NATURAL GROWTH PROMOTERS: THE ROLE OF PHYTOBIOTICS IN POULTRY PRODUCTION

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Abstract

Global demand for poultry is rising, necessitating efficient and sustainable production techniques. The intensive poultry industry used to rely heavily on antibiotic growth promoters (AGPs). When added to feed at subtherapeutic levels, these chemicals were effective in improving growth rate, feed conversion ratio (FCR), and overall flock health by reducing subclinical illnesses and altering gut microbiota. However, because of the widespread and often negligent use of AGPs in animal agriculture, there were raised significant public health concerns regarding the development of antimicrobial resistance (AMR) in bacteria interfering human health. The European Union spearheaded this trend by completely banning the use of AGPs in animal feed in 2006. This decision was followed by many other countries, including the United States. In Canada and other Asian nations, the use of AGP has been limited or phased out completely. This global ban has spurred a rush of research into safe, natural, and effective alternatives to protect poultry health and productivity without worsening the AMR pandemic. Phytobiotics have emerged as one of the most promising and thoroughly researched categories of possibilities. They are referred to as phytogenics or herbal remedies, compounds derived from vegetal organisms that are incorporated into diets of animals in order to improve performance, health, and well-being. The diverse range of bioactive compounds in phytbiotics offers several benefits, from improving gastrointestinal functionality and nutrient utilization for boosting immune system performance and stress reduction, all of which ultimately contribute to the production of safe and superior poultry products.

Key words: *phytobiotics, botanicals, antibiotic growth promoters, extracts, essential oils, herbs*

INTRODUCTION

Adopting effective and sustainable production techniques is essential due to the growing demand for poultry meat and eggs worldwide. Antibiotic Growth Promoters (AGPs) have historically been a major component of intensive poultry operations. By altering the gut microbiome and preventing low-grade, subclinical infections, these substances effectively increased growth rate and improved Feed Conversion Ratio (FCR) when administered at sub therapeutic doses [1]. However, because of the growing emergence and worldwide spread of Antimicrobial Resistance (AMR) in bacteria, which constitutes a direct threat to human health, the widespread and occasionally unrestricted use of AGPs in animal farming raised serious public health concerns [2]. This worry led to a global change in regulations. Many other jurisdictions followed the European Union's 2006 complete prohibition on AGPs in animal feed, including the United States (via the 2017 Veterinary Feed Directive), Canada, and a number of Asian nations. A focused search for natural, safe, and efficient feed

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substitutes that can sustain production performance without adding to the AMR dilemma was required as a result of this worldwide effort. The most promising and well-researched class of alternatives is phytobiotics, sometimes referred to as phytogenics or botanicals. These plant-based compounds are added to animal diets with the express purpose of improving overall health, welfare, and performance [3]. Phytobiotics provide a sustainable substitute for contemporary chicken farming and are in perfect harmony with the growing customer demand for "naturally raised" and "antibiotic-free" poultry products. Their effectiveness is based on a broad range of bioactive substances that offer a variety of advantages, from strengthened immunity and decreased physiological stress to better nutritional utilization and gastrointestinal health [4]. The steady production of high-quality and safe chicken products is eventually supported by these combined benefits (Figure 1).

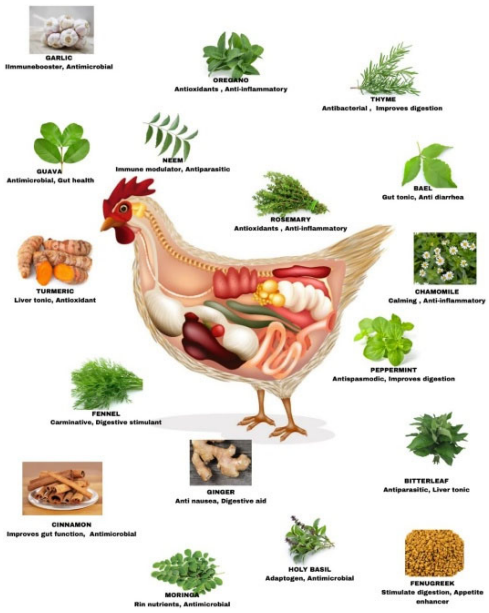

Fig. 1 Common phytogenic additives and their functional roles in poultry, adapted after Oni, 2025 [8]

In terms of poultry nutrition, this natural approach essentially signifies a strategy shift from symptomatic therapy to systemic optimization. AGPs have historically worked by "sparing" energy that would have been used to combat low-grade illnesses by reducing the microbial load [5]. In contrast, phytobiotics offer a comprehensive, multi-target approach: they improve metabolic efficiency through anti-inflammatory [6] and antioxidant effects [7], strengthen the host's natural defense [8], and structurally optimize the digestive system for better nutrient absorption [9] (see figure 1).

CATEGORIES OF PHYTOBIOTICS USED IN THE DIET OF POULTRY

Phytobiotics are a very varied group of plant-based substances that are mainly classified according to their molecular makeup, place of origin, and typical use in feed [10].

The main categories of phytobiotics are: herbs, spices, essential oils (EOs) and plant extracts.

Herbs are non-woody blooming plants or certain plant parts (stems, leaves, flowers) with aromatic, medicinal, or flavoring qualities fall under this group [11]. Complex combinations of flavonoids, bitter principles, and essential oils can be found in herbs [12]. Ginger, garlic (*Allium sativum*), oregano (*Origanum vulgare*), thyme (*Thymus vulgaris*), and rosemary (*Rosmarinus officinalis*) are typical examples. Their main mechanisms of action are antibacterial, antioxidant, and anti-inflammatory; these are frequently fueled by organosulfur compounds like allicin found in garlic or active ingredients like carvacrol and thymol found in thyme and oregano [13].

Spices are dried plant parts with strong flavors and aromas, such as seeds, bark, fruits, or roots. They are employed for certain medicinal purposes or to improve the palatability of feed [14]. Black pepper (*Piper nigrum*), turmeric (*Curcuma longa*),

cinnamon (*Cinnamomum verum*), and capsicum (*Capsicum annuum*) are a few examples. Turmeric contains curcuminoids, which are potent antioxidants and anti-inflammatory substances [15]. Piperine, which is found in black pepper, has been demonstrated to improve nutritional absorption by promoting the production of digestive enzymes. Cinnamonaldehyde, which has potent antibacterial and antioxidant qualities, is found in cinnamon [17].

EOs are volatile, lipophilic secondary metabolites that are collected from different plant sections using techniques like distillation or solvent extraction. Terpenes (such pinene and limonene) and terpenoids (like thymol, carvacrol, and eugenol) predominate in these intricate chemical mixtures [18]. Anethole and other phenylpropanoids are important constituents. Clove oil, which is high in eugenol, and essential oils from thyme and oregano [19] are common examples. Because EOs are lipophilic, they can easily pierce and damage bacterial cell membranes, disrupting ion channels and enzymatic function and ultimately causing microbial cell death. They also have strong antioxidant and anti-inflammatory properties [20].

Plant extracts are concentrated versions of bioactive compounds that are extracted from plants using methods like supercritical CO2 extraction, ethanolic extraction, or aqueous extraction. Compared to essential oils, extracts usually contain a greater variety of components, such as non-volatile compounds including flavonoids, glycosides, saponins, and tannins [21]. Examples include the catechin-rich green tea extract, the proanthocyanidin-rich grape seed extract, the tannin-rich chestnut wood extract, and the polyphenol and saponin-rich *Yucca schidigera* extract. Flavonoids are prized for their strong anti-inflammatory and antioxidant properties. Due to their astringent qualities, tannins may alter the gut microbiota and possibly lower intestinal permeability [22]. It is well known that saponins, like those found in *Yucca schidigera*, can reduce intestinal ammonia production by blocking urease activity [23].

Synergistic interactions, in which a combination of various phytobiotic chemicals produces an effect far stronger than the simple sum of their individual contributions (see Table 1), are frequently responsible for the success seen in feed applications [24]. This necessitates careful formulation, making sure that elements are chosen that work well together throughout the whole digestion process, from microbial management and enzyme stimulation (pre-absorption) to structural reinforcement (gut barrier protection) [25].

EFFECT OF PHYTOBIOTICS ON CHICKEN BROILERS GROWTH PERFORMANCE AND FEED CONVERSION

The capacity of phytobiotics to reliably increase Body Weight Gain (BWG) and Feed Conversion Ratio (FCR) in broilers, making them a competitive alternative to AGPs, is the main economic justification for their use. This improvement in performance is the result of several interconnected physiological and microbiological processes [26].

Enhanced Nutrient Digestibility and Absorption Endogenous digestive enzyme activity and secretion are either directly or indirectly stimulated by phytobiotics. For instance, it has been shown that essential oils high in carvacrol, thymol, or cinnamonaldehyde can increase the activity of pancreatic enzymes such as lipase, protease, and amylase. This enzymatic boost increases the total amount of nutrients available for absorption by facilitating a more effective breakdown of dietary proteins, lipids, and carbs [27]. Additionally, phytobiotics maximize the surface area accessible for nutrient intake by improving the intestine's structural design.

Modulation of Gut Microbiota For the best possible digestion and nutrient utilization, a balanced, healthy microbiome

is necessary. Particularly, phytobiotics prevent the formation of harmful bacteria such *Clostridium perfringens*, *E. coli*, and *Salmonella spp*. These dangerous microbes create toxins that injure the gut lining and compete with the host for nutrition. More nutrients are effectively directed towards the broiler's growth by reducing this pathogenic burden [28]. At the same time, several phytobiotics encourage the growth of beneficial species like Bifidobacterium and Lactobacillus. These commensal bacteria produce Short-Chain Fatty Acids (SCFAs), which help maintain a healthy gut environment and provide intestinal epithelial cells with essential energy [29].

Table 1 List of bioactive substances derived from various phytobiotics*

Plant sample	Bioactive compound
Glycyrrhiza glabra (Licorice) extract	Glycyrrhizin, glycyrrhizinic acid, glabridin, glabrene, and glabrol
Chamomile flower extract	β-Famesene
Thymol oil extract	Gamma-terpinene and thymol
Olive leaf extract	Oleuropein, polyphenols and flavonoids
Fennel essential oil	Anethol, fenchon, *trans*-anethole
Quillaja saponaria and *Yucca schidigera*	Saponins polyphenols
Froriepia subpinnata	Thymol, carvacrol, lomonene and terpinene
Pulicaria jaubertii	Dimethoxy dimethylsilane, benzaldehyde thiosemicarbazone
Pulicaria gnaphalodes	1,8-Cineole
Turmeric	Curcumin and turmerones
Coriandrum sativum	Carvone, geraniol, limonene, camphor and linalool
Epimedium	Prenyl flavonols: Icarin, epimedin A-C and baohuoside 1
Cynara cardunculus (Artichoke)	Cynarine
Pueraria extract	Puerarin
Portulaca oleracea L.	Phenolic alkaloids such as oleraceins
Radix *Sophorae flavescentis*	Alkaloids and flavonoids
Thalictrum glandulosissimum	Berberine
Terra flavausta	Silicic acid
Pogostemon cablin	Phytosterols, flavonoids

adapted after Obianwuna et al., 2024 [9, 41]

Anti-inflammatory Effects (Metabolic Efficiency) Subclinical inflammation, which is often brought on by infections or dietary irritants, places a heavy metabolic burden on the gastrointestinal tract and diverts a substantial amount of energy and nutrients from productive growth to tissue repair and immunological responses [30]. Many phytobiotics have potent anti-inflammatory qualities because of their high phenolic and flavonoid content. The metabolic cost of sustaining immunological activation is greatly reduced by lowering chronic inflammation in the gut, which frees up metabolic energy specifically for muscle growth and acquisition [31].

Antioxidant Activity Oxidative stress, which jeopardizes cellular integrity and adversely affects physiological processes necessary for growth, is brought on by intensive production, rapid growth, and environmental stressors [32]. Phytobiotics are powerful antioxidants, especially those high in polyphenols (from rosemary or grape seed extract, for example). They protect cellular integrity and neutralize free radicals. Better growth rates are the outcome of this protective action, which improves metabolic efficiency [33].

The cumulative effect of minimizing nutrient loss (by lowering pathogen competition and anti-inflammatory energy expenditure) and maximizing nutrient capture (via structural and enzymatic changes) is essentially responsible for the observed improvement in FCR [34].

Because of this, phytobiotics are advanced nutrient-partitioning agents that preferentially focus dietary energy on muscle growth as opposed to physiological defense. Phytogenic feed additives dramatically boost broiler daily growth and FCR, according to research, including meta-analyses [35].

EFFECT OF PHYTOBIOTICS ON CHICKEN BROILERS INTESTINAL MICROBIOTA

In broiler chickens, the intestinal microbiota's balanced activity is essential for host immunity, health, and nutritional absorption. This microbial community is being dynamically shaped towards a more stable and advantageous composition by phytobiotics [36].

Selective Antimicrobial Activity against Pathogens Numerous plant extracts and essential oils (EOs) exhibit strong antibacterial properties that target common poultry diseases. Bacterial cell membranes are disrupted, cell permeability is increased, enzyme performance is inhibited, and genetic material is interfered with by active chemicals such thymol, carvacrol, cinnamonaldehyde, and allicin (found in garlic) [37]. This selective activity effectively mitigates intestinal dysbiosis by limiting the colonization and growth of pathogenic bacteria such as Escherichia coli, *Salmonella spp*., and *Clostridium perfringens* (the cause of necrotic enteritis). Research demonstrates that broilers given phytobiotic supplements have lower intestinal levels of *Clostridium spp*. and coliform [38].

Promotion of Beneficial Bacteria Some phytobiotics suppress infections while simultaneously promoting the growth and metabolic activities of beneficial commensal species like *Lactobacillus spp.* and *Bifidobacterium spp.*. The production of Short-Chain Fatty Acids (SCFAs), such as butyrate, acetate, and propionate, depends on these helpful bacteria. In addition to giving intestinal epithelial cells energy, SCFAs help reduce the pH of the gut, which further prevents the growth of many pH-sensitive pathogens through competitive exclusion [39].

Modulation of Microbial Metabolites By promoting SCFA-producing organisms, phytobiotics have a direct impact on the gut flora's metabolic output. Elevations in SCFA levels, especially butyrate, boost immune responses, improve overall host metabolism, and improve intestinal barrier integrity[40].

The ability of phytobiotics to strategically control and regulate the intestinal microbiota towards a balanced, healthy composition is critical to their successful use as growth promoters. Improved nutritional absorption, decreased intestinal dysbiosis, and increased immunity are all directly attributed to this healthy habitat [41].

EFFECT OF PHYTOBIOTICS ON CHICKEN BROILERS INTESTINAL HISTOLOGY

Maintaining a functioning barrier against infections and optimizing nutrition absorption and digestion depend heavily on the structural integrity and morphology of the mucosa. Villus height, crypt depth, and the V/C ratio are three important structural metrics where phytobiotics have clearly been shown to improve intestinal histology.

Increased Villus Height (VH) Important extensions in the small intestine that expand the surface area accessible for nutrient absorption are called intestinal villi. A higher absorptive capacity is indicated by a higher VH. Taller villi are supported by phytobiotics in a number of ways:

- Inflammation Reduction: By reducing inflammation, phytobiotics can stop the damage and eventual atrophy of villus structure brought on by long-term inflammatory conditions [42].
- Pathogen Load Management: Reducing dangerous bacterial populations promotes villus growth and integrity by lessening the toxic damage done to the intestinal epithelium [43].

• Metabolite Provision: Phytobiotics supply an essential energy source for enterocyte growth and differentiation by promoting the formation of SCFA, particularly butyrate [44].

• Antioxidant Protection: By shielding the enterocyte cell membranes from oxidative stress, damage that may otherwise result in villus shortening is avoided [45].

Decreased Crypt Depth (CD) New epithelial cells are produced in the Lieberkühn crypts to replace injured or older cells at the tip of the villus. Higher cell turnover rates are frequently associated with deeper crypts, indicating continued cellular damage and a continual need for repair. On the other hand, a shorter CD denotes a slower rate of regeneration and less cellular damage, suggesting a healthier intestinal environment and less metabolic energy diversion towards tissue maintenance [46].

Improved Villus Height to Crypt Depth Ratio (V/C Ratio) A common metric for evaluating gut health and digestive efficiency is the V/C ratio. In comparison to the energy expended on tissue renewal (shallow CD), a larger ratio denotes a strong absorptive surface (tall VH). By simultaneously encouraging villus growth and reducing the requirement for quick crypt regeneration, phytobiotics continuously increase this ratio [46].

EFFECT ON GENERAL HEALTH STATUS, FLOCK LIVABILITY AND WELFARE OF CHICKEN BROILERS

Beyond direct growth promotion and localized gut effects, phytobiotics have a good impact on general health, flock livability, and overall welfare-all of which are essential elements of sustainable chicken farming.

Enhanced Immune Response (Immunomodulation) Many phytobiotics have important immunomodulatory properties that enhance grill innate and adaptive immune responses. Important immune cells like macrophages, natural killer cells, and lymphocytes (T and B cells) are activated by substances like certain polyphenols and flavonoids. Additionally, they control the production of cytokines, directing the immune system towards a state of equilibrium that effectively fights infections without causing undue tissue damage or inflammation. Phytobiotics indirectly support the Gut-Associated Lymphoid Tissue (GALT), the largest immunological organ in chickens and important for effective local and systemic defense, by maintaining intestinal integrity and promoting a healthy gut flora [47].

Antioxidant Characteristics and Decreased Oxidative Stress - increased levels of Reactive Oxygen Species (ROS) and consequent oxidative stress are often caused by the rapid growth rates and high metabolic demands of intensive grill manufacturing. Rich in flavonoids and polyphenols, phytobiotics scavenge free radicals, lower lipid peroxidation, and increase the activity of intrinsic antioxidant enzymes like superoxide dismutase. By maintaining cellular integrity and metabolic efficiency, this defense increases the bird's resistance to a variety of environmental stresses (such as heat stress), which promotes better health and longer life [48].

Anti-inflammatory Effects (Metabolic Sparing) - at the molecular level, phytobiotics have potent anti-inflammatory effects that include altering inflammatory signaling pathways including the NF-KB pathway. They lessen the long-term metabolic burden of inflammation by reducing the production of pro-inflammatory mediators and preserving the integrity of the intestinal barrier, freeing up resources for healthy growth and maintenance [49].

Improved Disease Resistance and Livability - the bird's natural defenses against bacterial, viral, and parasite illnesses are strengthened by the combination of direct antibacterial activity,

strong immunomodulation, and maintained gut integrity. As a result, there are fewer instances of sickness, which immediately improves flock livability and lowers mortality rates. This strong natural defense is essential since it greatly reduces the need for therapeutic antibiotic treatments, satisfying customer demands for poultry products free of residues as well as legal requirements [50].

Stress Alleviation and Welfare Enhancement - as adaptogens, some phytobiotics help birds deal with stressors associated with production, including as handling, heat, and transportation. They increase overall animal comfort by lessening negative physiological stress reactions, which in turn lessens abnormal behaviors linked to stress and improves overall wellbeing [51].

THE USE OF PHYTOBIOTICS AS GROWTH PROMOTERS IN CHICKEN BROILERS: OBSTACLES AND RESTRICTIONS

Despite the tremendous benefits that have been demonstrated, a number of serious scientific and industrial obstacles stand in the way of phytobiotics' widespread, regular commercial utilization.

Variability in Efficacy and Composition - The main obstacle is the intrinsic variation in the chemical profile and concentration of the active substances found in raw plant materials. The particular plant genotype, geographic origin, harvesting conditions (such as plant maturity and season), environmental factors (such as climate, soil type, and rainfall), and the technical parameters utilized during processing and storage all have an impact on this discrepancy. Because of this considerable variability, it is difficult to ensure consistent product quality, which leads to inconsistent efficacy across various commercial studies and batches [52].

Absence of Quality Control and Standardization - One major obstacle is the absence of industry-wide, standardized procedures for active component compositional analysis and Quality Control (QC). Many commercial phytobiotic formulations are released without extensive chemical profiling or standardization, in contrast to pharmaceutical medicines that are subject to strict restrictions. It is very challenging to assess various commercial products, confirm potency claims on labels, or develop trustworthy dosage recommendations due to the lack of regulatory consensus. Inadequate standardization can result in dosages that are either too high, putting performance at risk, or suboptimal, failing to produce the desired effects [53].

Intricate Connections and Mechanism Clarification - Phytobiotics are intricate mixtures of hundreds of distinct compounds. It is analytically difficult to pinpoint the exact methods by which these elements interact with the host's physiological systems (e.g., enzyme pathways) or with one another (synergism, antagonism). Although primary active compounds are frequently the focus of research, secondary constituents may have important but sometimes neglected functions in the overall biological activity, making efforts to optimize products more difficult [54].

Methods of Application and Dosage - finding the ideal, highly variable dose is essential. The optimal dosage is determined by the broiler's age, health, environment, and feed matrix composition in addition to the intended benefit (e.g., immunological modulation versus growth stimulation). Additionally, to guarantee excellent bioavailability and stability of the active ingredients in the digestive tract, the application technique (such as water or feed additive) needs to be precisely optimized [55].

Cost-effectiveness and Palatability - strong, occasionally disagreeable flavors or scents can be added to feed by high quantities of particular essential oils.

Reduced feed intake and hence subpar growth performance may follow from this. Although encapsulation technology can help with these stability and palatability problems, it greatly raises the cost of the finished product. An economic hurdle, particularly in price-sensitive markets, is the initial investment needed for standardized, high-quality phytobiotics, which frequently surpasses the cost of conventional AGPs or more straightforward feed additives [56].

CONCLUSIONS

Phytobiotics have successfully emerged as a key, sustainable alternative to antibiotic growth promoters (AGPs) in modern chicken production. These plant-derived compounds act as comprehensive natural growth enhancers, promoting safer, superior poultry products through various biological pathways.

Phytobiotics reliably improve growth performance and Feed Conversion Ratio (FCR) by maximizing nutrient digestibility, enhancing gut integrity, and exerting an energy-sparing, anti-inflammatory effect. They stabilize the gut by regulating the intestinal microbiota, promoting beneficial commensal species (e.g., via Short-Chain Fatty Acid (SCFA) synthesis) while reducing pathogens. Structural evidence, such as increased villus height and an improved villus/crypt (V/C) ratio, confirms better absorptive ability. Crucially, their strong immunomodulatory, antioxidant, and anti-inflammatory properties boost overall health, stress tolerance, flock liveability, and reduce the need for therapeutic antibiotics.

Despite these benefits, several barriers impede the widespread commercial use of phytobiotics. These drawbacks include significant variability in raw material composition, a lack of uniform standardization for commercial formulations, the challenge of clarifying complex synergistic interactions, and the need to optimize dosage and application methods. Economic constraints and the requirement for larger, long-term studies under commercial farm conditions also remain key factors.

Future commercial success depends on scientific rigor and technological innovation. Investment should focus on accurately defining molecular mechanisms and interactions using advanced "omics" technology. Additionally, technological innovation in formulation and delivery, such as microencapsulation, is essential to ensure consistent effectiveness, high bioavailability, and stability in industrial settings.

Phytobiotics represent a natural, scientifically supported, and comprehensive approach to enhancing chicken health and productivity, going beyond a mere replacement for AGPs. Their continuous improvement and standardization are vital to meet the global demand for high-quality, antibiotic-free poultry while supporting animal welfare and environmental sustainability.

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