CHAPTER 33

BOTANICAL CONTROL OF POULTRY COCCIDIOSIS

Asghar Abbas*[1], Zurisha Rani[2], Rao Zahid Abbas[2], Kashif Hussain[1], Faisal Siddiqui[3], Atif Rehman*[1], Baseer Ahmad[1], Muhammad Asif Raza[1], Junaid Ali Khan[1], Riffat Yasin[1], Shahid Ali Rajput[1], Waqar Zaib[1], Tauseef ur Rehman[4], Muhammad Mazhar Ayaz[5] and Hafeezur Rehman Ali Khera[1]

[1]Faculty of Veterinary and Animal Sciences, MNS-University of Agriculture, Multan, Pakistan
[2]Department of Parasitology, University of Agriculture Faisalabad, Pakistan
[3]Department of Microbiology, Cholistan University of Veterinary and Animal Sciences, Bahawalpur, Pakistan
[4]Department of Parasitology, The Islamia University Bahawalpur, Pakistan
[5]Faculty of Veterinary and Animal Sciences Cholistan University of Veterinary and Animal Sciences, Bahawalpur, Pakistan
*Corresponding author: asghar.abbas@mnsuam.edu.pk; atif.rehman@mnsuam.edu.pk

INTRODUCTION

The poultry sector is vibrant, fast growing and potential sector playing an important role in food security and economy of developing countries (Abbas et al. 2020; Zhang et al. 2020). Each year, over 50 billion chickens are raised as a source of meat, accounting for over one-third of protein source in food of humans (Quiroz-Castañedaet al. 2015). However, the poultry sector is facing challenges due to outbreak of certain diseases of parasitic, viral and bacterial origin. Among parasitic diseases, Coccidiosis is major parasitic diseases affecting poultry industry all over the world (Blake et al. 2020). Coccidiosis is a parasitic disease caused by different species of genus Eimeria, which is obligate and intracellular protozoa. This is host-specific protozoa and also related to other protozoa like Besnoitia, Babesia, Cystoisospora, Caryptosporidium, Plasmodium, Neospora, Theileria, Toxoplasma and Sarcocystis. There are seven species which are causing coccidiosis in *Gallus gallus domesticus*. These species of Eimeria include *Eimeria brunetti*, *E. acervulina, E. maxima, E. necatrix, E. mitis, E. tenella* and *E. praecox* (Blake et al. 2021; El-Shall et al. 2022).

Coccidiosis is transmitted by ingestion of sporulated oocysts of Eimeria from feces and litter. All Eimeria species show noticeable tropism for definite areas of the gut (Lai et al. 2011). The lifecycle of Eimeria includes variety of asexual reproduction (Walker et al. 2013; Abbas et al.2017a, 2017b), followed by a sexual phase known as gametogony as shown in Fig. 1. Following fertilization, oocysts are excreted and sporulated in the environment. Sporulated oocysts are infectious for avian hosts. The pathology related to every Eimeria species varies, taking place in exclusive sections of the gut and inflicting both malabsorptive or hemorrhagic lesions at intestine (Abbas et al. 2019a, 2019b; Burrell et al. 2020). By infecting the digestive tract, coccidiosis reduces poultry output by compromising the final body weight, intestinal health, and meat quality of broiler chickens. (Swelum et al. 2021; Yaqoob et al. 2021). Coccidiosis is controlled by use of synthetic anticoccidial drugs. Since 1939, a wide range of anticoccidial drugs have been used against poultry coccidiosis (Nogueira et al. 2009). However, due to development of anticoccidial drug resistance (Abbas et al. 2019a, 2020), toxic effects on bird's health this method now be came ineffective. Heavy cost is spent on anticoccidial drugs annually. Fortunately, Eimeria infections create long-lasting and powerful immunity including vaccination as substitute to anticoccidial drugs (Abbas et al. 2011; Chapman, 2014). On the other hand, vaccination may trigger severe hemorrhagic reactions and lack of a "standard" protocol for assessing vaccine efficacy makes the development and validation of vaccine complicated against avian coccidiosis (Shirley et al. 2005).

Due to anticoccidial drug resistance and lower efficacy of Eimeria vaccines, alternative novel compounds are center of recent research now a days. Among alternative anticoccidial agents, use of phytogenic compounds has shown significant results in control of coccidiosis (Abbas et al. 2017a; Abou-Kassem et al. 2021). Recently, there has been a surge of interest around the world in adopting herbal remedies as safe alternatives to treat a variety of ailments with minimum chances of resistance (Abd El-Hack et al. 2020). Because of their growth-promoting and natural immunostimulating properties, different botanicals are extensively researched against poultry coccidiosis (Muthamilselvan et al. 2016; Abbas et al. 2017c, 2019a).

This chapter contains valuable information on potential of different botanicals against Eimeria and positive effects on performance of poultry. Furthermore, herbal medicines, their extracts, bioactive substances, particular anticoccidial characteristics are also summarized for future perspectives of research against coccidiosis. Different herbal blends along with their associated bioactive ingredients having anticoccidial potential with different species are also discussed.

Mechanism of Action of Botanicals Against Coccidiosis

Antioxidants

The antiprotozoal activity of botanicals has also been attributed due to ability to reduce oxidative stress by scavenging oxygen free radicals which induce oxidative stress

How to cite this chapter: Abbas A, Rani Z, Abbas RZ, Hussain K, Siddiqui F, Rehman A, Ahmad B, Raza MA, Khan JA, Yasin R, Rajput SA, Zaib W, Rehman TU, Ayaz MM and Khera HRA, 2022. Botanical control of poultry coccidiosis. In: Abbas RZ, Khan A, Liu P and Saleemi MK (eds), Animal Health Perspectives, Unique Scientific Publishers, Faisalabad, Pakistan, Vol. I, pp: 247-252. https://doi.org/10.47278/book.ahp/2022.33

Table 1: Major *Eimeria* species infecting Poultry

Species Name	Infection Site	Pathogenicity Level	Reference
Chicken			
E. acervulina	Upper small intestine	Medium	Tyzzer1929
E. brunetti	Distal small intestine and colon	High	Levine 1942
E. hagani	Upper small intestine	Low	Edgar and Siebold 1964
E. maxima	Middle small intestine	Medium	Tyzzer1929
E.mivati	Upper small intestine	Low	Tyzzer 1929
E. mitis	Upper small intestine	Low	Tyzzer 1929
E. necatrix	Middle small intestine	High	Tyzzer1929
E.praecox	Upper small intestine	Medium	Tyzzer1929
E. tenella	Ceca	High	Raillet and Lucet 1891
Turkey			
E. adenoeides	Small intestine, caeca, colon	High	Moore and Brown 1951
E. gallopavonis	Large intestine, caeca	Moderate	Hawkins 1952
E. meleagrimitis	Small intestine	Moderate	Tyzzer1929
E. dispersa	Small, large intestine	Low	Tyzzer 1929
Pigeons			
E. columbarum	Intestine	Low to Mild	Mitraand Das Gupta 1937
E. labbeana	Intestine	Low to Mild	Pinto 1928
Ducks			
E. anatis	Small intestine	Mild	Scholtyseck 1955
E. danailovi	Small intestine	High	Gräfneret al. 1965
E. saitamae	Small intestine	High	Inoue 1967
Geese			
E. anseris	Small intestine	Moderate	Kotlan 1932
E. nocens	Small intestine	Moderate	Kotlan 1932
E. truncate	Kidney	High	Raillet and Lucet 1891

Table 2: Botanicals reported for Anticoccidial effects against *Eimeria* Species

Botanical Name	Active Compounds	Anticoccidial Activity	Other Beneficial Effects	*Eimeria* Species	Reference
Ageratum conyzoides	Flavonoids, Vernoside and Berberine	Reduced lesion and oocyst score	Improves weight gain, FCR, chicken	Mixed species	Hussain et al. 2021
Allium sativum	Alliin, diallylsulphide, Allicin, Sulphur derivatives	Lowers fecal oocyst count, lower pathology	Increase in performance, organ weight, FCR	Mixed species	Sidiropoulou et al. 2020
Aloe vera	Trepenoidscarbohydtrates Flavonoids	Lesser fecal oocyst counts.	Reduces mortality Immunomodulation	*E.tenella*	Akhtar et al. 2012
Artemisia brevifolia	Artemisinin	Diminishes oocyst and lesion scores	Improves weight gain, FCR	*E.tenella*	Hussain et al. 2021
Artemisia sieberi	Artemisinin	Diminishes oocyst scores in infested chickens.	Improves FCR and promotes weight gain.	Mixed species	Kheirabadiet al. 2014
Azadirachta indica	Azadirachtin, nimbolinin, nimbin, sodium nimbinate, salannin and quercetin.	Lesser fecal oocyst counts and reduction in lesion score	Improves weight gain, FCR, reduces mortality	*E. tenella*	Abbas et al. 2006
Beta vulgaris	Betaine	Reduced Oocysts shedding and lesion scores	Enhances FCR, improves organ weight, serum chemistry	Mixed species	Abbas et al. 2017b
Bidenspilosa	Favonoids, porphyrins, quercetin, porphyrins, phenylpropanoids	Lesser fecal oocyst counts and reduction in lesion score	Enhanced Immunity, Survival rate, weight gain	*E. tenella*	Yang et al. 2019
Camellia sinensis	Polyphenolic compounds	are blocked.	Antioxidant properties are demonstrated.	Mixed species	Zhang et al. 2020: Abbas et al. 2017c
Carica papaya	Papain, Vitamin A	Reduced oocysts shedding	Enhanced immunity and improves growth performance	*E.tenella*	Nghonjuyiet al. 2015
Cinnamomum cassia	Cinnamaldehyde	Reduced oocysts shedding	Immunity is boosted. Survival rate, Weight gain	Mixed species	Orengoet al. 2012
Curcuma longa	Curcumins	Inhibits life cycle stages	Increases body weight gain. Shows antioxidative, anti-inflammatory	Mixed species	Abbas et al. 2011
Cyamopsistetragonoloba	Saponins	Reduces the shedding of oocysts	Increases daily body weight while lowering feed conversion ratio. increase	Mixed species	Sánchez-Hernández et al. 2019
Emblica officinalis	Polyphenolics, carbohydrates, amino acids, Tannins, alkaloids (gallic acid, ellagic acid), Emblicanin	Oocysticidal properties and prevents sporulation. Inhibits parasite's life cycle from progressing.	Body weight gain improvement improved cellular and humoral immunity	Mixed species	Sharma et al. 2021
Fomitella fraxinea	Fungal lectin.	Improves the cellular and humoral immunity	It has immunostimulatory properties.	Mixed species	Dalloul et al. 2006

Gallarhois	Methyl gallate and phenolic compounds	Oocyte shedding is stopped, and lesion scores are reduced.	Reduces feed consumption while improving body weight increase. Antibacterial and antiviral properties.	*E. tenella*	Lee et al. 2012
Ganodermalucidum	Glycoproteins, organic acids, Glycosides	Oocyst sporulation is inhibited.	Increases the weight of the carcass. Improves bloody diarrhea.	*E. tenella*	Ahad et al. 2016
Botanical Name	Active Compounds	Anticoccidial Activity	Other Beneficial Effects	Eimeria Species	Reference
Khayasenegalensis	Phenolics and alkaloids	Reduces fecal, lesion scores,	Antioxidant effects	*E. tenella*	Dakpogan et al. 2019
Moringaoleifera	Flavonoids, phenolics, Ascorbic acid, caffeoylquinic acid and kaempferol.	Osmoprotectant Reduces the amount of lipid peroxidation in the intestine.	Enhances body weight gain, reduces mortality, faecal score, Inhibits the production of oocysts.	Mixed species	Ola-Fadunsin and Ademola 2013
Musa paradisiaca	Pectinand flavonoids compounds	Prevents the development of coccidial infections and decreases their reproduction.	Enhances body weight gain, improved FCR	*E. tenella*	Anosa and Okoro 2011
Oleaeuropaea	Maslinic acid, polyphenolic compounds	Damaging impact on oocysts	Improves the anticoccidial, the oocyst, lesion	Mixed species	Debbou-Iouknane et al. 2021
Origanumvulgare	Carvacol and thymol	Damaged life cycle stages of *Eimeria*	Reduces FCR while increasing body weight gain.	Mixed species	Tsinas et al. 2011
Pimpinellaanisum	Methylchavicol, Anethole, anisaldehyde, estragole and eugenol.	Only when combined with A. annua it reduces the extent of oocytes in broiler chickens.	Improves performance by increasing FCR	*E. tenella*	Drăgan et al. 2010
Pinusradiata	Tannins	Reduced oocysts excretion and lesion score	Improves performance by increasing body weight gain More	Mixed Species	Abbas et al. 2017a
Punicagranatum	Corilagin, Ellagic acid and punicalagin	Lessens oocyst output.	Reduces feed conversion ratio while improving intestinal lesions and increasing body weight.	Mixed Species	Ahad et al. 2018
Saccharumofficinarum	Flavones (tricin, luteolin, derivatives)	In vitro inhibitory activity against coccidian oocyst sporulation.	Immunomodulatory antioxidant, Anti-inflammatory, antiviral, antibacterial	Mixed species	Abbas et al. 2015
Salvadorapersica	Alkaloids, Cyanogenic glycosides Vitamin C, salvadourea, tannins, saponins	Inhibits or impairs the incursion, reproduction, and progression of Eimeria parasite species	Anti-inflammatory and antioxidant activities have been reported.	Mixed species	Thagfan et al. 2017
Trachyspermum ammi	Carvacrol and Thymol.	Affecting Eimeria oocyst sporulation (percent) in a dose-dependent manner. Oocyst morphology is affected	Increased body weight and FCR	Mixed species	Abbas et al. 2019a
Tulbaghia violacea	marasmine), bis (methylthiomethyl) methyl disulfide, S - (methylthiomethyl), cysteine sulfoxide	Reduces oocyst formation, host cell death caused by lipid oxidatives	Acts as antioxidant, Improves weight gain and intestinal pathology	Mixed Species	Naidoo et al. 2008
VitisVinifera	Proanthocyanidins, epicatechin and catechin, dimeric, polymeric, trimeric, phenolic acids	Oocyst morphology is defined in some factors such as shape, size, and the amount of sporocysts.	Improves intestinal pathology and weight gain in the chicken's body. Presents antioxidant activity	Mixed Species	Wang et al. 2008: Abbas et al. 2020
Yucca schidigera	Saponins	Oocyst morphology, Excretion is reduced	Enhances productive efficiency (FCR and body weight).	Mixed Species	Hassan et al. 2008
Zingiberofficinale	Oleoresin and Gingerol	Reduced oocysts shedding	Increases the rate of weight gain in the body.	Mixed Species	Ali et al. 2019

due to Eimeria (Abbas et al. 2019b). Botanicals are enriched with antioxidant compounds and are likely to play role in the control of the coccidiosis disease. The beneficial effects against Eimeria are derived from phenolic and flavonoid compounds which attribute to antioxidant activity (Abbas et al. 2020). Many studies have shown that flavonoids have the capacity to act as powerful antioxidants by scavenging free radicals and thus reducing oxidative stress in host caused by Eimeria parasite. Flavonoids having multiple hydroxyl groups act as pro-oxidants. The mechanism of action of flavonoids is conversion of hydroxyl group into pro-oxidant when oxidized by Reactive Oxygen Species (ROS) present in inner cell membrane which leads to late necrosis or apoptosis of damaged cells by eliminating potential mutants (Masood et al. 2013).

Osmoprotectant

Many botanicals including Beta vulgaris and Camellia sinensis reduce coccidiosis infection by their osmoprotectant activity

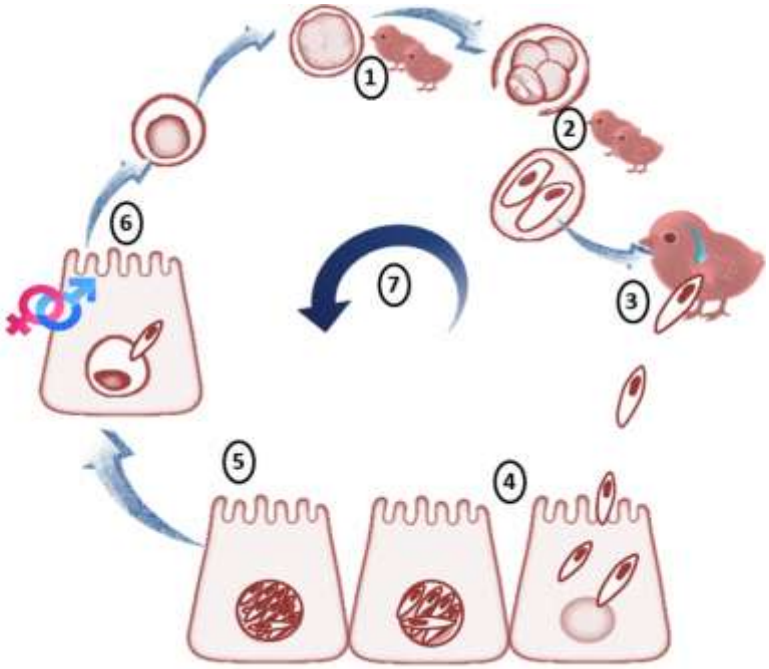

Figure 1: Life Cycle of *Eimeria*. Birds get infected by sporulated oocysts from fecal matter and reproduction occurs in the intestinal cells which leads to damage to the intestinal wall (El-Shall et al. 2022).

by stabilization intestinal cell membranes and immune stimulation thus acting as osmoprotectant against Eimeria parasite (Abbas et al. 2015, 2017a). Plants protect different cell types against chemical and environmental stress (Allen 2003).

Destruction of Life Cycle Stages

The protective effect of botanicals is not only restricted to the intestinal cells, but they also affect and damage life cycle stages of the coccidia including the asexual stages (sporozoites) and sexual life cycle stages (Zhang et al. 2020; El-Shall et al. 2022).

Immunomodulatory and Stimulation of Mucosal immunity

The essential oils of different botanicals such as *Trachyspermum ammi*, *Origanum vulgare* and many others are known for their immunomodulatory effects against parasites by stimulation of mucosal immunity and also known to enhance cellular and humoral immunity against coccidiosis. They are involved in immune stimulation, enhancement by macrophage activity and enhancing antibodies level in infected birds (Abbas et al. 2012a, 2012b, 2017).

Target the Exogenous Phase of Eimeria

Many botanicals such as Artemisia, thyme, clove, and tea tree oils target the exogenous phase as tested in in vitro trials leading to oocyst disruption (Remmal et al. 2011). A pure product extracted from *Artemisia annua* i.e., artemisinin showed a dose-dependent increase of dead oocysts shed in feces, an alteration in the sporulation rate, and a significant reduction of calcium ATPase in macrogamete endoplasmic reticulum, which most likely leads to abnormal oocyst formation (Cacho et al. 2010).

Target the Endogenous Phase of Eimeria

Botanicals also effect the endogenous phases of Eimeria parasite as considerable alterations were observed in sporozoite morphology effecting Eimeria viability and infectivity in an in vitro invasion assay using cumin derived from turmeric plant (Khalafalla et al. 2011). The effect of curcumin was also tested with other phytochemicals including carvacrol (major constituent of Oregano) and Echinacea purpurea extract which also showed immunomodulatory activity (Burt et al. 2013). A similar study was performed using essential oils of oregano and garlic showed strong anticoccidial activity, exhibited a positive effect on intestinal microorganisms in in vitro trial and improved growth performance in in vivo trial. Garlic is also known to have anticoccidial compounds like allicin, propyl thiosulfinate, propyl thiosulfinate oxide, and allicin have been shown to affect the endogenous phase of Eimeria and have anticoccidial efficacy against *E. tenella* (Sidiropoulou et al. 2020).

REFERENCES

Abbas A et al., 2015. In vitro anticoccidial potential of Saccharum officinarum extract against Eimeria oocysts. Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas 14: 456-461.

Abbas A et al., 2017a. Immunomodulatory activity of Pinus radiata extract against coccidiosis in broiler chicken. Pakistan Veterinary Journal 37:145-9.

Abbas A et al., 2017b. In vivo anticoccidial effects of Beta vulgaris (sugar beet) in broiler chickens. Microbial Pathogenesis 111:139-44.

Abbas A et al., 2017c. Immunomodulatory effects of Camellia sinensis against coccidiosis in chickens. The Journal of Animal and Plant Sciences 27:415-21.

Abbas RZ et al., 2019a. In vitro anticoccidial activity of Trachyspermum ammi (Ajwain) extract on oocysts of

Eimeria species of Chicken. Advancements in Life Sciences 7:44-7.

Abbas A et al., 2019b. Anticoccidial Effects of Trachyspermum ammi (Ajwain) in broiler chickens. Pakistan Veterinary Journal 39:301-4.

Abbas RZ et al., 2012a. Options for integrated strategies for the control of avian coccidiosis. International Journal of Agriculture and Biology 14: 1014-1020.

Abbas RZ et al., 2006. Anticoccidial screening of Azadirachta indica (Neem) in broilers Pharmacology 3: 365-371.

Abbas RZ et al., 2011. Anticoccidial drug resistance in fowl coccidia: the state of play revisited. World's Poultry Science Journal 67: 337-350.

Abbas RZ et al., 2012b. Botanicals: an alternative approach for the control of avian coccidiosis. Worlds Poultry Science journal 68: 203-215.

Abbas RZ et al., 2020. In vitro anticoccidial activity of Vitisvinifera extract on oocysts of different Eimeria species of broiler chicken. Journal of Helleneic Veterinary Medical Society 71:2267-72.

Abd El-Hack et al., 2021. Approaches to prevent and control Campylobacter spp. colonization in broiler chickens: a review. Environmental Science and Pollution Research 28: 4989-5004.

Abou-Kassem DE et al., 2021. Influences of dietary herbal blend and feed restriction on growth, carcass characteristics and gut microbiota of growing rabbits. Italian Journal of Animal Science 1: 896-910.

Ahad S et al.,2016. Anticoccidial activity of aqueous extract of a wild mushroom (Ganodermaapplanatum) during experimentally induced coccidial infection in broiler chicken. Journal of Parasitic Diseases 40:408-414.

Ahad S et al., 2018. Anticoccidial activity of fruit peel of Punica granatum L. Microbial Pathogenesis 116:78-83.

Akhtar M et al., 2012. Immunostimulatory and protective effects of Aloe vera against coccidiosis in industrial broiler chickens. Veterinary Parasitology 186:170-177.

Ali M et al., 2019.Anticoccidial effect of garlic (Allium sativum) and ginger (Zingiber officinale) against experimentally induced coccidiosis in broiler chickens. Journal of Applied Animal Research 47: 79-84.

Allen PC, 2003. Dietary supplementation with echinacea and development of immunity to challenge infection with coccidian. Parasitology Research 91: 74-78.

Anosa GN and Okoro OJ, 2011. Anticoccidial activity of the methanolic extract of Musa paradisiaca root in chickens. Tropical Animal Health and Production 43: 245-248.

Blake DP et al., 2021. Genetic and biological characterisation of three cryptic Eimeria operational taxonomic units that infect chickens (Gallus gallusdomesticus). International Journal of Parasitology 51:621-634.

Blake et al., 2020. Re-calculating the cost of coccidiosis in chickens.Veterinary Research 51:115.

Burrell A et al. 2020. Life cycle stages, specific organelles and invasion mechanisms of Eimeria species. Parasitology 147:263–78.

Burt SA et al., 2013. In vitro inhibition of Eimeria tenella invasion of epithelial cells by phytochemicals. Veterinary Parasitology 191:374–378.

Cacho ED et al., 2010. Effect of artemisinin on oocyst wall formation and sporulation during Eimeria tenella infection. Parasitology International 59: 506-511.

Chapman HD, 2014. Milestones in avian coccidiosis research: A review. Poultry Science 93: 501-511.

Dakpogan HB et al., 2019. Anticoccidial activity of Khayasenegalensis, Senna siamea and Chamaecrista rotundifolia in chicken (Gallus gallus). International Journal of Biological and Chemical Sciences13: 2121-2128.

Dalloul RA et al., 2006. Immunopotentiating effect of a Fomitella fraxinea-derived lectin on chicken immunity and resistance to coccidiosis. Poultry Science 85: 446-451.

Debbou-Iouknane N et al., 2021. In vitro anticoccidial effects of olive leaf (Oleaeuropaea L. var. Chemlal) extract against broiler chickens Eimeriaoocysts.Veterinarijair Zootechnika 79: 1-8.

Drăgan L et al., 2010. Effects of Artemisia annua and Pimpinella anisum on Eimeria tenella (Phylum Apicomplexa) low infection in chickens. Science Parasitology 11: 77-82.

Edgar SA and Siebold CT, 1964. A New coccidium of chickens, Eimeria mivati sp. n. (Protozoa: Eimeriidae), with details of its life history. Journal of Parasitology50: 193-204.

El-Shall et al., 2022. Phytochemical control of poultry coccidiosis:areview. Poultry Science 101:1-22.

Gräfner G et al., 1965. Small intestinal coccidiosis in domestic ducks caused by a new species of coccidia, Eimeria danailovi n. Sp. Journal of the Scientific Society for Veterinary Medicine in the German Democratic Republic 20: 141-143.

Hassan SM et al., 2008. Guar meal ameliorates Eimeria tenella infection in broiler chicks. Veterinary Parasitology 157:133-138.

Hawkins PA, 1952. Coccidiosis in turkeys. Michigan State College Technical Bulletin. 226.

Hussain et al., 2021. Anticoccidial and Biochemical effects Artemisia brevifolia extract in Broiler Chickens. Brazilion Journal of Poultry Science 23:1-6.

Hussain et al., 2021. Anticoccidial potential of Ageratum conyzoides and its effect on Blood parameters of experimentally infected Broiler Chickens. Journal of Hellenic Veterinary Medical Society 72:3085-3090.

Inoue I, 1967. Eimeria saitamaen. sp.: a new cause of coccidiosis in domestic ducks (Anasplatyrhynchavar. domestica). Japanese Journal of Veterinary Science 29:209-215.

Khalafalla RE et al., 2011. Effects of curcumin (diferuloylmethane) on Eimeria tenella sporozoites in vitro. Parasitology Research108: 879–886.

Kheirabadi KP et al., 2014. Comparison of the anticoccidial effect of granulated extract of Artemisia sieberi with monensin in experimental coccidiosis in broiler chickens. Experimental Parasitology 141:129-133.

Kotlan A, 1932. Data on the knowledge of coccidiosis in waterfowl (ducks, geese). Veterinary Sheets 55: 103-107.

Lai L et al., 2011. The role of sialyl glycan recognition in host tissue tropism of the avian parasite Eimeria tenella. PloSPathogens7:e1002296

Lee JL et al., 2012. Anticoccidial effect of supplemental dietary GallaRhois against infection with Eimeria tenella in chickens. Avian Pathology 41:403-407.

Levine PP, 1942. A new coccidium pathogenic for chickens, Eimeria brunettin. sp. (Protozoa: Eimeriidae). Cornell Veterinarian32: 430-439.

Masood S et al., 2013. Role of natural antioxidants for the control of coccidiosis in poultry. Pakistan Veterinary Journal 33:401-407.

Mitra AN and Das-Gupta M, 1937. On a species of Eimeria (Coccidia-Sporozoa) from the intestine of a pigeon, Columba intermedia. Proceedings of the 24th Indian Science Congress Associationpp. 291.

Moore EN and Brown JA, 1951. A new coccidium pathogenic for turkeys, Eimeriaadenoeides n. sp. (Protozoa: Eimeriidae). Cornell Veterinary 41: 124-125.

Muthamilselvan T et al., 2016. Herbal remedies for coccidiosis control: a review of plants, compounds, and anticoccidial actions. Evidence-Based Complementary and Alternative Medicine 2016: 1-19.

Naidoo V et al., 2008. The value of plant extracts with antioxidant activity in attenuating coccidiosis in broiler chickens. Veterinary Parasitology 154:214-219.

Nghonjuyi NW et al., 2015. Efficacy of ethanolic extract of Carica papaya leaves as a substitute of sulphanomide for the control of coccidiosis in KABIR chickens in Cameroon. Journal of Animal Health and Production 3: 21-27.

Nogueira V et al., 2009. Ionophore poisoning in animals. PesquisaVeterináriaBrasileira 29: 191 197.

Ola-Fadunsin SD et al., 2013. Direct effects of Moringa oleifera Lam (Moringaceae) acetone leaf extract on broiler chickens naturally infected with Eimeria species. Tropical Animal Health and Production 45:1423-1428.

Orengo J et al., 2012. Evaluating the efficacy of cinnamaldehyde and Echinacea purpurea plant extract in broilers against Eimeria acervulina. Veterinary Parasitology 185:158-163.

Pinto C, 1928. Synonymy of some species of the genus Eimeria (Eimeridia, Sporozoa). Reports of the Biological Society (Paris). 98: 1564-1565.

Quiroz-CastañedaRE and Dantán-González E, 2015. Control of avian coccidiosis: future and present natural alternatives, BioMed Research International 2015: 1-11.

Raillet A and Lucet A, 1891. Note sur quelquesespeces de coccidies encore peuetudiees. Bulletin de la SociétéZoologique de France16: 246-250.

Remmal A et al., 2011. In vitro destruction of Eimeria oocysts by essential oils.Veterinary Parasitology 182: 121-126.

Sánchez-Hernández S, et al., 2019. Evaluation of a feed plant additive for coocidiosis control in broilers herbals for coccidiosis control. Brazilian Journal of Poultry Science 21: 1-6.

Scholtyseck E, 1955. Eimeriaanatis n. Sp., A new coccid from the mallard (Anasplatyrhynchos). Archive for Protist Studies100: 431-434.

Sharma HNS et al., 2021.Anticoccidial effects of Phyllanthusemblica (Indian gooseberry) extracts: potential for controlling avian coccidiosis. Veterinary Parasitology: Regional Studies and Reports 25:100592.

Shirley MW et al., 2005. The biology of avian Eimeria with an emphasis on their control by vaccination. Advances in Parasitology 60: 85-330.

Sidiropoulou E et al., 2020. In vitro anticoccidial study of oregano and garlic essential oils and effects on growth performance, fecal oocyst output, and intestinal microbiota in vivo. Frontiers in Veterinary Science 7:420.

Sidiropoulou et al., 2020. In vitro anticoccidial study of oregano and garlic essential oils and effects on growth performance, fecal oocyst output, and intestinal microbiota in vivo. Frontiersin Veterinary Science 7: 420.

Swelum et al., 2021. Ways to minimize bacterial infections, with special reference to Escherichia coli, to cope with the first-week mortality in chicks: an updated overview. Poultry Science 100:101039.

Thagfan FA et al., 2017. In vivo anticoccidial activity of Salvadorapersica root extracts.Pakistan Journal of Zoology 49: 53-57.

Tsinas A et al., 2011. Effects of an oregano based dietary supplement on performance of broiler chickens experimentally infected with Eimeriaacervulina and Eimeria maxima. Journal of Poultry Science 48: 194-200.

Tyzzer EE, 1929. Coccidiosis in gallinaceous birds. American Journal of Hygiene10:269-383.

Walker RA et al., 2013. Sex and Eimeria: a molecular perspective. Parasitology 140:1701.

Wang et al., 2008. Influence of grape seed proanthocyanidin extract in broiler chickens: effect on chicken coccidiosis and antioxidant status. Poultry Science 87:2273-2280.

Yang WC et al., 2019. Anticoccidial properties and mechanisms of an edible herb, Bidenspilosa, and its active compounds for coccidiosis. Scientific Reports9: 1-11.

Yaqoob et al., 2021. The potential mechanistic insights and future implications for the effect of prebiotics on poultry performance, gut microbiome, and intestinal morphology. Poultry Science100 :101143.

Zhang et al., 2020. Anticoccidial effects of Camelliasinensis (green tea) extract and its effect on Blood and Serum chemistry of broiler chickens. Pakistan Veterinary Journal 40:77-80.