



The Use of Phytochemicals as Functional Additives in Poultry Nutrition

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Abstract. Ensuring poultry health, promoting optimal growth, and maintaining high productivity depend on balanced diets and appropriate housing conditions. For decades, antimicrobial agents were extensively employed to control bacterial diseases and enhance performance. Nevertheless, their uncontrolled application and subsequent accumulation in animal tissues have contributed to the emergence of microbial resistance mechanisms, which has complicated the prevention of bacterial infections. Limitations on antibiotic usage have also produced unfavorable economic consequences for the poultry sector. Against this background, identifying effective alternatives to antibiotics has become a major focus of scientific research. Recently, increasing attention has been directed toward phytobiotics, biologically active plant-derived compounds. These substances exhibit anti-inflammatory, antioxidant, antimicrobial, and antiparasitic effects and demonstrate promising applications in livestock production, including poultry. Although numerous plant-based extracts are now available, their modes of action require further in-depth investigation, particularly in relation to the physiological characteristics of poultry. This review highlights the potential of phytobiotics in modern poultry farming and examines the scientific rationale for their use as substitutes for antimicrobial agents.

Keywords: Poultry, Poultry Nutrition, Plant Extracts, Feed Antibiotics.

1 Introduction

In accordance with the Regional Development Program of the Republic of Azerbaijan, measures aimed at addressing the food security problem envisage the regulation of poultry population, per capita poultry meat availability, and the implementation of optimal feeding systems. To achieve these objectives, the application of advanced technologies in poultry farming has been prioritized, with the aim of increasing production while minimizing labor input. Within this framework, the proper nutrition of poultry and the inclusion of micro-additives in feed rations are considered critical factors. Such approaches make it possible to enhance both poultry meat and egg production. Unlike traditional feeding methods, this can be achieved through the use of restricted feeder technologies based on modern systems. Research conducted in this area has

demonstrated that the application of such technologies not only improves feeding conditions but also ensures a feed economy of approximately 4–6%. Poultry meat plays a significant role in ensuring the population's access to affordable and high-quality food products. Poultry farming represents one of the most intensively developing branches of agriculture, primarily due to its distinct advantages: relatively low feed consumption, the capacity to influence and improve the quality parameters of the final products, and the rapid return of production costs.

It is well established that antibiotics have long constituted the cornerstone of bacterial infection therapy and have simultaneously exerted beneficial effects on poultry growth and productivity. Nevertheless, their application is associated with significant adverse consequences for human health. Prolonged and widespread use results in the accumulation of antibiotic residues within poultry tissues and fosters the emergence of antimicrobial resistance in microorganisms, thereby rendering the effective prevention and control of bacterial infections increasingly unfeasible. The extent of contamination with antibiotic residues has become a critical public health concern. For instance, a recent large-scale investigation conducted in China revealed that urinary samples from 58% of thousands of school-aged children contained detectable traces of multiple veterinary-specific antibiotics, including tylosin, chlortetracycline, and enrofloxacin (Wang HX et al., 2015). In response to such findings, recent years have witnessed a pronounced reduction—and in certain contexts, a complete prohibition—of antibiotic use in animal feed formulations (Gaucher ML et al., 2015). While these measures aim to safeguard public health, they have also posed economic challenges to the livestock sector, primarily by escalating production costs. Consequently, the identification and development of efficacious alternatives to antibiotics in poultry nutrition have emerged as one of the most pressing research priorities (Castillo-Lopez RI et al., 2017; Podobed L., 2019). Promising candidates include antibacterial vaccines, immunomodulators, probiotics, prebiotics and synbiotics, bacteriophages and their lysins, antimicrobial peptides, phytogetic extracts, quorum sensing (QS) inhibitors, modulators of biofilm formation and virulence factors, feed enzymes, and other novel bioactive agents (Millet S. and Maertens L., 2011).

The imposition of restrictions on the use of antibiotics initially leads to an increase in production costs within the poultry sector. This increase is mainly due to the application of alternative prophylactic agents (phytobiotics, probiotics, organic acids, enzyme preparations, and immunomodulators), strengthening of sanitary measures, and an increase in the frequency of veterinary services. Studies indicate that in the first 1–2 years after transitioning to antibiotic-free systems, total production costs may rise by 5–10% (Casewell et al., 2003; Castanon, 2007). This increase is especially related to feed additives and biosecurity measures. For example, after the ban on antibiotics in the European Union (2006), the production cost per chicken increased by 0.04–0.07 euros. However, within 3–4 years, this difference was compensated through market adaptation and the premium price of "antibiotic-free" labeled products.

In the long term, antibiotic-free production systems have advantages in terms of export potential, market reputation, and brand value. Research shows that 60–75% of consumers are willing to pay 10–20% more for antibiotic-free products (Huyghebaert et al.,

2011). This factor creates long-term economic stability and facilitates access to new markets.

In Azerbaijan, the analysis of this issue shows that the transition to antibiotic-free production systems may lead to increased production costs in the initial phase. Specifically, the application of alternative additives such as phytobiotics, probiotics, and organic acids, along with the strengthening of veterinary services and sanitary controls, results in a 5–10% increase in production costs on average.

At the same time, mortality may increase by 1–3%, and feed conversion ratio (FCR) may deteriorate by 0.05–0.10 points. This decrease is primarily due to the loss of the immunomodulatory effects of antibiotics and changes in microbiological balance during the adaptation period. However, with proper biosecurity and enrichment of the diet with phytogetic additives, these indicators stabilize within 3–4 months. In terms of growth indicators, antibiotic-free systems show improvements in daily live weight gain.

The restriction or complete removal of antibiotics may have a negative impact on poultry health in the short term. Studies show that after the withdrawal of antibiotics, mortality can increase by 1.5–3.0% (Huyghebaert et al., 2011; Castanon, 2007). This increase is mainly due to gut microbiota imbalance, stress, and decreased resistance to infectious diseases. However, strengthening biosecurity measures, regular disinfection, control of feed and water hygiene, and the use of probiotics and prebiotics stabilize this difference within 1–2 months. Based on observations in Azerbaijani farms, the transition to an antibiotic-free environment increases the mortality rate from an average of 5–6% to 6–7.5%. However, with proper implementation of biosecurity measures, this rate returns to previous levels.

Antibiotics stabilize the gut flora and have a positive effect on feed efficiency. Their ban results in a deterioration of the FCR indicator by 0.05–0.10 points (e.g., from 1.65 to 1.72). However, when phytogetic additives (oregano, thyme, garlic extracts), enzymes (xy-lanase, protease), and probiotics (*Bacillus subtilis*, *Lactobacillus acidophilus*) are applied, this difference is eliminated. In studies conducted in Turkey and Georgia, the FCR in antibiotic-free broilers was on average 1.70–1.73, while in antibiotic systems it was 1.60–1.65. In Azerbaijan, this indicator varies between 1.68 and 1.75 in local farms, stabilizing with proper diet management.

With the removal of antibiotics, the ADG in broiler chickens can decrease by 2–4% in the short term. For example, in an antibiotic system, a daily gain of 60 g/day is observed, while in an antibiotic-free system, this indicator may be 57–58 g/day (Dibner & Richards, 2005). This difference is mainly related to weakened gut health and reduced nutrient absorption in the early period. In local experiences conducted in Azerbaijan's climate conditions (2022–2023, poultry farms in Gabala and Khachmaz), the ADG in antibiotic-free diets was on average 56.8–58.2 g/day, while in antibiotic systems it was 60.1 g/day. However, with the use of phytobiotic additives (rosmarinic acid, thymol, carvacrol) and organic acids (formic, butyric acid), this difference remains within 1–2%.

Table 1. Effects of antibiotic and antibiotic-free systems on different parameters.

Indicator	Antibiotic System	Antibiotic-Free System (Initial Phase)	Antibiotic-Free System (Post-Adaptation)
Mortality Rate (%)	5.5	7.0	5.8
FCR (Feed Conversion Ratio)	1.65	1.73	1.68
ADG (Average Daily Gain, g/day)	60.0	57.5	59.2
42-Day Live Weight (kg)	2.5	2.38	2.47

In contemporary poultry nutrition, the incorporation of plant-derived biologically active compounds—collectively referred to as *phytobiotics*—has gained growing recognition as an essential component of sustainable feeding strategies (Buyarov VS, 2019). Owing to their anti-inflammatory, antioxidant, antimicrobial, and antiparasitic properties, plant extracts are increasingly utilized in poultry diets (Vondruskova H. et al., 2010; Hashemi SR and Davoodi H., 2010). The diverse functional benefits of these phytochemical additives are primarily attributed to their complex repertoire of bioactive constituents. These include a wide spectrum of secondary metabolites such as terpenoids, phenolic compounds (notably tannins), glycosides, and alkaloids, along with alcohols, aldehydes, ketones, and both simple and complex esters (Huyghebaert G. et al., 2011).

Experimental *in vitro* assays have demonstrated that many plant extracts exert notable antibacterial effects, with minimum inhibitory concentrations (MIC) typically ranging from 100 to 1000 µg/ml (Simoes M. et al., 2009). The antimicrobial efficacy of phytobiotics is mediated through diverse and compound-specific mechanisms. For instance, tannins disrupt microbial growth by chelating iron and interacting with essential proteins, including key enzymatic systems (Scalbert A., 1991). Saponins compromise microbial viability by forming complexes with sterols in cell membranes, thereby inducing structural damage and eventual cell lysis (Morrissey JP and Osbourn AE, 1999). Essential oils also display broad-spectrum antimicrobial activity (Lee KW et al., 2004), though the precise mechanisms underlying their bactericidal properties remain incompletely elucidated. Importantly, despite the promising potential of phytobiotics, the antimicrobial activity of numerous plant extracts has not yet been comprehensively investigated and warrants further systematic study (Stavri M. et al., 2007).

Overall, plant-derived extracts are widely regarded as safe and efficacious against specific bacterial species. Their incorporation into animal feed has a long history in Asia,

Africa, and South America, and has more recently gained prominence in developed nations as a strategy to promote growth and sustain animal health (Hashemi SR and Davoodi H., 2011; Abreu AC et al., 2012). Numerous studies have demonstrated that extracts derived from oregano, cinnamon, Mexican pepper, and thyme are capable of reducing intestinal populations of pathogenic microorganisms (Manzanilla EG et al., 2004; Namkung H. et al., 2004; Zanchi R. et al., 2008). Commercial products such as *Sangrovit*, fermented garlic extract, and allicin have been shown to enhance body weight gain (Borovan L., 2004; Tatara MR et al., 2008), while thyme, clove, oregano, and eugenol have been associated with improved productivity in swine production systems. Collectively, such evidence underscores the beneficial role of phytobiotics across diverse sectors of animal husbandry, with growing documentation of their positive effects on poultry performance in particular (Hashemi SR and Davoodi H., 2010).

In practical poultry production, phytogetic additives may be administered in a variety of preparations, including fresh, dried, fermented, or freeze-dried forms, as well as aqueous or alcoholic extracts derived from these substrates (Aroche R. et al., 2018). From a classification perspective, phytobiotics are generally divided into several categories:

Herbs – short-lived, non-woody flowering plants;

Spices – aromatic herbs characterized by a strong taste or odor, commonly employed in the food industry;

Essential oils – volatile, lipophilic compounds obtained through processes such as cold pressing, steam distillation, or alcohol extraction;

Resins – concentrated extracts or saps isolated using non-aqueous solvents.

A diverse array of phytogetic additives—including cinnamon, ginger, garlic, fenugreek, oregano, burdock, thyme, sage, marjoram, echinacea, lemon balm, cumin, mint, nettle, chamomile, bilberry, milk thistle, and alfalfa—have been shown to enhance metabolic processes and improve nutrient absorption. These compounds also mitigate gastrointestinal inflammation, exert general tonic effects, prevent diarrheal disorders, and positively influence the intestinal microbiota. Such benefits are largely mediated by the promotion of beneficial microorganisms, which outcompete pathogens, enhance enterocyte permeability, facilitate nutrient uptake, establish protective biofilms, and restrict pathogen colonization and proliferation. As a consequence, both the structure and function of enterocytes are strengthened, the maturation of intestinal immune cells is accelerated, and overall immune responsiveness is enhanced (Vinus et al., 2018).

Furthermore, dietary inclusion of phytobiotics has been reported to increase digestive enzyme secretion and activity, thereby accelerating digestion while supporting pancreatic and hepatic function (Suresh D. and Srinivasan K., 2007). Experimental studies indicate that supplementation of broiler diets with essential oils and plant extracts stimulates the activity of key enzymes such as amylase, maltase, trypsin, and pancreatic lipase (Rao RR et al., 2003; Lee MK et al., 2007; Yang Y et al., 2019). For instance, the incorporation of cinnamon essential oil has been associated with improved body weight gain, enhanced health status, and more favorable feed conversion ratios (FCR) (Al-Kassie GAM, 2009). Similarly, supplementation with garlic or turmeric powder not only improves growth performance and FCR but also reduces mortality in broilers (Yarru LP, 2009; Akyildiz S. and Denli M., 2016).

Additional evidence from Hernandez F. and colleagues (2004) demonstrated that the inclusion of medicinal rosemary, carvacrol, cinnamaldehyde, and capsaicin in broiler diets enhances feed utilization efficiency. Other plant-based additives such as mint and pansy have been shown to increase the proportion of unsaturated fatty acids in poultry meat, thereby modifying its fatty acid profile, while supplements including hops, nettle, and lemon significantly elevate the proportion of polyunsaturated fatty acids (Kapica M. et al., 2006).

The primary bioactive compounds in oregano are carvacrol and thymol, which exhibit antimicrobial, antioxidant, and immunomodulatory effects. According to studies, a diet supplement containing carvacrol at levels of 100–150 mg/kg in broiler chickens resulted in improved Feed Conversion Ratio (FCR) from 1.72 to 1.65, Daily Weight Gain (ADG) increased from 58.4 g/day to 61.2 g/day, reduced mortality from 6.2% to 4.8% (Botsoglou et al., 2002; Hashemipour et al., 2013). This is primarily due to the increase in populations of *Lactobacillus* and *Bifidobacterium* in the gut microbiota, along with a reduction in pathogenic *E. coli* and *Clostridium perfringens* loads. Oregano essential oils also increase the surface area of the intestinal epithelium, improving nutrient absorption and enhancing feed efficiency.

The active compound in garlic, allicin, has potent antimicrobial and antioxidant properties. At levels of 1–2% garlic powder or 100 mg/kg allicin supplementation, the following results were observed FCR improved from 1.70 to 1.66, ADG increased from 57.0 g/day to 60.5 g/day, serum cholesterol levels were reduced by 8–12% (Issa & Omar, 2012; Qureshi et al., 2017). Furthermore, garlic supplementation stimulated the immune system, increasing IgA and IgG levels, which resulted in enhanced disease resistance in the birds. The primary mechanisms of action of both plants include disrupting the cell membrane permeability of pathogenic bacteria to restore microbiological balance, increasing enzymatic activity in the gut (amylase, protease), activating antioxidant systems (SOD, GPx, CAT), reducing inflammatory signaling (TNF- α , IL-6). In the context of Azerbaijan, the use of oregano and garlic as phytobiotics can partially replace antibiotics. The application of these plants in local poultry farms has the potential to increase productivity by 3–5% and reduce mortality by 1–2%. Additionally, these supplements facilitate the acceptance of antibiotic-free products in export markets and ensure compliance with food safety standards. As a result of these effects, feed efficiency and productivity indicators stabilize at levels similar to antibiotics, but without the risk of antibiotic residues.

Table 2. Comparison of effects of phytobiotics and antibiotics on different indicators.

Group	Supplement Type	FCR	ADG (g/day)	Mortality (%)	Serum Cholesterol (mg/dL)
Control (Antibiotic)	Bacitracin 50 ppm	1.65	61.0	5.0	135
Phytobiotic 1	Oregano 150 mg/kg	1.66	60.8	4.9	132
Phytobiotic 2	Garlic 2%	1.66	60.5	4.8	120

Thyme, in particular, has been highlighted as having a pronounced positive effect on poultry production efficiency. The addition of phytobiotics to feed or drinking water has been shown to improve laying performance, as well as the chemical composition and overall quality of eggs. For example, dietary supplementation with ginger essential oil or powder (100–150 μ l/kg body weight) has been demonstrated to increase laying rates, enhance the chemical composition of eggs, and improve their overall quality (Al-Kassie GAM, 2009; El-Ghousein SS. and Al-Beitawi NA, 2009; Najafi P. and Toriki M., 2010).

Incorporation of phytogetic additives such as garlic powder (1–5%), ginger, mulberry, black cumin, thyme, mint, and golden yarrow into the diets of laying hens has been demonstrated to increase egg mass and enhance the protein content of egg white (Azeke MA and Ekpo KE, 2009; Mahmoud KZ, 2010; Olobatoke RY and Mulugeta SD, 2011; Xu X et al., 2012; Hojati H, 2014; Abd El-Hack A et al., 2020; Tahan M and Bayram I, 2012). Among plant extracts, those exhibiting the most potent antibacterial and antifungal activities include oils and extracts derived from thyme, echinacea, St. John's wort, sage, garlic, and cinnamon. The bioactivity of these plants is attributed to their high concentrations of polyphenols, particularly flavonoids, alongside tannins, coumarins, triterpenoids, isoprenoid derivatives, glucosinolates, and alkaloids (Burt SA, 2004; Si W et al., 2006). The antimicrobial effects of these phytochemicals are primarily associated with the disruption of microbial cell membranes, resulting in ion leakage into the extracellular environment and reduced pathogenic virulence (Windisch W et al., 2008; Krauze M et al., 2019).

Experimental evidence has further clarified these mechanisms. Pasqua RD and colleagues (2006) demonstrated that limonene and cinnamaldehyde interfere with the structural integrity of long-chain fatty acids in *Escherichia coli* membranes. Additionally, the hydrophobic nature of essential oils is thought to facilitate penetration into the phospholipid bilayers of bacterial cytoplasmic and mitochondrial membranes, causing

leakage of ions and intracellular components and ultimately leading to the lysis of pathogenic cells (Prabuseenivasan S et al., 2006). Beyond antimicrobial properties, phyto-biotics also exert probiotic-like effects, selectively modulating intestinal microbial composition and promoting eubiosis (Si W et al., 2006; Castillo M et al., 2006). Castillo M. and colleagues (2006) reported that a mixture containing cinnamaldehyde, capsaicin, and carvacrol increased the abundance of lactobacilli in the gastrointestinal tract. Similarly, Jamroz D. et al. (2006) showed that supplementation with a plant extract comprising 5% carvacrol, 3% cinnamaldehyde, and 2% capsicum oleoresin induced the formation of a thick mucosal layer in the stomach and small intestine of chicks. This mucus barrier reduced adhesion of pathogens to the intestinal epithelium, consequently lowering the populations of harmful bacteria and fungi, including *E. coli* and *Clostridium perfringens*.

Moreover, phytobiotics enhance poultry resilience against pathogens, toxins, and undesirable metabolites such as ammonia and biogenic amines (Tipu MA et al., 2006). Puvača N. and colleagues (2014) demonstrated that bioactive constituents of essential oils significantly reduced the abundance of *Clostridium* spp. in both the digestive tract and feces of poultry. Recent studies highlight preparations based on cinnamon as particularly promising: cinnamon bark, powder, and oil—owing to their cinnamic acid and cinnamaldehyde content—promote the proliferation of beneficial lactobacilli within the gastrointestinal tract.

The investigation conducted by Maryati RS and colleagues (2007) yielded noteworthy results, demonstrating that dietary supplementation with 5% essential oil derived from basil (*Ocimum basilicum*) leaves exerted pronounced antibacterial effects against *Staphylococcus aureus* and *Escherichia coli*.

Among biologically active complex feed additives, the preparation *ProStor* has received attention for its synbiotic properties. Formulated with plant-derived constituents such as purple coneflower (*Echinacea purpurea*) herb and spotted milk thistle (*Silybum marianum*) fruits, *ProStor* has been demonstrated to enhance growth rates and viability in replacement pullets of the broiler line Ross-308. Birds receiving this supplement were characterized by improved natural resistance, enhanced survival, and higher productivity at maturity (Buyarov VS et al., 2020).

A key advantage of plant-based antimicrobials lies in their selective activity. Unlike conventional antibiotics, which indiscriminately suppress both pathogenic and beneficial bacterial populations, extracts such as those obtained from cinnamon, thyme, and oregano selectively inhibit the proliferation of pathogenic microorganisms. However, it is important to note that such selective effects typically require highly concentrated extracts containing complex mixtures of bioactive compounds (Tipu MA et al., 2006). Another phyto-genic additive of considerable significance is *Yucca schidigera* extract, which has been shown to reduce toxic ammonia formation in the digestive tract of chicks owing to its high saponin content. Nazeer MS and colleagues (2002) reported that its application significantly diminished urease activity in the intestines and feces of broilers.

The inclusion of oak bark (*Quercus cortex*) extract in poultry diets has also produced promising results. Its use has been shown to increase feed intake without adverse physiological effects. When combined with the enzyme preparation “Glucolyux-F,” oak

bark extract stimulated digestive processes (Kazachkova NM, 2017). Moreover, supplementation of purified extract together with enzymatic preparations favorably influenced hematological and biochemical blood parameters, while exhibiting no detrimental effects on mineral, lipid, carbohydrate, or protein metabolism in poultry (Kazachkova NM et al., 2017).

Another notable preparation is Dosto® liquid 10%, which contains water-soluble oregano essential oil and is administered during the initial five days of chick rearing as an alternative to antibiotic prophylaxis. Its efficacy has been substantiated by immunostimulatory, antistress, and antimicrobial properties (Yunyaeva NV et al., 2016). Similarly, dietary supplementation with oils of oregano, thyme, cinnamon, and chili pepper has been reported to promote growth in poultry production systems (Gunchak AV et al., 2016).

Recent research has also explored innovative approaches to phytobiotic development through the valorization of forestry by-products. Bioactive compounds extracted from tree leaves and coniferous needles have been identified as promising raw materials for livestock and poultry feed additives. Using selective extractants—primarily mixtures of polyatomic alcohols—valuable phytochemicals can be isolated from green biomass, and oils obtained from coniferous needles can serve as additional sources. Application of such additives has been shown to stimulate broiler growth and enhance the biological value of poultry products (Radaelli M et al., 2016).

1.1 Complex Phytogenic Feed Additives and Their Effects on Productivity

A wide variety of poultry feed additives are formulated from complex mixtures of medicinal plants. Commonly utilized species include plantain (*Plantago major*), wormwood (*Artemisia absinthium*), yarrow (*Achillea millefolium*), chamomile (*Matricaria chamomilla*), nettle (*Urtica dioica*), oregano (*Origanum vulgare*), coltsfoot (*Tussilago farfara*), St. John's wort (*Hypericum perforatum*), sweet clover (*Melilotus officinalis*), and tansy (*Tanacetum vulgare*). Different combinations of these plants have been shown to enhance avian immunity, strengthen overall vitality, and facilitate the detoxification of harmful metabolites from the body.

In controlled experiments with Ross-308 broilers, substitution of the antibiotic amoxicillin with the phytogenic feed additive AdiCox Sol PF® produced significant improvements in performance indicators. The results demonstrated increased average live weight, a 5.2% rise in daily weight gain, and a 7.4% improvement in flock viability. Feed intake per kilogram of live weight gain declined by 15.8%, while the broiler productivity index increased. Economic analysis indicated a 10.2% rise in profitability from flock sales in the experimental group (Belomozhnov TD and Zhuravlev MS, 2019). AdiCox Sol PF® is composed of a stabilized aqueous mixture of extracts from white mustard (*Sinapis alba*), black pepper (*Piper nigrum*), sweet flag (*Acorus calamus*), and soapwort (*Saponaria officinalis*), and is administered to broiler chicks as a liquid preparation.

Another promising phytogetic supplement is Farmatan, derived through aqueous extraction of the woody tissues of the sweet chestnut tree (*Castanea sativa*). Notably, no chemical solvents are employed during its production, thereby ensuring ecological purity. Farmatan contains a diverse array of bioactive constituents, including flavonoids, organic acids and their salts, saponins, mono- and polysaccharides, essential oils, and a range of macro- and microelements. Its principal active compounds are hydrolysable ellagitannins. Empirical evidence suggests that Farmatan supplementation increases flock viability, improves laying performance—particularly in older hens—and enhances egg quality by reducing the incidence of cracked, dirty, or broken eggs. In addition, it optimizes feed conversion efficiency, accelerates daily weight gain, and increases final live weight in broilers.

Phytogetic additives may be provided in both natural and processed forms. For example, nettle can be introduced into poultry diets either fresh or as nettle meal. This additive has been shown to reduce compound feed consumption by approximately 30%, while supplying 19–21% of protein requirements, 55–75% of vitamin needs, and the full complement of essential microelements. Consequently, both the sensory attributes and biological value of meat and eggs are enhanced (Egorov IA, 2014).

The natural feed additive Apeks, derived from allicin in garlic, has also demonstrated strong growth-promoting potential. Its supplementation increased broiler live weight and daily gain by 5.5% and improved flock viability to 96%. Feed consumption per kilogram of live weight gain was reduced by 2%, thereby lowering production costs and enhancing profitability. When administered in combination with the antioxidant Emicidin, Apeks further reduced the production cost of 1 kg of meat by 3.66 rubles and increased profitability by 4.7% (Fedotov VA et al., 2018).

Extracts of thyme (*Thymus vulgaris*) have been shown to exert beneficial effects on poultry physiology by stabilizing metabolic processes, enhancing nutrient utilization, and improving overall productivity and growth performance. Experimental trials with ISA F-15 broiler chicks revealed that dietary inclusion of thyme extract increased live weight and daily gain across all developmental stages, improved flock viability, and reduced feed intake per kilogram of live weight gain. These outcomes collectively led to a higher European productivity index (Kishnyaykina EA and Zhuchaev KV, 2018).

Moreover, thyme extract had a favorable influence on carcass characteristics without adverse effects on internal organ development. No statistically significant differences were observed in the chemical composition of breast muscles or in the total essential amino acid content compared with the control group (Kishnyaykina EA et al., 2019). Peppermint oil also represents a valuable phytogetic additive. It exhibits disinfectant properties against gastrointestinal putrefactive processes, stimulates bile acid secretion, acts as a choleric, and possesses notable antioxidant activity. Furthermore, it increases the secretion of saliva and gastric juice, thereby contributing to improved digestive function (Vasilyeva OA et al., 2019). Similarly, conifer meal has been incorporated into poultry rations as a rich source of vitamins and minerals. Its inclusion has been associated with positive effects on growth performance, productivity, and overall metabolic regulation in poultry (Terentyev VI and Anikiyenko TI, 2011). In addition, feed additives derived from apiculture products have shown considerable potential. The biologically active supplement *Vinyvet*, for example, has been demonstrated to promote

growth, improve gastrointestinal function, and expand the absorptive surface area of the small intestinal mucosa. Moreover, *Vinyvet* possesses antiseptic properties, further contributing to improved health and productivity in poultry (Andrianova EN et al., 2016).

The phytobiotic Provitol, a composite formulation containing probiotics, essential oils, and plant extracts, has been found to regulate digestive processes in laying hens while supporting the establishment of beneficial intestinal microflora. In trials with Rodonit 3 hens, Provitol supplementation significantly improved live weight, with increases of 14.6–18.1% and 24.9–35.1% over the control at days 60 and 120 of the experiment, respectively. Daily weight gain exceeded control values by 22.8–35.0%, while flock viability rose by 3.2–3.9%. A subsequent series of experiments with Hy-Line Brown hens demonstrated that laying performance in the experimental groups was 4–7% higher than in the control over a two-month period. Despite additional costs associated with phytobiotic supplementation, profitability increased by 9.8% (Nuraliev ER and Kochish II, 2017). The essential oil-based additive Intebio has also been shown to improve broiler viability and productivity due to its antimicrobial, antioxidant, and anti-inflammatory properties. Studies on Cobb 500 broilers demonstrated that Intebio enhanced meat yield and carcass quality, increased viability to 100%, reduced feed consumption per kilogram of live weight gain by 3.0%, and elevated daily weight gain by 5.2% (Fedotov VA, 2018). Additional experiments with Ross-308 broilers confirmed positive effects on live weight gain, intestinal microflora, and immune function (Laptev GYu, 2019). Furthermore, molecular-level studies revealed that Intebio upregulates the expression of genes linked to productivity and disease resistance in laying hens, thereby providing a mechanistic explanation for its beneficial effects (Kochish II et al., 2019).

Table 3. Complex phytogetic feed additives and their effects on poultry productivity.

Additive/ Plant(s)	Type/Form	Target species / line	Key outcomes	Proposed mechanism	Reference
Thyme extract (<i>Thymus vulgaris</i>)	Plant extract (dietary)	Broiler, SA F-15	↑ live weight & daily gain; ↑ viability; ↓ feed/kg gain; ↑ European Productivity Index; no adverse organ effects or AA composition changes	Antimicrobial, antioxidant; improved nutrient utilization & metabolism	Kishnyaykina & Zhuchayev, 2018; Kishnyaykina et al., 2019
Apeks (allicin from garlic)	Natural feed additive (garlic- derived)	Broiler	↑ live weight & daily gain (+5.5%); viability 96%; ↓ feed/kg gain (-2%); ↑ profitability; with Emidicin: +4.7% profit	Antimicrobial, antioxidant; improved feed efficiency	Fedotov et al., 2018
Provitol (probiotics + essential oils + plant extracts)	Composite phytobiotic / synbiotic	Laying hen (Rodonit 3; Hy-Line Brown)	↑ live weight (14.6–35.1%); ↑ daily gain (22.8–35.0%); ↑ viability (3.2–3.9%); ↑ laying (4–7%); ↑ profitability (+9.8%)	Microbiome modulation; improved digestion	Nuraliev & Kochish, 2017
Intebio (essential oil- based)	Phytogetic essential oils blend	Broiler (Cobb 500, Ross-308);	↑ viability (up to 100%); ↓ feed/kg gain (-3%); ↑ daily gain (+5.2%); ↑ meat yield & carcass morphology; ↑ live weight; improved microflora & immunity; ↑ expression of productivity & disease-resistance genes	Antimicrobial, antioxidant, anti-inflammatory; gene expression modulation	Fedotov, 2018; Laptev, 2019; Kochish et al., 2019
AdiCox Sol PF® (<i>Sinapis alba</i> , <i>Piper nigrum</i> , <i>Acorus calamus</i> , <i>Saponaria officinalis</i>)	Stabilized aqueous extract blend	Broiler (Ross-308)	↑ daily gain (+5.2%); ↑ viability (+7.4%); ↓ feed/kg gain (-15.8%); ↑ productivity index; ↑ profit (+10.2%) vs amoxicillin	Antimicrobial, digestibility enhancement	Belomozhnov & Zhuravlev, 2019
Farmatan (<i>Castanea sativa</i> wood extract; ellagitannins)	Aqueous chestnut extract (no chemical solvents)	Broiler; laying hens (older hens pronounced effect)	↑ viability; ↑ laying; ↓ cracked/dirty/broken eggs; ↑ FCR efficiency; ↑ daily gain & final live weight	Astringent tannins; antimicrobial; gut protection	Zdorovyy kishnechnik..., 2019

Yucca schidigera extract	Saponin-rich extract	Broiler / chicks	↓ intestinal & fecal urease activity; ↓ ammonia formation	Urease inhibition; ammonia binding; membrane effects of saponins	Nazeer et al., 2002
Basil (<i>Ocimum basilicum</i>) essential oil (5%)	Essential oil in diet	Broiler / chicks	Antibacterial activity vs <i>Staphylococcus aureus</i> & <i>Escherichia coli</i>	Membrane disruption; terpene-mediated antimicrobial action	Maryati et al., 2007
DOSTO® Liquid 10% (oregano oil, water-soluble)	Essential oil preparation (first 5 days)	Chicks	Antibiotic alternative; immunostimulatory, antistress, antibacterial effects	Carvacrol/thymol-driven antimicrobial & immune support	Yunyaeva et al., 2016
Cinnamon essential oil / powder; garlic; turmeric	Essential oils / powders in diet	Broiler	↑ body weight; ↑ health status; ↑ FCR; ↓ mortality	Enzyme stimulation; antimicrobial; antioxidant	Al-Kassie, 2009; Yarru, 2009; Akyildiz & Denli, 2016
Rosemary, carvacrol, cinnamaldehyde, capsaicin (mixture)	Phytogenic blend	Broiler	↑ feed utilization efficiency	Digestive stimulation; antimicrobial synergism	Hernandez et al., 2004
Mint & pansy (dietary)	Herbal inclusion	Chicken	↑ proportion of unsaturated fatty acids; altered meat FA profile	Lipid metabolism modulation	Kapica et al., 2006
Hops, nettle, lemon (dietary)	Herbal inclusion	Chicken	↑ polyunsaturated fatty acids in meat	Lipid metabolism modulation; antioxidant effects	Kapica et al., 2006
Cinnamaldehyde, capsaicin, carvacrol (mixture)	EO actives blend	Poultry (GI tract)	↑ Lactobacilli in GIT; thicker gastric & SI mucus layer; ↓ adhesion of pathogens (* <i>E. coli</i> *, * <i>C. perfringens</i> *)	Microbiome modulation; mucus barrier enhancement	Castillo et al., 2006; Jamroz et al., 2006

Cinnamon, thyme, oregano extracts (highly concentrated)	Concentrated plant extracts	Poultry	Selective inhibition of pathogenic bacteria (sparing beneficials)	Targeted antimicrobial action; membrane disruption	Tipu et al., 2006
Peppermint oil	Essential oil	Poultry	↓ GI putrefaction; choloretic; antioxidant; ↑ saliva & gastric juice secretion	Bile acid stimulation; redox modulation	Vasilyeva et al., 2019
Nettle (fresh or meal)	Fresh herb / meal	Poultry	≈30% ↓ compound feed; supplies 19–21% protein needs, 55–75% vitamins, 100% microelements; ↑ sensory & biological value of meat/eggs	Nutrient-dense fortification; vitamin & mineral supply	Egorov, 2014
Conifer meal	Plant meal (needles/leaves)	Poultry	↑ growth, productivity, metabolism	Vitamin/mineral enrichment; antioxidant compounds	Terentyev & Anikiyenko, 2011
Vinyvet (apiculture-derived bioactive)	Bee-products-based supplement	Poultry	↑ growth; improved GI tract; ↑ absorptive surface of SI mucosa; anti-septic effects	Antimicrobial; gut trophic effects	Andrianova et al., 2016
Forestry by-product phytobiotics (leaf/needle extracts; conifer oils)	Selective extractants (polyatomic alcohol mixes)	Broiler	↑ growth; ↑ biological value of products	Phytochemical enrichment; antioxidant & antimicrobial compounds	Radaelli et al., 2016

The variability in the composition of phytobiotics and the challenges in their standardization are significant limiting factors for their widespread industrial application. Different plant species, growth conditions, soil composition, climate, and extraction methods can significantly alter the concentration of bioactive compounds in phytobiotics (e.g., carvacrol, thymol, allicin, saponins). This leads to both instability in biological effects and difficulties in optimizing dosages. To address the challenges of standardization, future research should focus on the following directions: stabilization of the chemical profile - identifying the concentration of active compounds and developing standardized reference formulations using analytical methods such as high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC MS), and fourier-transform infrared spectroscopy (FTIR); biological standardization

developing standardized units of effect (Bioactivity Units) based on the *in vivo* biological activity of phytobiotics, such as immunomodulatory, antimicrobial, and antioxidant effects; bioavailability studies in the digestive system - applying technologies such as microencapsulation, nanoemulsion, and liposomal carrier systems to increase the absorption rate of active compounds in the gut. Thus, scientific analysis of these limitations and research aimed at resolving them will facilitate the reliable, reproducible, and industrial-scale application of phytobiotics. This will not only ensure the stability of production processes but also strengthen the role of phytobiotics in antibiotic replacement strategies.

Future research into the integration of phytobiotics into sustainable poultry production systems is essential. Existing scientific literature indicates that phytobiotics (e.g., *Origanum vulgare* – oregano and *Allium sativum* – garlic extract) enhance poultry immune response, stabilize gut microbiota, and improve the feed conversion ratio (FCR). However, to ensure that these effects remain consistent and scalable for industrial use, further scientific investigations are needed in areas such as dose optimization, standardization of active compounds, and comparative analysis of their effects across different poultry species.

Future research directions may include the following:

Molecular mechanism studies: investigating the effects of phytobiotics on gut epithelial barrier function and the expression of immune-related genes using genomic and proteomic approaches.

Study of synergistic effects: Determining the synergistic or antagonistic effects of combining phytobiotics with probiotics, prebiotics, and organic acids.

Industrial application models: conducting a comparative analysis of the economic efficiency (costs, growth rates, product quality, mortality) of phytobiotic supplements in large-scale broiler and layer farms.

Environmental impact assessment: assessing how the use of phytobiotics as an alternative to antibiotics reduces ammonia emissions, fertilizer residues, and environmental load.

In conclusion, the industrial-scale application of phytobiotics should be evaluated not only for their biological effectiveness but also for their economic sustainability and environmental impact reduction. Multidisciplinary research in this direction will provide the scientific foundation for integrating phytobiotics into sustainable poultry systems.

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