Coccidiosis and its Phytogenic Control: A Review

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ABSTRACT

Coccidiosis remains a major parasitic disease of poultry, caused by protozoa of the genus *Eimeria*, leading to substantial economic losses through reduced performance, morbidity and mortality. Traditional control measures have relied primarily on anticoccidial drugs, supplemented by limited vaccine use. However, the prolonged and extensive use of chemotherapeutics has resulted in the emergence of drug-resistant *Eimeria* strains and concerns over drug residues in poultry products. These challenges have shifted research focus toward alternative, sustainable control strategies, particularly phytogenic compounds known for their safety, cost-effectiveness and broad biological activities. This review summarizes current research on plant-derived substances with anticoccidial potential, highlighting their bioactive components, effective dosages and mechanisms of action. The information presented may support the development of improved and eco-friendly strategies for coccidiosis control in the poultry industry.

INTRODUCTION

The poultry industry is one of the fastest-growing components of the agricultural sector and plays a crucial role in global nutrition[1]. Infectious diseases adversely affect poultry production, particularly those compromising gut health, leading to increased morbidity and mortality[2-4]. Among parasitic diseases of poultry, coccidiosis is one of the most significant, causing major economic losses worldwide due to its impact on bird health and productivity[5]. Annual global losses attributed to coccidial infections are estimated to be approximately 3 billion dollars[6,7]. In the United Kingdom, coccidiosis is ranked among the top three poultry diseases based on its economic burden[8]. Economic losses result from mortality, morbidity and the expenses associated with treatment and disease management. Clinically, the disease is characterized by diarrhea ranging from mucoid and watery to hemorrhagic, accompanied by reduced feed intake and impaired weight gain[9]. Most *Eimeria* species infect birds between 3 and 18 weeks of age[10,11] and outbreaks are often associated with high mortality rates[12]. To mitigate these impacts, various preventative and therapeutic strategies have been developed to control the disease and reduce economic losses in poultry production.

Etiology: Coccidiosis in poultry birds is caused by genus *Eimeria*[13]. Genus *Eimeria* contains more than one thousand species[14]. Nine species of *Eimeria* are reported to affect different parts of intestine named as *E. tenella*, *E. necatrix*, *E. acervulina*, *E. brunetti*, *E. maxima*, *E. mitis*, *E. praecox*, *E. hagani* and *E. mivati.* Seven out of these nine species are reported to be pathogenic. *E. tenella*, *E. maxima* and *E. acervulina* are the most prevalent species in broilers[15]. Infection with more than one species are also noted[16,17]. *Eimeria* species affect different parts of intestine as described in Table 1[18].

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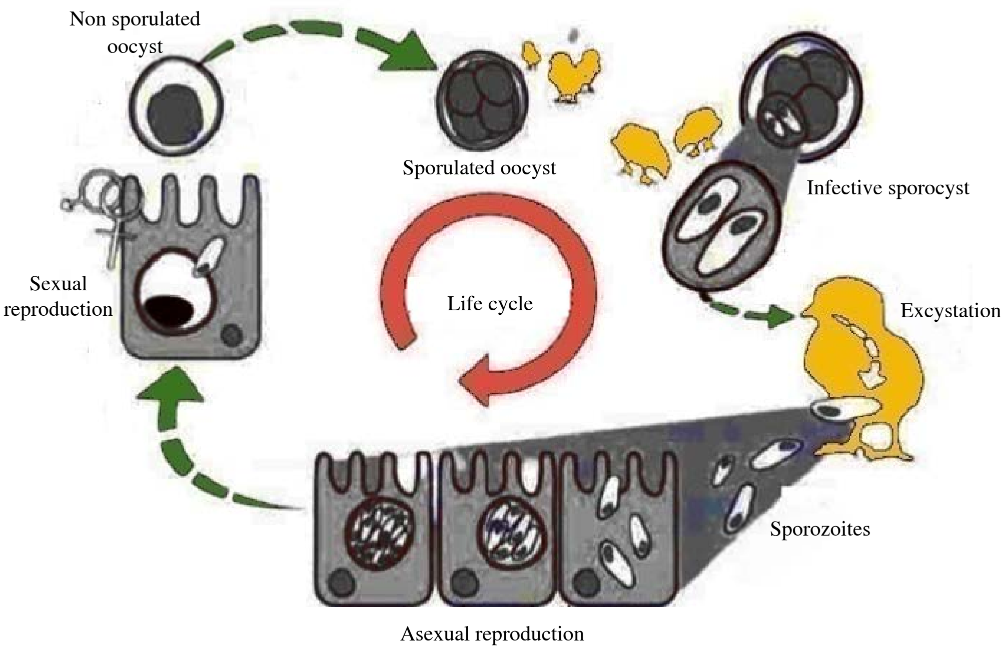

Fig. 1: Life cycle of *Eimeria* in poultry

Table 1: Predilection site of different species of *Eimeria*

Species	Predilection site
E. acervulina	Upper small intestine
E. tenella	Ceca
E. brunetti	Lower small intestine and rectum
E. necatrix	Middle and entire small intestine
E. maxima	Middle and lower small intestine
E. mitis	Anterior gut
E. mivati	Upper small intestine
E. praecox	Anterior gut
E. hagani	Anterior gut

Source: Foreyt[19]

Life cycle: The life cycle of *Eimeria* consists of two major phases: an exogenous phase and an endogenous phase[20]. It includes two or more rounds of asexual replication, known as schizogony or merogony, followed by a sexual phase termed gametogony, which results in the formation of oocysts. Under favorable environmental conditions, such as suitable temperature and moisture, these oocysts develop into sporulated oocysts that are infective to the host[21]. Following ingestion by the host, excystation occurs within the intestinal tract due to mechanical and chemical factors, including trypsin and bile salts, leading to the release of sporocysts and sporozoites into the duodenal lumen. Sporozoites invade the epithelial cells of the intestine, where they develop into trophozoites and subsequently into schizonts through asexual multiplication[7]. The released merozoites then infect new epithelial cells, where they may either continue asexual replication or initiate the sexual phase, forming microgametes and macrogametes. Fusion of these gametes results in the formation of zygotes, which develop into oocysts and are shed into the environment through feces. The complete *Eimeria* life cycle typically requires 4-7 days (Fig. 1).

Epidemiology: Under field conditions, the establishment of a coccidia-free environment is virtually impossible[22]. Favorable climatic conditions, inadequate housing and poor management practices significantly increase the risk of disease occurrence[23,24]. Therefore, epidemiological studies are essential for effective coccidiosis control, as they provide critical information for developing targeted and successful strategies to limit *Eimeria* infection in highly affected areas. Some of the epidemiological data collected from South Asian region is presented in Table 2.

Transmission: Coccidiosis is primarily transmitted via the fecal-oral route through ingestion of water or feed contaminated with sporulated oocysts[50,51]. These infective oocysts may also be disseminated by wild birds, rodents, insects, dust particles and various fomites. Additionally, personnel movement between farms can contribute to the spread of infection[52].

Clinical signs: Clinical signs of coccidiosis in poultry include reduced feed intake accompanied by diarrhea, which may range from mucoid to bloody depending on the *Eimeria* species involved. The severity of clinical symptoms corresponds to the extent of intestinal damage, resulting in anorexia, diarrhea and impaired growth performance in

Fig. 2: Geographical distribution of coccidiosis

Table 2: Prevalence of coccidiosis

Site of study	No. of samples	Prevalence (%)	References
Southern Punjab, Pakistan	500	58	Khan[25]
Faisalabad, Pakistan	7480	43.89	Awais et al.[26]
Hamedan, Iran	220	31.8	Gharekhani et al.[27]
Jammu, Jammu & Kashmir	720	39.58	Sharma et al.[28]
Potohar Punjab, Pakistan	420	23.80	Yousaf et al.[29]
Mazandaran, Iran	120	75	Shirzad et al. 2011[30]
Rawalpindi/Islamabad, Pakistan	359	71.86	Khan et al.[31]
Southern Punjab, Pakistan	500	65	Bachata et al.[32]
Dera Ismail Khan, Pakistan	300	44	Jamil et al.[33]
Shiraz, Iran	200	64	Mohammad et al.[34]
Tabriz, Iran	218	55.96	Nematollahi et al.[35]
Northern India	107	79.4	Prakashbabu et al.[36]
Southern India	133	76	Prakashbabu et al. [36]
Central java, Indonesia	699	25.04	Hamid et al.[37]
Sirajgonj, Bangladesh	660	35.45	Belal[38]
Gondar town, Ethiopia	384	42.2	Wondimu et al.[39]
Maiduguri, Nigeria	600	31.8	Lawal et al.[40]
Sidi Thabet, northeast Tunisia	630	31.75	Kaboudi et al.[41]
Southern brazil	512	90.6	Balestrin et al.[42]
East wollega Ethiopia	384	19.5	Firamye et al.[43]
Abuja, FCT, Nigeria	200	69	Olanrewaju[44]
Kombolcha poultry farm, Ethiopia	638	22.3	Amare et al.[45]
Quetta, Pakistan	250	18.4	Ali et al.[46]
Southern brazil	251	96	Moraes et al.[47]
Romania	23	91	Györke et al.[48]
Meghalaya, India	674	30.12	Das[49]

affected birds[6]. In susceptible populations, infection typically persists for 4 to 7 days and is associated with significant destruction of the intestinal mucosa[13].

Diagnosis: Traditionally, the diagnosis of coccidiosis and identification of *Eimeria* species are based on the site of infection and the morphology of intestinal lesions[53]. Accurate species identification is crucial for evaluating drug resistance and the effectiveness of vaccination programs[54]. Additionally, computational methods such as COCCIMORPH, which rely on oocyst morphology, have been developed to support species differentiation[55].

Treatment and control: Multiple strategies are employed for the control of coccidiosis, including improved management practices, the use of anticoccidial drugs and vaccination[56]. A variety of chemical compounds and ionophore feed additives have been utilized to combat *Eimeria* infections[57]. Commonly used anticoccidial agents include sulfonamides, amprolium, salinomycin, ionophores and several others[58]. However, increasing concerns regarding drug resistance and residual chemicals in poultry products have accelerated the search for alternative control strategies[59,60]. Many field isolates of *Eimeria* now exhibit varying levels of resistance to routinely applied anticoccidial drugs[61]. Vaccination offers an effective approach to induce strong and long-lasting immunity[62], nonetheless, vaccines may lead to adverse reactions in poorly managed flocks[63]. Considering these limitations, there is growing interest in the use of herbal and phytogenic products as promising alternative options[64,65].

Plants and compounds used in Coccidiosis: Globally, more than 0.3 million species of flowering plants have been documented; however, only about 1% of these have been evaluated for their antiprotozoal properties[66]. The use of natural dietary products for coccidiosis control may help address critical challenges such as drug resistance, concerns related to chemical residues and improvement of feed intake[67-69].

- **Green tea (*Camellia sinensis*):** Green tea extracts contain selenium, which has been reported to inhibit enzymes involved in the sporulation of *Eimeria* oocysts[70]. Supplementation of green tea has also been associated with improved hematological parameters and serum biochemical profiles in infected birds[71]. According to a previous study[72], dietary inclusion of 0.5 and 2% green tea led to a significant reduction in fecal oocyst shedding ($p<0.05$)
- **Garlic (*Allium sativum*):** Garlic contains allicin, alliin, flavonoids and other sulfur-containing compounds. Its dietary supplementation has been associated with improved feed intake and enhanced body weight gain, likely due to increased nutrient utilization resulting from allicin-mediated improvements in intestinal epithelial structure and function[73]. A research study[74] demonstrated that administration of 5 and 10 g of garlic powder per liter of drinking water to birds infected with mixed *Eimeria* spp. significantly reduced fecal oocyst counts (3 ± 0.09 and $0.75\pm0.01\times10^3$, respectively) compared with the positive control group ($33\pm0.10\times10^3$) on day 7 post-infection ($p\leq0.05$)
- **Turmeric (*Cucuma longa*):** Dietary supplementation of turmeric has been shown to enhance both cellular and humoral immune responses[75]. Curcumin, the principal bioactive component of turmeric, has also been reported to exert lethal effects on *Eimeria* sporozoites[76]. In a previous study[74], it was observed that administration of 5 and 10 g of turmeric powder per liter of drinking water for 8 hrs per day (following 1 hour of water withdrawal) to birds infected with mixed *Eimeria* spp. significantly reduced fecal oocyst counts (6 ± 0.10 and $4\pm0.10\times10^3$, respectively) compared with the positive control group ($33\pm0.10\times10^3$) on day 7 post-infection ($p\leq0.05$)
- **Sweet wormwood (*Artemisia annua*):** *Artemisia annua* contains the active compound artemisinin, which has been reported to inhibit the formation of the oocyst wall, thereby reducing the rate of sporulation[77]. In an evaluation of its anticoccidial efficacy, Dragan et al.[78] demonstrated that dietary supplementation of 1.5% *A. annua* leaf powder in *Eimeria tenella*-infected broiler chicks significantly reduced fecal oocyst shedding by 95.6% compared with the positive control group ($p = 0.027$)
- **Pine bark (*Pinus radiate*):** Pine bark extract contains tannins, which have been reported to reduce oocyst sporulation by penetrating the oocyst wall and inactivating endogenous enzymes[79]. Additionally, its immunomodulatory properties contribute to enhanced disease resistance. In a study evaluating the effects of pine bark extract, Abbas et al.[80] demonstrated that birds treated with pine bark extract at 300 mg/kg body weight exhibited cellular and humoral immune responses comparable to those of the positive control group supplemented with vitamin E ($p>0.05$).
- **Kashmal (*Berberis lycium*):** It contains berberine, which has been demonstrated to be effective against coccidial infections by inducing oxidative stress that inhibits sporozoites. Research conducted by Nguyen et al.[81] reported a significant ($p<0.05$) reduction in fecal oocyst shedding in birds fed a diet supplemented with 0.2% berberine following prior infection with *Eimeria.*
- **Flavonoids and vernolide:** Extracts of *Ageratum conyzoides* and *Vernonia amygdalina* contain flavonoids and vernosides, respectively, which have been reported to mitigate coccidial infections via oxidative stress. A study investigating the anticoccidial effects of *A. conyzoides* demonstrated that administration of 500 and 1000 mg of *A. conyzoides* extract to birds infected with *E. tenella* progressively reduced fecal oocyst counts to zero and significantly ($p<0.05$) improved red blood cell count and packed cell volume[82]. Similarly, Bassey and Okoi[83] reported a significant ($p<0.05$) increase in red blood cell count and packed cell volume in *Eimeria*-infected birds treated separately with *A. conyzoides* and *V. amygdalina* extracts at doses of 1.5, 3 and 6 g per liter
- **Saponins:** Inclusion of guar meal (*Cyamopsis tetragonoloba*) in the diet has been shown to suppress coccidiosis in chickens[84]. Similarly, *Mesembryanthemum cordifolium*, *M. citrifolia* and *M. arboreus* have also demonstrated anticoccidial effects[85]. These plants contain saponins, which bind to sterols present in cell

membranes[84]. Hassan et al.[84] reported that feeding *Eimeria*-infected birds a diet containing 5% guar meal significantly ($p \leq 0.05$) reduced fecal oocyst counts compared to birds fed a diet lacking guar meal

- **Beet (*Beta vulgaris*):** Beet plant extract contains betaine and has been reported to exhibit anticoccidial effects due to its stabilizing and protective action on intestinal epithelium[86]. Administration of aqueous methanolic extract of *B. vulgaris* at doses of 100, 200 and 300 mg/kg body weight resulted in a significant ($p \leq 0.05$), dose-dependent reduction in fecal oocyst counts per gram in *Eimeria*-infected birds[86]
- **Olive (*Olea europaea*):** Leaf and fruit extracts of olive contain maslinic acid, which has demonstrated both *in vivo* and *in vitro* anticoccidial activity in various studies[87,88]. An *in vitro* study evaluating the efficacy of olive against coccidiosis showed that the addition of olive pulp extract at 0.743 mL per coccidial oocyst suspension resulted in a 25.36% reduction in oocyst count after 8 hrs of treatment, with LD of 14.44±1.20690
- **Carica papaya:** The extract of *C. papaya* contains papain, which has demonstrated anticoccidial effects in various *in vivo* and *in vitro* studies[89,90]. Proteolytic degradation is considered the most likely mode of action. A study investigating the antiparasitic effect of feeding dried papaya seed meal reported a significant ($p<0.05$) reduction in infection rates in flocks administered 1 mg of dried papaya seed meal daily for 5 days[90]
- **Grape seed (*Vitis vinifera*):** Grape seeds contain the naturally occurring phenolic compound proanthocyanidin, which acts as an antioxidant and has been reported to reduce coccidial infections by improving gut health, thereby decreasing mortality and enhancing body weight[91]. Additionally, it has been shown to positively influence gut microbiota[92] and maintain intestinal homeostasis[93]. In a study conducted by Wang et al.[90], administration of grape seed extract at 5, 10, 20 and 30 mg/kg resulted in a significant ($p \leq 0.05$) reduction in mortality and improvement in body weight gains of *Eimeria*-infected birds
- ***Echinacea pupure:*** *E. purpurea* contains numerous bioactive compounds, including polysaccharides, flavonoids, glycoproteins, alkamides, essential oils and various phenolic compounds[94]. This plant is considered to exhibit anticoccidial activity due to its anti-inflammatory, immunostimulant and antioxidant properties. In a study, experimental feeding of ground *E. purpurea* root at 0.1-0.5% of the diet resulted in a reduction of clinical signs and severity of mixed coccidial infections[95]
- **Neem plant (*Azadirachta indica*):** Neem plant is commonly found in African and Asian region. It is considered to have active ingredient azadirachtin which has anticoccidial effect[96]. Feeding of neem fruit @0.03% of feed reduces oocyst counts and mortality in broilers infected with *Eimeria*[97]. Other than neem fruit, extract of neem leaves have also shown anticoccidial activity against *E. tenella* as well as against mixed coccidial infections[98]
- **Aloe vera:** In an *In-vitro* study, Mwale et al[98] has shown that *A. vera* at concentrations of 15, 30 and 45% is able to inhibit sporulation of coccidial oocysts
- **Essential oils and their plant sources:** Essential oils derived from various plant sources can also be employed to control coccidiosis, as they are capable of inhibiting multiple developmental stages of *Eimeria* both *in vivo* and *in vitro*[99]. Notably, essential oils with anticoccidial activity can be obtained from *Rosmarinus officinalis*, *Anredera cordifolia*, *Citrus sinensis*, *Morinda citrifolia*, *Syzygium aromaticum*, *Thymus vulgaris*, *Melaleuca alternifolia*, *Origanum compactum* and *Malvaviscus arboreus*

CONCLUSION AND PERSPECTIVES

Coccidiosis is a major disease affecting both commercial and backyard poultry, causing substantial economic losses worldwide. In light of the growing concerns regarding drug resistance and drug residues impacting end users, herbal extracts may serve as effective alternatives. These phytochemical compounds can be utilized for both prophylactic and therapeutic purposes. Further detailed studies are required to elucidate their efficacy, mechanisms of action and to determine optimal dosages.

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