorbed and available for use or storage in the body. Bioaccessibility, on the other hand, is the fraction of a compound that is released from its food matrix and becomes available for absorption in the gastrointestinal tract. The combination of bioactive compounds can alter bioavailability and bioaccessibility. For example, interactions between phytochemicals during intestinal absorption can lead to changes in the bioavailability of these compounds, subsequently affecting their biological activity. The presence of other food components, including other bioactive constituents, can either enhance or impair the bioavailability of the target compounds (Phan *et al*., 2017). Various delivery systems have been developed to enhance the bioaccessibility and bioavailability of bioactive compounds, including encapsulation technologies that protect these compounds from degradation and facilitate their absorption. Nanostructured delivery systems have been shown to improve the bioaccessibility and bioavailability of carotenoids, which are essential diet-derived bioactive compounds for human health (Molteni *et al*., 2022). Similarly, polysaccharide-based porous biopolymers have been used to enhance the stability and bioavailability of bioactive compounds, such as lycopene and curcumin, which tend to have poor chemical stability and low bioavailability (Ubeyitogullari *et al*., 2022). The design of excipient nanoemulsions can significantly increase the oral bioavailability of hydrophobic bioactive compounds found in natural foods because of their ability to enhance bioaccessibility, absorption, and chemical transformation of these compounds (Salvia-Trujillo *et al*., 2016). These delivery systems not only improve the absorption of bioactive compounds but also enhance their stability against environmental stresses, ensuring a more effective health benefit when consumed. Increasing the bioavailability and bioaccessibility of bioactive compounds through advanced delivery systems and understanding their interactions can potentially lead to enhanced health benefits. These strategies are essential to maximize the therapeutic potential of bioactive compounds in functional foods and nutraceuticals (Lazar *et al*., 2024; Rein *et al*., 2013). This review provided an updated overview of the use of phytobiotic feed additives to replace synthetic antibiotics in poultry production.

The Ban of Synthetic Antibiotics

The prohibition of synthetic antibiotic use in poultry production has been implemented in several regions, including the European Union, Canada, and the United States, in response to escalating global concerns regarding antibiotic resistance and its implications on human health (Alghirani *et al*., 2021; Hasted *et al*., 2021; Lone *et al*., 2022; Alabi *et al*., 2024; Ishaq *et al*., 2024). This policy has necessitated urgent exploration of alternative methods to sustain poultry health and productivity without relying on synthetic antibiotics. A primary motivation for this ban is the increasing prevalence of antibiotic resistance resulting from the misuse of antibiotics in poultry, which has led to the emergence of resistant bacterial strains capable of being transferred to humans through the food chain. Resistance can propagate through horizontal gene transfer, wherein resistant bacteria transfer resistance genes to other bacteria via plasmids and integrons (Apata, 2009; Tsujii *et al*., 2020). This phenomenon poses a significant public health risk (Alabi *et al*. 2024; Azizi *et al*. 2024; Ishaq *et al*. 2024; Lone *et al*. 2022). Food safety concerns have also driven this movement, as the presence of antibiotic residues in poultry products has increased consumer demand for antibiotic-free poultry, thereby prompting the development of stringent regulations in various countries (Alghirani *et al*., 2021; Alabi *et al*., 2024; Ishaq *et al*., 2024).

In poultry and swine production, antibiotics are routinely employed both prophylactically to prevent and therapeutically to treat diseases. In poultry, antibiotics are administered at subtherapeutic doses to mitigate the risk of disease transmission in densely populated farming environments (Ogbuewu *et al*., 2022). These antibiotics inhibit the growth of pathogenic bacteria, thereby reducing disease incidence and enhancing overall animal health and productivity. In swine, antibiotics, such as carbadox, are pivotal in preventing diseases, such as dysentery, and improving feed efficiency. Carbadox, an in-feed antibiotic, influences the swine gut microbiota by inhibiting the proliferation of harmful bacteria, such as Escherichia coli (Looft *et al*., 2014). Their therapeutic mechanisms involve direct targeting of bacterial pathogens responsible for infections in these animals. Antibiotics are also administered via medicated feed or water to treat bacterial infections including respiratory and enteric diseases. These antibiotics function by inhibiting bacterial growth or eradicating bacteria, thereby aiding the control of infectious diseases in livestock (Lekagul *et al*., 2020; Islam *et al*., 2024). However, the use of antibiotics at subtherapeutic doses as growth promoters has been a prevalent practice aimed at enhancing production performance. The extensive use of antibiotics in poultry and swine farming has been instrumental in promoting animal growth and preventing disease. Nonetheless, this practice has also led to significant challenges such as antimicrobial resistance (AMR). The misuse and overuse of antibiotics have contributed to the development and dissemination of antibiotic-resistant bacteria, posing a threat to both animal and human health (Abreu *et al*., 2023; Koch *et al*., 2017). Improper application of antibiotics in livestock has resulted in the emergence of multidrug-resistant (MDR) bacteria, such as methicillin-resistant Staphylococcus aureus (MRSA) and colistin-resistant strains. These bacteria can be transmitted between animals and humans as well as across the animal production chain, raising concerns about treatment failures and public health risks (Lekagul *et al*., 2020; Islam *et al*., 2024).

Antibiotic resistance has been documented in pathogens, such as Escherichia coli and Salmonella spp., in poultry, meat, and eggs. For instance, research indicates that E. coli strains isolated from raw chicken and raw meat exhibit varying levels of resistance, reaching up to 23.3% in chicken and 13.3% in raw meat (Rasheed *et al*., 2014). Similarly, Salmonella spp., a common pathogen in poultry products, demonstrates considerable antibiotic resistance. Resistance among Salmonella isolates from eggs can be notably high, with some studies reporting the presence of multidrug-resistant strains (Kemal *et al*., 2016; Li *et al*., 2020). These resistant strains pose a significant health risk as they can result in foodborne illnesses that are challenging to treat. Additionally, antibiotic residues in poultry products, such as meat and eggs, may adversely affect consumer health by triggering allergic reactions and facilitating the transmission of antibiotic-resistant infections (Mund *et al*., 2016). In light of the growing awareness of antibiotic resistance, there is an increasing focus on reducing antibiotic use in livestock through the enforcement of stringent regulations and exploration of alternative strategies.

Natural Feed Additive

The search for alternative materials to replace antibiotics has prompted research into natural substances that can fulfill similar roles and functions. For instance, potential substitutes, such as essential oils, bacteriophages, antimicrobial peptides, probiotics, prebiotics, synbiotics, and plant extracts or phytobiotics, are being investigated to replace antibiotics while simultaneously enhancing animal health and production efficiency (Hill and Li, 2017; Jiang *et al*., 2024).

Essential oil

Essential oils represent a viable natural alternative to synthetic antibiotics, particularly in response to the escalating issue of microbial antibiotic resistance. These oils, which are composed of aromatic compounds extracted from plants, have demonstrated antimicrobial, antioxidant, and immunomodulatory properties (Valdivieso-Ugarte *et al*., 2019). The efficacy of essential oils against a range of pathogens, including multidrug-resistant strains, underscores their potential as promising antimicrobial agents (O'Bryan *et al*., 2015). Numerous studies have investigated the antimicrobial properties of essential oils. For instance, essential oils derived from aromatic plants and nanoencapsulated essential oils have been evaluated for their antimicrobial properties to control foodborne pathogens and antibiotic-resistant bacteria in animal production (Zhang *et al*., 2022).

Essential oils have been investigated as safe and effective natural agents in the context of animal agriculture. For example, Syzygium aromaticum essential oil effectively combats bacterial resistance in poultry and promotes safe antibacterial standards without adverse effects (Oliveira *et al*., 2024). Furthermore, essential oils serve as natural alternatives to antibiotic growth promoters in poultry nutrition, demonstrating beneficial effects such as appetite stimulation, enhancement of enzyme secretion, and activation of immune responses (Krishan and Narang, 2014).

Bacteriophages

Bacteriophages, often termed phages, are viruses that specifically infect and lyse bacterial cells. Thus, they have emerged as promising alternatives to synthetic antibiotics. The primary advantage of using bacteriophages is their ability to selectively target bacterial pathogens without affecting human cells or beneficial bacteria within the microbiome. This specificity mitigates complications such as antibiotic-induced dysbiosis and secondary infections (Aminov *et al*. 2017). Furthermore, phages possess an intrinsic capacity to self-amplify at the site of infection, potentially requiring fewer doses compared to conventional antibiotics (Jo *et al*., 2023). Phage therapy has garnered renewed interest owing to its potential efficacy against multidrug-resistant (MDR) bacterial infections, which pose a significant public health challenge. This therapeutic approach leverages the natural predation of bacteriophages on bacteria to effectively manage such infections (Febrianti *et al*., 2025).

Antimicrobial peptides

Antimicrobial peptides (AMPs) are small molecules recognized for their efficacy against a diverse array of pathogens, including bacteria, yeasts, fungi, viruses, and tumor cells. These peptides are promising alternatives to traditional antibiotics, particularly considering the increasing prevalence of multidrug-resistant (MDR) bacteria (Da Costa *et al*., 2015; S.-J. Kang *et al*., 2022). AMPs possess distinct advantages over conventional antibiotics owing to their broad-spectrum antimicrobial activities and various mechanisms of action. Unlike conventional antibiotics, which typically target specific molecular sites, AMPs demonstrate rapid and diverse mechanisms of action, thereby complicating the development of resistance in microorganisms (Piotrowska *et al*., 2017). Additionally, these peptides offer therapeutic benefits such as anti-inflammatory, immunomodulatory, wound healing, and antitumor properties, thereby enhancing their potential applications in various medical fields (H.-K. Kang *et al*., 2016; Piotrowska *et al*., 2017).

Probiotic, prebiotic and synbiotics

Probiotics present several advantages over other natural additives when used as alternatives to antibiotics. These primarily consist of live microorganisms that confer health benefits to the host when ingested in sufficient quantities. A principal advantage of probiotics is their capacity to maintain and restore the balance of the gut microbiota, which is essential for digestive health and overall well-being (Bahaddad *et al*., 2022; Ali *et al*., 2023). Probiotics are effective in enhancing immune function and providing protection against pathogens, aiding in the prevention of gastrointestinal disorders, such as diarrhea and irritable bowel syndrome. These microorganisms, predominantly comprising strains of the genera Lactobacillus and Bifidobacterium, are also associated with antihypertensive and antihypercholesterolemic effects, thereby contributing to cardiovascular health (Zaib *et al*., 2024). Prebiotics have attracted considerable interest as feed additives because of their potential benefits in enhancing the health and growth of livestock and aquaculture species. Prebiotics are typically fermentable non-digestible oligosaccharides such as fructooligosaccharides, inulin, and mannanoligosaccharides, which are metabolized by specific members of the intestinal microbiota (Pourabedin and Zhao, 2015). These compounds are known for their ability to enhance gut health, immune function, and growth performance by modulating the microbiota of the gastrointestinal tract. Synbiotics have been employed to enhance growth performance and improve gut health, serving as substitutes for routine antibiotic use. Research indicates that synbiotics significantly enhance weight gain and feed conversion efficiency and positively influence the gut microbiota of broiler chickens (Tayeri *et al*., 2018; Khomayezi and Adewole, 2021). Despite these promising benefits, the development of synbiotic products necessitates careful selection of compatible probiotic strains and prebiotic compounds to ensure synergistic effects. In addition, appropriate delivery systems must be developed to maintain the viability and efficacy of these compounds. Ongoing research continues to focus on these aspects to maximize their potential as natural alternatives to synthetic antibiotics (Kvakova *et al*., 2021; Trone *et al*., 2023).

Organic Acids

Over the past four decades, organic acids and their salts have been employed as feed additives and have demonstrated promising outcomes across various animal species. The primary roles of organic acids in animal nutrition include reduction of gastric pH, enhancement of protein hydrolysis, and improvement of nutrient digestibility (Suiryanrayna and Ramana, 2015). By decreasing the pH within the gastrointestinal tract, organic acids facilitate the conversion of inactive pepsinogen to active pepsin, thereby aiding effective protein hydrolysis. Furthermore, organic acids exhibit both bacteriostatic and bactericidal properties, which contribute to the regulation of pathogenic bacteria in the gut (Rathnayake *et al*. 2021).

Enzymes

Enzymes play a pivotal role in augmenting the nutritional value of animal feed by catalyzing the breakdown of complex nutrients into simpler and more readily absorbable forms. The incorporation of exogenous enzymes into animal feed is primarily aimed at enhancing productive parameters by improving feed efficiency and reducing associated costs (Velazquez-De Lucio *et al*., 2021). These enzymes facilitate the digestion of feeds that are otherwise challenging for animals to decompose, such as those containing nonstarch polysaccharides. This process enhances overall feed utilization and can lead to improved growth rates and feed conversion ratios.

Phytobiotic Feed Additive as Natural Antibiotic

Phytobiotics, also referred to as phytogenic feed additives, are natural compounds extracted from plants, herbs, and spices. These compounds have several roles, including functioning as immune system modulators, antimicrobials, antimutagenics, antioxidants, and growth promoters, particularly in non-ruminant livestock, such as swine and poultry (Biswas *et al*., 2024). Phytobiotics comprise a diverse array of substances, including polyphenols, terpenoids, flavonoids, and phenolic compounds, which are responsible for their antimicrobial, antioxidant, and anti-inflammatory properties (Mahfuz *et al*., 2021; Rafeeq *et al*., 2023). Determining the optimal dosage of phytobiotics presents a challenge owing to variations in the chemical composition and physiological status of animals. Nonetheless, research has indicated that phytobiotics can be effectively utilized in controlled doses to improve nutrient digestibility and animal performance. In poultry, the effectiveness of these compounds varies with the concentration of the phytochemical mixtures employed, positively influencing feed intake and gut health (Rafeeq *et al*., 2023). Phytobiotics are utilized as feed additives to enhance digestive health and overall livestock performance. They exert their effects by altering gut bacterial populations, inhibiting bacterial adhesion, promoting nutrient absorption, and enhancing antioxidant properties (Rafeeq *et al*. 2022). Owing to their natural origins and multifaceted benefits, phytobiotics are frequently used as alternatives to antibiotic growth promoters (Rafeeq *et al*., 2023).

Phytobiotics can be derived from whole plants, extracts, or purified compounds. Plant extracts, such as those from green tea, are utilized for their antioxidant and immunomodulatory properties (Abd El-Ghany 2025). Functionally, phytobiotics serve as antimicrobials (controlling harmful gut bacteria), antioxidants (protecting cells from oxidative stress), digestive stimulants (enhancing feed intake and nutrient absorption), anti-inflammatory agents (reducing inflammation in the digestive tract), and palatability enhancers (improving the taste and smell of the feed to encourage increased consumption by animals). Phytobiotics have been shown to improve growth performance and feed efficiency, enhance gut health and immune response, potentially reduce stress, and improve reproductive performance. Despite their potential, the mechanisms of action of phytobiotics are not fully understood, and their efficacy can vary depending on the type, dosage, and formulation. Phytobiotics are employed in poultry nutrition as alternatives to antibiotic growth promoters (AGPs) because of the global prohibition of antibiotics in animal feed (Sapsuha *et al*., 2021; Alghirani *et al*., 2021; Biswas *et al*., 2024). Research has underscored the importance of optimizing phytobiotic use by understanding the specific properties of herbs, their bioactive components, and their interactions with animal physiology and microbiota. Several sources, active compounds, and the potential roles of phytobiotic feed additives are presented in Table 1.

Gut health improvement

Phytobiotics enhance gut morphology, integrity, and microflora composition, thereby improving nutrient absorption and overall gut health (Jin *et al*. 2024; Obianwuna *et al*. 2024). Phytobiotics contribute to the maintenance of a healthy gut environment by inhibiting pathogenic bacteria and promoting beneficial bacteria (Abd El-Ghany *et al*., 2020; Rafeeq *et al*., 2022). These compounds are known to stimulate the production of digestive secretions and enhance nutrient absorption, which in turn improves feed efficiency, a critical factor in optimizing growth perfor-

Table 1. Several source, active compounds and potential roles from phytobiotic feed additive.

Source	Active compounds	Potential roles	Reference
Ficus fruits	Carotenoid, flavonoid, phenol, vitamin C	Antioxidant, anti-inflammatory, antidiabetic, antimicrobial, hepato-protective	(Walia *et al*., 2022)
Macrofungi	Unique metabolites like anti-Alzheimer, anti-diabetic compounds	Drug discovery, therapeutic agents, various medical applications	(De Silva *et al*., 2013)
Microalgae and Cyanobacteria	Antibiotics, antiviral, antineoplastic compounds	Pharmaceutical, nutraceutical, agriculture	(Bilal *et al*., 2021)
Endophytic Fungi	Steroids, xanthones, terpenoids, phenols	Antimicrobial, antiviral, antioxidant, anticancer	(Hashem *et al*., 2023)
Ribes and Rubus spp	Polyphenol, terpenic compound, organic acids, vitamin	Antioxidant, anti-inflammatory capacities, various health benefit	(Donno *et al*., 2016)

mance and productivity in poultry (Abdelli *et al*., 2021; Biswas *et al*., 2024). Various herbs and plants are used as phytobiotics owing to their antimicrobial, antioxidant, and digestive properties. They can reduce microbial populations in the gastrointestinal tract, either directly or by modulating the gut environment to favor beneficial bacteria (Rafeeq *et al*., 2022). Coniferous resin acids possess antimicrobial, anti-inflammatory, and wound healing properties that support broiler intestinal health. They are known to reduce inflammatory T-cell infiltration and matrix metalloproteinase activity, which may aid in maintaining intestinal barrier integrity (Aguirre *et al*., 2019). Berberine, a plant-derived alkaloid, enhances gut wall morphology and reduces gut inflammation by modulating gut microbiota. Although the exact mechanism and dose optimization remain under investigation, they affect the diversity and functionality of the microbiota (Dehau *et al*., 2023).

Antimicrobial action and antioxidant properties

Phytobiotics exhibit intrinsic antimicrobial and antioxidant properties, which contribute to the maintenance of gut health. By diminishing the pathogenic load within the gastrointestinal tract, these additives enhance microbial equilibrium, thereby improving the overall health and immune response of birds (Rafeeq *et al*., 2022; Abd El-Ghany, 2024). Essential oils derived from plants, such as thyme, peppermint, savory, and black pepper, have demonstrated promising outcomes. When microencapsulated, these oils have been shown to enhance the microbial population in the intestine, improve growth performance, and strengthen the antioxidant status of broilers (Moharreri *et al*., 2021). Botanical medicines sourced from various plant parts, including flowers, fruits, roots, leaves, seeds, and bark, have been employed to enhance broiler performance. These phytobiotics exert their effects through antimicrobial activity, modification of gastrointestinal tract (GIT) bacterial populations, stimulation of digestive secretions, and enhancement of nutrient absorption (Rafeeq *et al*., 2022).

Immune system support

Phytobiotics interact with the gut ecosystem to modulate the poultry immune system. These additives enhance mucus secretion and inhibit bacterial adhesion to the gut lining, facilitating the competitive exclusion of harmful microbes, while supporting the proliferation of beneficial microbes (Rafeeq *et al*., 2022). They stimulate the immune system, thereby increasing poultry resilience against infections and diseases (Abd El-Ghany *et al*., 2020; Alghirani *et al*., 2021; Drannikov *et al*., 2021). Notable examples of phytobiotics that support the immune system include Aloe vera, which is recognized for its anti-inflammatory, immunomodulatory, and antioxidant properties. Aloe vera serves as an effective natural feed additive, available in forms such as gel, powder, or extracts, and has been demonstrated to enhance the immune response and growth performance in broilers (Babak and Nahashon, 2014). Flavonoids and polyphenols, compounds found in various herbs and spices, exhibit immune-modulating properties and improve the health and productivity of broilers by enhancing immune responses and mitigating stress effects (Oni *et al*., 2023). Polysaccharide β-Glucan is known for enhancing the immune system by improving macrophage activity, thereby supporting cell-mediated immune responses in broilers (Cheng *et al*., 2004). Yeast- and yeast-derived products are beneficial for boosting humoral immunity by increasing serum immunoglobulin levels and aiding the development of a stronger innate immune response under pathogenic challenges (Bilal *et al*., 2021). Olive oil byproducts and alfalfa, which are readily available plant-derived additives, have shown potential for supporting the immune system of broilers. Research suggests that they provide immunomodulatory benefits, contributing to the maintenance of health and performance of chickens (Phillips *et al*., 2023).

Oxidative stress reduction

The antioxidant properties of phytobiotics enable them to safeguard cellular structures from oxidative stress, thereby preserving their cellular integrity and functionality. This function is crucial for mitigating stress, whether induced by environmental factors or pathogens, ensuring that avian species maintain optimal health and productivity (Ali *et al*., 2021). Active compounds such as polyphenols exhibit antioxidant characteristics that are advantageous for alleviating oxidative stress. For example, a dietary polyphenol mixture derived from sugarcane has been shown to enhance growth performance and meat quality in broilers subjected to heat stress, mitigate oxidative damage, and improve physiological responses at various dosages (Shakeri *et al*., 2020). A specific formulation comprising red pepper fruit, white mustard seed, soapwort root, Calamus rhizome, and thymol has demonstrated beneficial effects on oxidative stress markers in broilers. When incorporated into diets at a concentration of 100 mg/kg, it improves feed efficiency and reduces tumor necrosis factor levels, indicating a decrease in oxidative damage (Chodkowska *et al*., 2022). Flavonoids and terpenes are antioxidants that alleviate oxidative stress by enhancing gut health and overall poultry performance. These natural compounds contribute to the maintenance of a redox balance, thereby reducing oxidative insults in the gastrointestinal tract (Biswas *et al*., 2024).

Conclusion

The use of synthetic antibiotics in poultry production has been banned in several regions. The ban on synthetic antibiotics in poultry is driven by a pressing need to combat antibiotic resistance and ensure food safety. Phytobiotic feed additives are alternatives to synthetic antibiotics. The combination of bioactive compounds in phytobiotics represents a promising approach for the development of novel antimicrobial properties, antioxidant effects, immune modulation, growth promotion, and anti-inflammatory effects.

Acknowledgments

The authors acknowledge the financial support and sponsorship for this research by the Review Article Research Scheme, Universitas Diponegoro (grant number: 222-034/UN7).D2/PP/IV/2025). We would like to thank the Poultry Production Laboratory, Department of Animal Science, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang, Indonesia.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdelli, N., Sola-Oriol, D., Perez, J.F., 2021. Phytogenic feed additives in poultry: achievements, prospective and challenges. Animals. 11, 3471.
Abd El-Ghany, N.M., Abd El-Aziz, S.E., Marei, S.S., 2020. A review: application of remote sensing as a promising strategy for insect pests and diseases management. Environ. Sci. Pollut. Res. 27, 33503-33515.
Abd El-Ghany, W.A., 2024. Applications of organic acids in poultry production: an updated and comprehensive review. Agriculture. 14, 1756
Abreu, R., Cunha, E., Semedo-Lemsaddek, T., Oliveira, M., Tavares, L., 2023. Antimicrobial drug resistance in poultry production: current status and innovative strategies for bacterial control. Microorganisms. 11, 953.
Aguirre, M., Haesebrouck, F., Vuorenmaa, J., Kettunen, H., Valkonen, E., Ducatelle, R., Callens, C., Van Immerseel, F., Goossens, E., 2019. In-feed resin acids reduce matrix metalloproteinase activity in the ileal mucosa of healthy broilers without inducing major effects on the gut microbiota. Vet. Res. 50.
Ali, A., Dunshea, F.R., Ponnampalam, E.N., Suleria, H.A.R., Cottrell, J.J., Pushpakumara, G., 2021. Cinnamon: A natural feed additive for poultry health and production-A Review. Animals 11, 2026.
Ali, M.S., Suk, K., Park, S.C., Lee, E.B., Lee, S.J., Hsu, W.H., Ullah, H.M.A., Sayem, S.A.J., 2023. Probiotics and postbiotics as an alternative to antibiotics: An emphasis on pigs. Pathogens 12, 874.
Aminov, R., Rohde, C., Wittmann, J., Coffey, A., Sybesma, W., Pantucek, R., Doskar, J., Friman, V.P., Resch, G., Pirnay, J.P., Cooper, I., Kurtboke, I., Caplin, J., Chanishvili, N., De Vos, D., 2017. Application of bacteriophages. Microbiol. Aust. 38, 63.
Abd El-Ghany, W.A., 2025. The different influences of a phytobiotic, green tea (Camellia sinensis L.) on the poultry health and production. J. App. Vet. Sci. 10, 32-45.
Alabi, O.J., Makinde, O.J., Egena, S.S.A., Mbajiorgu, F.E., Adewara, O.A., 2024. Antibiotics in broilers chicken production: a review of impacts, challenges and potential alternatives. Vet. Integrat. Sci. 22, 559-578.
Alghirani, M.M., Chung, E.L.T., Jesse, F.F.A., Sazili, A.Q., Loh, T.C., 2021. Could phytobiotics replace antibiotics as feed additives to stimulate production performance and health status in poultry? An Overview. J. Adv. Vet. Res. 11, 254–265.
Apata, D.F., 2009. Antibiotic resistance in poultry. Int. J. Poult. Sci. 8, 404-408.
Azizi, M.N., Zahir, A., Mahaq, O., and Aminullah, N., 2024. The alternatives of antibiotics in poultry production for reducing antimicrobial resistance. World. Vet. J. 14, 270-283.
Babak, D., Nahashon, S.N., 2014. A review on effects of aloe vera as a feed additive in broiler chicken diets. Ann. Anim. Sci. 14, 491–500.
Bahaddad, S.A., Almalki, M.H.K., Alghamdi, O.A., Sohrab, S.S., Yasir, M., Azhar, E.I., Chouayekh, H., 2022. Bacillus species as direct-fed microbial antibiotic alternatives for monogastric production. Prob. and Antimicrob. Proteins 15, 1-16.
Bilal, R.M., Hassan, F.U., Saeed, M., Rafeeq, M., Zahra, N., Fraz, A., Saeed, S., Khan, M.A., Mahgoub, H.A.M., Farag, M.R., Alagawany, M., 2021. Role of yeast and yeast-derived products as feed additives in broiler nutrition. Anim. Biotech. 34, 392-401.
Biswas, S., Kim, I.H., Ahn, J.M., 2024. Assessing the potential of phytogenic feed additives: A comprehensive review on their effectiveness as a potent dietary enhancement for nonruminant in swine and poultry. J. of Anim. Phys. and Anim. Nut. 108, 711–723.
Cheng, Y.H., Wen, C.M., Lee, D.N., Weng, C.F., 2004. Effects of β-Glucan supplementation on lymphocyte proliferation, macrophage chemotaxis and specific immune responses in broilers. Asian-Aust. J. Anim. Sci. 17, 1145–1149.
Chodkowska, K. A., Abramowicz-Pindor, P. A., Tuśnio, A., Gawin, K., Taciak, M., Barszcz, M., 2022. Effect of phytobiotic composition on production parameters, oxidative stress markers and myokine levels in blood and pectoral muscle of broiler chickens. Animals 12, 2625.
Da Costa, J.P., Vitorino, R., Ferreira, R., Cova, M., 2015. Antimicrobial peptides: an alternative for innovative medicines?. Appl. Microbiol. Biotech. 99, 2023–2040.
Dehau, T., Croubels, S., Van Immerseel, F., Cherlet, M., Goossens, E., 2023. A high dose of dietary berberine improves gut wall morphology, despite an expansion of enterobacteriaceae and a reduction in beneficial microbiota in broiler chickens. Msystems. 8.
De Silva, D.D., Sudarman, E., Stadler, M., Xu, J., Rapior, S., Aisyah Alias, S., Hyde, K.D., 2013. Bioactive metabolites from macrofungi: ethnopharmacology, biological activities and chemistry. Fungal Diversity. 62, 1-40.
Donno, D., Mellano, M.G., Cerutti, A.K., Beccaro, G.L., 2016. Biomolecules and natural medicine preparations: analysis of new sources of bioactive compounds from ribes and rubus spp. buds. Pharmaceuticals. 9, 7.
Drannikov, A.V., Derkanosova, A.A., Korotaeva, A.A., Orinicheva, A.A., Iskusnykh, A.Y., Litvinov, E.V., 2021. Phytobiotics as an alternative to antibiotics in feeding farm birds. IOP Conference Series: Earth Environ. Sci. 640.
Febrianti, R.A., Narulita, E., Sulistyaningsih, E., Addy, H.S., 2025. Innovations in bacteriophage genome engineering for combating multidrug-resistant bacterial infections. Foodborne Path. Dis
Franz, C., Baser, K.H.C., Windisch, W., 2010. Essential oils and aromatic plants in animal feeding, a European perspective. A review. Aromatic Plants, spices and volatiles in food and beverages. 25, 327-340.
Gadde, U., Kim, W.H., Oh, S.T., Lillehoj, H.S., 2017. Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: a review. Anim. Health Res. Rev. 18, 26-45.
Hill, E.K., Li, J., 2017. Current and future prospects for nanotechnology in animal production. J. Anim. Sci. Biotech. 8.
Hasted, T.L., Sharif, S., Boerlin, P., Diarra, M.S., 2021. Immunostimulatory potential of fruits and their extracts in poultry. Front. Immunol. 12.
Hashem, A.H., Khader, M.S., Khodaira, M.A., Fawzi, M.M., Abdelrahman, A.S., Kandil, E.K., Goma, M.A., Abdelaziz, A.M., Attia, M.S., Emam, A.E., 2023. Bioactive compounds and biomedical applications of endophytic fungi: a recent review. Microb. Cell Factories. 22.
Hasan, M.T., Je Jang, W., Lee, J.M., Lee, B.J., Hur, S.W., Gu Lim, S., Kim, K.W., Han, H.S., Kong, I.S., 2019. Effects of immunostimulants, prebiotics, probiotics, synbiotics, and potentially immunoreactive feed additives on olive flounder (Paralichthys olivaceus): A review. Reviews in Fish. Sci. Aquacult. 27, 417-437
Ishaq, H.M., Ishaq, W., Usman, M., Ghayas, A., Yameen, R.M.K., Abdullah, Saleem, K., Ahmad, S., 2024. Non-antibiotic growth promoters in poultry nutrition. Ann. Anim. Sci. 2478.
Islam, M.A., Bose, P., Rahman, M.Z., Muktaruzzaman, M., Sultana, P., Ahamed, T., Khatun, M.M., 2024. A review of antimicrobial usage practice in livestock and poultry production and its consequences on human and animal health. J. Adv. Vet. Anim. Res. 1, 675.
Jiang, A., Liu, Z., Lv, X., Zhou, C., Ran, T., Tan, Z., 2024. Prospects and challenges of bacteriophage substitution for antibiotics in livestock and poultry production. Biol. 13, 28.
Jo, S.J., Lee, S.J., Kwon, J., Kim, S.G., 2023. The biotechnological application of bacteriophages: what to do and where to go in the middle of the post-antibiotic era. Microorganisms 11, 2311.
Kang, H.K., Kim, C., Seo, C.H., Park, Y., 2016. The therapeutic applications of antimicrobial peptides (AMPs): a patent review. J. Microbiol. 55, 1–12.
Kang, S.J., Nam, S.H., Lee, B.J., 2022. Engineering approaches for the development of antimicrobial peptide-based antibiotics. Antibiotics 11, 1338.
Kemal, J., Menkir, S., Sibhat, B., Beyene, D., 2016. Prevalence, assessment, and antimicrobial resistance patterns of Salmonella from raw chicken eggs in Haramaya, Ethiopia. The J. Infect. Develop. Count. 10, 1230–1235.
Khomayezi, R., Adewole, D., 2021. Probiotics, prebiotics, and synbiotics: an overview of their delivery routes and effects on growth and health of broiler chickens. World's Poult. Sci. J. 57–81.
Koch, B.J., Hungate, B.A., Price, L.B., 2017. Food-animal production and the spread of antibiotic resistance: the role of ecology. Front. Eco. Env. 15, 309–318.
Krishan, G., Narang, A., 2014. Use of essential oils in poultry nutrition: A new approach. J. Adv. Vet. Anim. Res. 1, 156.
Kvakova, M., Bertkova, I., Stofilova, J., Savidge, T.C., 2021. Co-encapsulated synbiotics and immobilized probiotics in human health and gut microbiota modulation. Foods, 10, 1297.
Lazar, L., Vlas, O., Pantea, E., Boicenco, L., Marin, O., Abaza, V., Filimon, A., Bisinicu, E., 2024. Black sea eutrophication comparative analysis of intensity between coastal and offshore waters. Sustainability 16, 5146.
Lekagul, A., Tangcharoensathien, V., Mills, A., Rushton, J., Yeung, S., 2020. How antibiotics are used in pig farming: a mixed-methods study of pig farmers, feed mills and veterinarians in Thailand. BMJ Global Health 5, 001918.
Li, W., Li, H., Zheng, S., Shi, C., Wang, Z., Sheng, H., Yang, B., Niu, Q., Shi, X., 2020. Prevalence, serotype, antibiotic susceptibility, and genotype of Salmonella in eggs from poultry farms and marketplaces in Yangling, Shaanxi Province, China. Front. Microbiol. 11.
Looft, T., Stanton, T.B., Alt, D.P., Allen, H.K., Casey, T.A., 2014. Carbadox has both temporary and lasting effects on the swine gut microbiota. Front. Microbiol. 5.
Lone, A., Mottawea, W., Mehdi, Y., Hammami, R., 2022. Bacteriocinogenic probiotics as an integrated alternative to antibiotics in chicken production - why and how?. Critical Rev. Food Sci. Nut. 62, 8744–8760.
Mahfuz, S., Piao, X., Shang, Q., 2021. Phenolic compounds as natural feed additives in poultry and swine diets: a review. J. Anim. Sci. Biotechnol. 12.
Moharreri, M., Vakili, R., Oskoueian, E., Rajabzadeh, G., 2021. Phytobiotic role of essential oil-loaded microcapsules in improving the health parameters in Clostridium perfringens-infected broiler chickens. Italian J. Anim. Sci. 20, 2075–2085.
Mund, M.D., Khan, U.H., Tahir, U., Mustafa, B.E.-, Fayyaz, A., 2016. Antimicrobial drug residues in poultry products and implications on public health: A review. Inte. J. Food Prop. 20, 1433–1446.
Molteni, C., Valoppi, F., La Motta, C., 2022. Improving the bioaccessibility and bioavailability of carotenoids by means of nanostructured delivery systems: A comprehensive review. Antioxidants 11, 1931.
Obianwuna, U.E., Chang, X., Oleforuh-Okoleh, V.U., Onu, P.N., Zhang, H., Qiu, K., Wu, S., 2024. Phytobiotics in poultry: revolutionizing broiler chicken nutrition with plant-derived gut health enhancers. J. Anim. Sci. Biotechnol. 15.
O'Bryan, C.A., Crandall, P.G., Pendleton, S.J., Ricke, S.C., 2015. Potential of plant essential oils and their components in animal agriculture - in vitro studies on antibacterial mode of action. Front. Vet. Sci. 2.
Ogbuewu, I.P., Mbajiorgu, C., Mabelebele, M., Sebola, N.A., 2022. Bacillus probiotics as alternatives to in-feed antibiotics and its influence on growth, serum chemistry, antioxidant status, intestinal histomorphology, and lesion scores in disease-challenged broiler chickens. Front. Vet. Sci. 9.
Oliveira, G.D.S., Mcmanus, C., Dos Santos, V.M., 2024. Maintaining safe antibacterial standards in poultry production using Syzygium Aromaticum essential oil. World's Poul. Sci. J. 885–895.
Oni, A.I., Adeleye, O.O., Oke, O.E., & Adebowale, T.O., 2023. The role of phytogenic feed additives in stress mitigation in broiler chickens. J. Anim. Physiol. Anim. Nut. 108, 81–98.
Phan, M.A.T., Paterson, J., Bucknall, M., Arcot, J., 2017. Interactions between phytochemicals from fruits and vegetables: Effects on bioactivities and bioavailability. Critical Reviews in Food Sci. Nut. 58, 1310–1329.
Phillips, C.J.C., Hosseintabar-Ghasemabad, B., Seidavi, A., Gorlov, I.F., Mosolov, A.A., Slozhenkina, M.I., 2023. Immunomodulatory effects of natural feed additives for meat chickens. Life. 13, 1287.
Piotrowska, U., Sobczak, M., Oledzka, E., 2017. Current state of a dual behaviour of antimicrobial peptides-Therapeutic agents and promising delivery vectors. Chem. Biol. Drug Design. 90, 1079–1093.
Pourabedin, M., Zhao, X.,, 2015. Prebiotics and gut microbiota in chicken. FEMS Microb. Letters. 362.
Rafeeq, M., Bilal, R.M., Alagawany, M., Batool, F., Yameen, K., Farag, M.R., Ali, S., Elnesr, S.S., El-Shall, N.A., 2022. The use of some herbal plants as effective alternatives to antibiotic growth enhancers in poultry nutrition. World's Poult. Sci. J. 78, 1067–1085.
Rafeeq, M., Bilal, R.M., Batool, F., Yameen, K., Farag, M.R., Madkour, M., Elnesr, S.S., El-Shall, N.A., Dhama, K., Alagawany, M., 2023. Application of herbs and their derivatives in broiler chickens: a review. World's Poult. Sci. J. 79, 95–117.
Rasheed, M.U., Ahamed, P., Jamil, K., Teklemariam, Z., Thajuddin, N., 2014. Antimicrobial drug resistance in strains of Escherichia coli isolated from food sources. Revista Do Instituto de Medicina Tropical de Sao Paulo. 56, 341–346.
Rathnayake, D., Mun, H.S., Dilawar, M.A., Baek, K.S., Yang, C.J., 2021. Time for a paradigm shift in animal nutrition metabolic pathway: dietary inclusion of organic acids on the production parameters, nutrient digestibility, and meat quality traits of swine and broilers. Life. 11, 476.
Rein, M.J., Renouf, M., Cruz-Hernandez, C., Actis-Goretta, L., Thakkar, S.K., da Silva Pinto, M., 2013. Bioavailability of bioactive food compounds. Br. J. Clin. Pharmacol. 75, 588-602.
Shakeri, M., Cottrell, J.J., Wilkinson, S., Le, H.H., Suleria, H.A.R., Warner, R.D., Dunshea, F.R., 2020. A dietary sugarcane-derived polyphenol mix reduces the negative effects of cyclic heat exposure on growth performance, blood gas status, and meat quality in broiler chickens. Animals. 10, 1158.
Sapsuha, Y., Suprijatna, E., Kismiati, S., Sugiharto, S., 2021. Combination of probiotic and phythobiotic as an alternative for antibiotic growth promoter for broilers chickens - A review. Livest. Res. Rural. Dev. 33.
Salvia-Trujillo, L., Martín-Belloso, O., Mcclements, D., 2016. Excipient nanoemulsions for improving oral bioavailability of bioactives. Nanomaterials 6, 17.
Suiryanrayna, M.V.A.N., Ramana, J.V., 2015. A review of the effects of dietary organic acids fed to swine. J. Anim. Sci. Biotechnol. 6.
Tayeri, V., Seidavi, A., Asadpour, L., Phillips, C.J.C., 2018. A comparison of the effects of antibiotics, probiotics, synbiotics and prebiotics on the performance and carcass characteristics of broilers. Vet. Res. Communicat. 42, 195–207.
Trone, K., Martindale, R., Stroud, A., Venegas, C., Green, C.H., Rahman, S., 2023. Synbiotics and surgery: can prebiotics and probiotics affect inflammatory surgical outcomes?. Current Nut. Reports 12, 238–246.
Tsujii, M., Tanudjaja, E., Uozumi, N., 2020. Diverse physiological functions of cation proton antiporters across bacteria and plant cells. Int. J. Mol. Sci. 21, 4566.
Ubeyitogullari, A., Kandhola, G., Kim, J., Ahmadzadeh, S., 2022. Polysaccharide-based porous biopolymers for enhanced bioaccessibility and bioavailability of bioactive food compounds:

Challenges, advances, and opportunities. Comprehensive Rev. Food Sci. Food Saf. 21, 4610–4639.

Valdivieso-Ugarte, M., Gil, A., Gomez-Llorente, C., Plaza-Diaz, J., Gil, A., Gil, A., Gomez-Llorente, C., Gil, A., Gomez-Llorente, C., Gil, A., Plaza-Diaz, J., Plaza-Diaz, J., Gomez-Llorente, C., 2019. Antimicrobial, antioxidant, and immunomodulatory properties of essential oils: A systematic review. Nutrients 11, 2786.

Valenzuela-Grijalva, N.V., Pinelli-Saavedra, A., Muhlia-Almazan, A., Dominuguez-Diaz, D., Gonzales-Rios, H., 2017., Dietary inclusion effect of phytochemicals as growth promoters in animal production. J. of Anim. Sci. Technol. 58, 8.

Velazquez-De Lucio, B.S., Alvarez-Cervantes, J., Mendoza-Mendoza, B., Villa-Garcia, M., Mandujano-Gonzalez, V., Diaz-Godinez, G., Hernandez-Domínguez, E.M., 2021. Exogenous enzymes as zootechnical additives in animal feed: A review. Catalysts. 11, 851.

Walia, A., Kumar, H., Kaushik, R., Kumar, N., Kumar, V., Kumar, A. P., Singh, R., 2022. Bioactive compounds in ficus fruits, their bioactivities, and associated health benefits: A review. J. Food Quality. 2022, 1-19.

Zaib, S., Hayat, A., Khan, I., 2024. Probiotics and their beneficial health effects. Mini-Reviews in Medicinal Chem. 24, 110–125.

Zhang, L., Li, H., Shi, L., Ge, J., Xia, F., Gao, F., Piao, X., Bai, H., 2022. Potential of aromatic plant-derived essential oils for the control of foodborne bacteria and antibiotic Resistance in animal production: A Review. Antibiotics 11, 1673.