

Coccidiosis management through phytobiotics, current status and future perspective

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Abstract

Coccidiosis remains one of the most economically devastating protozoan diseases affecting the global poultry industry, causing substantial losses through reduced growth performance, increased mortality, and high preventive and therapeutic costs. The disease is caused by host-specific intracellular parasites of the genus *Eimeria*, which invade and damage the intestinal epithelium, impairing nutrient absorption and immune function. Although synthetic anticoccidial drugs have been widely used for disease control, their long-term application has resulted in drug resistance, residue concerns, and adverse effects on poultry health and productivity. These limitations have intensified the search for safe, sustainable, and effective alternatives. Phytobiotics bioactive plant-derived compounds have emerged as promising alternatives for the management of coccidiosis due to their antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory properties. This paper reviews the current status and future prospects of phytobiotics in coccidiosis control, with particular emphasis on commonly studied plants such as *Allium sativum* (garlic), *Curcuma longa* (turmeric), *Origanum vulgare* (oregano), and *Cinnamomum zeylanicum* (cinnamon). These phytochemicals act through multiple mechanisms, including disruption of parasite cell membranes, inhibition of oocyst sporulation, enhancement of gut integrity, modulation of gut-associated lymphoid tissue, and stimulation of both humoral and cell-mediated immune responses. Advances in drug delivery systems such as nanocarriers, liposomes, and herbosomes further enhance the bioavailability and efficacy of phytochemicals, making them suitable for large-scale poultry production. In the context of rising antimicrobial resistance and increasing demand for residue-free animal products, phytobiotics represent a viable, eco-friendly strategy for sustainable coccidiosis management.

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INTRODUCTION

Poultry is one of the fastest-growing segments of the agricultural sector in India today. According to the 2023-24 edition of Basic Animal Husbandry Statistics (BAHS 2024), published by the Ministry of Fisheries, Animal Husbandry & Dairying, Govt. of India, India ranks 2nd in the world in terms of total egg production and ranks 5th in the world in total meat production. The Annual growth rate of egg production was 10.19% (for yr 2019-20), 6.19% (for yr 2021-22), 3.17% (for yr 2023-24) which is significantly reduced from 2019 to 2024, and also in context of meat

production it was 5.62% (for yr 2021-22), 4.95% (2023-24) which is also slightly decreased. These data show that the poultry sector is affected by many infectious diseases, which ultimately lead to greater economic and production losses. By Blake *et al.*, 2020 Globally, losses related to the disease, including drug costs, decreased birds' performance, and increased mortality, exceed US\$3 billion per year, with 18% of this cost being for prevention alone. Hence, coccidiosis became a continuous economic threat to the poultry industry.

ETIOLOGY OF COCCIDIOSIS

Coccidiosis is the most fatal protozoan disease of poultry caused by an intracellular parasite of the genus *Eimeria* and *Isospora*, a host-specific parasite. By ingestion of oocysts of *Eimeria*, birds become infected. After ingestion of sporulated oocysts, parasites invade the epithelial cells of the intestine and multiply in it, which ultimately destroys the epithelium. There are 12 species of coccidia reported from domestic fowl. These are *Eimeria tenella*, *E.necatrix*, *E.brunetti*, *E.acervulina*, *E.maxima*, *E.mitis*, *E.mivati*, *E.hagani*, *E.praceox*, and *Isospora gallinae*, *Wenyonella gallinae*, *Cryptosporidium tyzzer* (Pal & Sanyal 2023)

AVIAN IMMUNE SYSTEM

The avian immune system involves various lymphoid organs, which are key components of the immune system. The bursa of Fabricius, which is the site of B-cells & thymus, which is the site of T-cells considered primary lymphoid organs. Whereas secondary lymphoid organs are also present, like bone marrow, spleen, and the harderian gland, which also contribute to immunomodulation. Similarly, the digestive tract also includes some tissues that function as lymphoid organs, which are referred to as Gut Associated Lymphoid Tissue (GALT), which include Peyer's patches and Caecal tonsils. The mucosa of the intestine is covered by mucus, which is a hydrated gel that protects epithelial cells from enzymatic, microbial, chemical, and mechanical injury according to Gomez *et al.*, (2023)

CURRENTLY AVAILABLE SYNTHETIC ANTICOCCIDIALS AND THEIR ADVERSE EFFECTS

Monensin, which is routinely used as an anticoccidial drug this is not recommended for layers or chicks over 16 weeks of age, as older birds attain sexual maturity at this age, and this drug causes ovarian dysfunction. Decoquinat, which is used as an anticoccidial, shows effects only against invading sporozoites, not against adult coccidia. Nicarbazine at higher doses causes adverse effects on egg production and hatchability. Due to the inhibition of collagen type 1 in avian cells, skin rupture-like problems arise from overdosage of halofuginone. At higher doses of amprolium and sulfaquinoxaline in laying hens, egg-drop and in broilers, growth inhibition and polyneuritis can occur. Other side effects may include crystalluria, anaemia, leukopenia, and thrombocytopenia (Sandhu, 2006). Hence, in the 21st century, phytochemicals gained attention as a promising alternative with easy availability, fewer side effects to promote the poultry industry.

PHYTOCHEMICALS: AS A PROMISING ALTERNATIVE

Phytochemical is a collective term used for chemicals or agents obtained from plants, having a

distinctive structure and functions. In the last two decades, phytochemicals have been widely researched by utilizing numerous numbers of vivo and in vitro models, which delivered the beneficial results of these compounds in ameliorating various diseases and enhancing the quality of life.

Allium sativum (Garlic)

Garlic is used in day-to-day life as a spice in kitchens, and also as a medicinal plant in human and veterinary medicine. Ahmad *et al.*, (2024) highlighted that there is a significant amount of organosulfur compounds such as diallyl sulfide, diallyl trisulfide, 2-Vinylthiols, and allicin. Aqueous extract of garlic contains phenols, flavonoids, and sulfur compounds. Phenolic content alters the permeability of the cytoplasmic membrane for various cations and affects all physiological activities. Loss of vital constituents of the cell to the surrounding environment also causes a decrease in the synthesis of ATP & proteins and ultimately causes cell death. He also stated that Garlic tincture (alcoholic extract of garlic), which is rich in sulphuric acid, shows immunostimulatory effect and is capable of inhibiting oocyst sporulation. Reports from a study conducted by Ali *et al.*, (2019) demonstrated that feed intake, body weight, and feed conversion ratio (FCR) were significantly higher in birds supplemented with ginger and garlic compared to the positive control. Similarly, oocyst shedding, lesion score, and histopathology of the small intestines improved in ginger and garlic-supplemented birds after induced infection in broilers. In this study, the infected birds were supplemented with ginger extract (5g/kg of feed), garlic extract (15g/kg of feed), and amprolium hydrochloride (1.25gm/L of water). It is important to treat coccidia through phytochemical modulation by supplementation with *Allium sativum* (Garlic) to broiler chicks, showing as same effect as amprolium, which is routinely used as a synthetic anticoccidial.

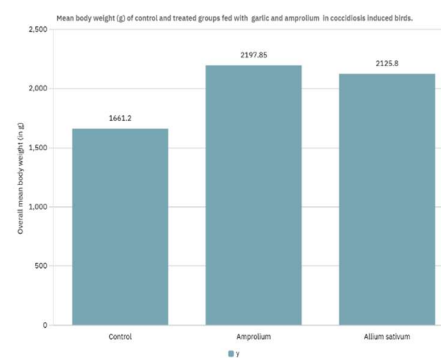


Fig 1. Mean body weight (in g) of control and treated groups fed with garlic and amprolium in coccidiosis-induced birds.

Curcuma longa (Turmeric)

Turmeric is a highly preferred, potent immunomodulator that contains bioactive phytochemicals like curcuminoids, volatile oils, and polysaccharides. Curcumin, which is the most potent

bioactive phytochemical, improves the activity of digestive gut enzymes, leading to easier nutrient absorption & its utilization. Kim *et al.*, (2013) performed a study in experimentally induced broiler chickens by *E. tenella* & *E. maxima* sporulated oocysts.

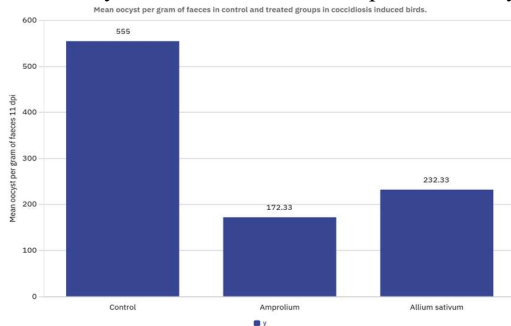


Fig 2. Mean oocyst per gram of faeces in control and treated groups in coccidiosis-induced birds

Showed that chickens fed with *Curcuma longa* diet had increased systemic humoral and cellular response compared with the control group. At the local tissue, *Curcuma longa* induces alterations in the transcriptome of lymphocytes of the intestine, causing up- and downregulation of inflammatory genes, and shows an overall anti-inflammatory effect. In that same experiment, feeding broiler chickens with diets containing *C. longa* did not show any toxic effects on the host, but enhanced BW gain and reduced fecal oocyst shedding compared with the noninfected birds with *E. tenella*-infected birds.

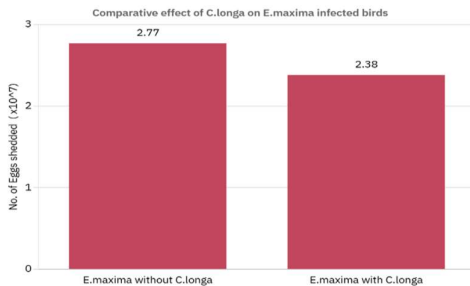


Fig 3 . Comparative effect of *C.longa* on *E.maxima* infected birds

In contrast, oocyst shedding was unaffected in *C. longa*-fed birds infected with *E. maxima*. Inclusion of *Curcuma longa* (Turmeric) shows immunomodulatory effects tremendously, which are species-specific to *Eimeria*, and these effects may reflect differential rates of phytonutrient absorption in the various regions of the gut.

***Organum vulgare* (Oregano Essential Oil)**

The primary phytochemicals or bioactive agents in oregano oil are polyphenols, specifically carvacrol and thymol, which exhibit immunomodulatory effects in the control of coccidiosis. Reports of Tsinas *et al.*, (2011) suggest its immunostimulating activity against *E.maxima* and *E.acervulina*.

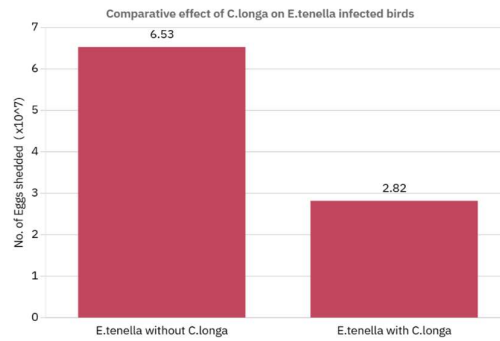


Fig 4. Comparative effect of *C.longa* on *E. tenella*-infected birds

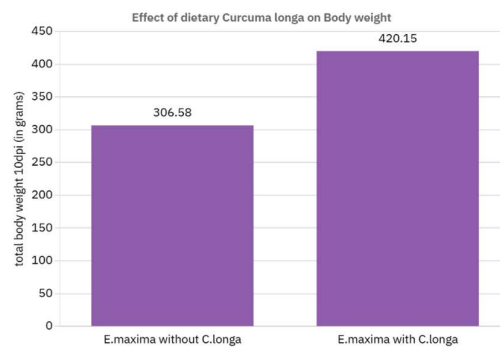


Fig 5. Effect of dietary *Curcuma longa* on body weight infected with *E.maxima*

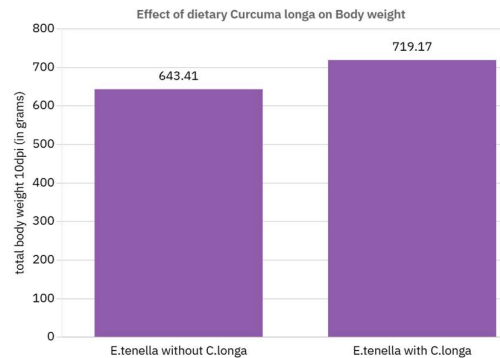


Fig 6. Effect of dietary *Curcuma longa* on body weight infected with *E.tenella*

In this study, the infected birds are supplemented with oregano oil (300mg/kg) for group 1, oregano oil (600mg/kg) for group 2, and salinomycin 60mg/kg for group 3. Results showed that dietary oregano oil supplementation in both oregano-supplemented groups resulted in body weight gains. The lesion score of the challenged oregano groups was similar to that of the salinomycin group and significantly lower than that of the challenged group. According to Ultee *et al.*, (1999), the hydrophobic property of carvacrol allows it to interact with the cytoplasmic membrane, thereby altering its permeability to cations (H⁺ & K⁺), resulting in the dissipation of ion gradients. Supplementation with *Organum vulgare* (Oregano Essential Oil), which

shows effects on the cytoplasmic membrane of coccidia, causes dissipation of gradients of ions and, hence, impairment occurs, causing leakage of cell contents, membrane potential collapse, decreased ATP production, and ultimately, cell death occurs.

***Cinnamomum zeylanicum* (Cinnamon)**

Cinnamon is used in the kitchen as a spice, and it exhibits phytochemical immunomodulatory activities due to the presence of cinnamaldehyde, the main flavor compound extracted from the bark, and eugenol, extracted from the leaves. Both of the above bioactive components are part of the cinnamon essential oil (CNO). Orengo *et al.*, (2012) reported that inclusion of cinnamaldehyde in broilers' diet reduced *Eimeria acervulina* oocyst infection and decreased gross lesion scores compared with other groups. Ali *et al.*, (2021) reviewed that Proanthocyanidins, such as procyanidin A and procyanidin B2, are metabolized by gut flora to produce phenolic acids and other metabolites and are detected in urine. It is suggested that these phenolic acids may have health effects in the gut. Also, Zhu *et al.*, (2020) studied the effect of cinnamon in humans in which reduces levels of malondialdehyde (MDA) biomarker of lipid peroxidation. High MDA levels increase lipid peroxidation ultimately causes damage to immune cell membranes. Oxidative damage to the bursa of Fabricius, thymus, and spleen is associated with excess MDA in the case of poultry. Cinnamon essential oil supplementation in broiler diet CNO supplementation in broiler feed increases the height of villi in the duodenum, hence it increase the surface area of villi and also increases absorption of nutrients. If villus height is more than, enzyme activity is also greater. It prevents the mucus layer from invasion and also stimulates gene expression of MUC2, which serves as a mucosal barrier and ultimately protects intestinal epithelial cells.

MISCELLANEOUS HERBS WITH IMMUNOMODULATORY EFFECTS

Other than those mentioned above, numerous herbal plants show phytochemical properties such as *Beta vulgaris* (Sugar beet) shows the phytochemical properties because of the presence of the bioactive agent betaine, from which osmolyte and methyl group donors maintain cellular homeostasis, stabilize the cell membrane, and maintain the integrity of the intestinal epithelium, The short chain fatty acids, including acetic and propionic acids, are essential for some beneficial intestinal bacteria, such as *Lactobacillus* and *Bifidobacterium*, in the gut of poultry. Accordingly, the inhibition of some intestinal colonization by harmful microorganisms may occur by Abd El-Ghany *et al.*,(2022). The combination of *Mangifera indica*, *Lawsonia inermis*, and *Carica papaya* in the herbal mixture showed higher antioxidant activity. The effect aligns with the hypothesis that diverse phytochemicals with different antioxidant pathways can work in combination to stabilize free

radicals more effectively. *Mangifera indica* is rich in mangiferin, a xanthone with antioxidant and anti-inflammatory activity; *Carica papaya* contains carotenoids and flavonoids; and *Lawsonia inermis* (Mehandi) provides phenolic acids & tannins. Together, these compounds act on multiple antioxidant pathways according to a study performed by Shahani *et al.*, (2025). Choi *et al.*, (2020) highlighted that Tannic acid at an appropriate dose enhances the proportion of CD4+ and CD8+ cells and B cells in cecal tonsils, and it increases mRNA expression of IFN- γ (acts as an adjuvant in vaccines and proinflammatory cytokine) in broiler chickens. We can extract these tannins from *Aloe vera*, guava fruit. Arabinoxylans are bioactive polysaccharides obtained from wheat bran, barley, and oats, which show an immunomodulatory effect in which levels of CD3+(T cell activation), IL2(T cell proliferation), and IFN- γ (macrophage activation) in the spleen of broiler chickens increase significantly reported by Sato *et al.*, (2012). Chlorogenic acid (CGA), quinic acid major phenolic compound obtained from Coffee. Studies have shown that CGA acts as an immunomodulator in coccidiosis control, in which it decreases levels of diamine oxidase (an enzyme from enterocytes that degrades histamine and maintains intestinal homeostasis) and D-lactic acid. Increased Levels of these biomarkers show that there is damage to the intestinal mucosa, and these biomarkers leak into the blood circulation and increase in levels by Liu *et al.*, (2024).

DRUG DELIVERY SYSTEM OF PHYTOCHEMICALS

We can administer these bioactive agents as nanocarriers like liposomes (hydrophilic and hydrophobic and with a phospholipid bilayer that easily biodegrades), microemulsions, microspheres, liquid crystals, transferosomes, herbosomes (improve bioavailability of herbal phytochemicals), and nanocrystals highlighted by Chaurasia *et al.*,(2025).

CONCLUSION AND FUTURE PERSPECTIVES

India is facing a major problem of antimicrobial resistance in humans and animals, which has become a major threat and ultimately causes economic and production loss. In this era of the AMR threat, hope for veterinary practitioners could be phytochemical modulation as an alternative to synthetic drugs.

Phytobiotics can be a cause or an alternative to synthetic anticoccidial drugs, which can be cheap, easily available, and have fewer side effects on the birds' entire immune system through above mentioned drug delivery system.

India has tremendous knowledge of phytochemicals and has been using them since the age of Ayurveda. This knowledge must be explored further through proper scientific research with advanced phytoanalytical techniques.

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