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PREVENTIVE MEASURES FOR THE CONTROL OF COCCIDIOSIS AND OTHER ALTERNATIVES IN POULTRY PRODUCTION – A REVIEW

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Abstract

Coccidiosis, caused by Eimeria sp. protozoan parasites, faces significant financial losses in the global chicken industry. This study examines the impact of coccidiosis on chicken productivity and evaluates the limitations of existing management strategies, such as anticoccidial medications and vaccinations. The need for drug-free food production arises due to concerns regarding drug resistance, high costs, and health risks associated with drug residues, despite the effectiveness of anticoccidial medications and live vaccinations. Various types of feed additives, including probiotics, synbiotics, organic acids, phytobiotics, antioxidants, and nanoparticles, are currently being researched for their potential applications in environmental, immunological, and genetic fields. The gastrointestinal tract provides protection against harmful substances for chickens. The GI tracts of birds can be influenced by factors such as diet and infection. The negative impact of interruptions on bird health and commercial production is significant. The use of probiotics, such as Saccharomyces cerevisiae, in chicken diets has shown potential benefits in terms of enhancing health and growth performance, potentially serving as an alternative to antibiotics. Issues have been raised regarding the potential for antibiotic resistance due to the use of antibiotics in chickens to enhance growth and feed efficiency. The importance of exploring other options is highlighted. Anticoccidial medications and vaccinations have helped to control the disease-related losses but the disease as a whole remains a significant problem. Although molecular diagnostics have great potential, there is little real-world use for them. Drug-resistant strains need an alternative coccidiosis treatment. Innovative solutions that integrate diet, immunology, and alternate therapies are needed to reduce this costly poultry illness.

Keywords: coccidiosis, Eimeria, poultry, anticoccidial medications, vaccinations

Introduction

Pakistan is now the seventh biggest chicken producer in the world because of years of rapid expansion and development in the industry and extensive upgrading of farms (Ghafoor et al., 2010). Pakistan's poultry industry is expanding at a rate of 10–12% each year, making it one of the country's fastest-growing industries. Since the government of Pakistan is putting more money into the poultry industry, this rate of expansion is likely to be sustained in the years to come. Over 1.5 million individuals in Pakistan now have jobs in this industry. Since 1962, when commercial poultry farming started in Pakistan, more than 15,000 farms have generated 1.94 million tons of chicken. From 5,000 to 500,000 broilers, these farms come in all shapes and sizes. It has been stated that the United States, Brazil, France, China, Pakistan, Mexico, and Russia are the top producers of meat, milk, and eggs in the globe. Canada produces 1.2% of the world's meat and 2.7% of the world's milk in 2021, with outputs of 1,952,038 tons of red meat, 2,245,770 tons of chicken meat, and 23,200,306 tons of milk (Can, 2023).

In addition, Poland is still the largest poultry producer in the EU with about 21–22 percent of the total EU poultry production which amounts to about 3.2–3.4 million tons in a year (Wachong Kum et al., 2025). The growth in 2024 was 5% per year with a production of more than 3.2 million tons and it was backed by a steady domestic demand and low feed prices and an increase in export volume (Buitenland, 2025). Poland is also emerging as the third poultry exporter after Brazil and USA. The exports stood at approximately 1.6 million tons in 2022, and in 2023, the exports have been higher with the value of the exports amounting to approximately USD 4.5 billion and the export going to Germany, UK, France and Netherlands among others. The domestic production will be on an increasing trend, with predictions of 7% growth in 2024 and 2% growth in 2025 due to high export demand and enhanced cost efficiencies (Trade.gov.pl, 2024).

Coccidiosis in poultry

Parasitic protozoa of the genus *Eimeria* sp. phylum Apicomplexa, and family *Eimeriidae*, are responsible for avian coccidiosis (Williams et al., 2009). Chicken coccidiosis is an intestinal ailment caused by the intracellular protozoan parasite of the genus *Eimeria. Eimeria tenella*, *Eimeria necatrix*, *Eimeria acervulina*, *Eimeria maxima*, *Eimeria brunetti*, *Eimeria mitis*, and *Eimeria praecox* are only some of the seven species known to infect hens. When it comes to infection site preference, pathogenicity, and immunogenicity, every species is unique (Kitandu and Juranova, 2006). The most pathogenic species are *E. tenella* and *E. necatrix* (Hamid et al., 2018). Rare as it may be, *E. brunetti* is nevertheless very dangerous. *E. acervulina*, *E. maxima*, and *E. mivati* are examples of bacteria with low to moderate pathogenicity. Finally, *E. mitis* and *E. praecox* are not very dangerous (if at all) (Chapman, 2018). Increased oocysts in the litter as a result of inappropriate recycling practices and an increase in the prevalence of *Alphitobius diaperinus*, which ‘‘may act as a vector of *Eimeria* sp. oocyst’’, have contributed to the spread of *E. tenella*-caused cecal coccidiosis in broilers (Frölich et al., 2013).

The protozoan *Eimeria* sp. reproduces after it reaches the gut epithelium. The fast proliferation of the parasite during this procedure might have the epithelial cells (enterocytes). Inflammatory processes, disturbance of intestinal integrity, intestinal hemorrhaging, and susceptibility to bacterial infections are all results of avian coccidiosis (Jenkins et al., 2008). There may also be a

significant rate of illness and death in infected chicken lots (Répérant et al., 2012). Parasites responsible for coccidiosis are obligate intracellular organisms that can only cause illness by invading the body of a susceptible host (Iqbal et al., 2022).

Life cycle

Eimeria has two main life cycle phases: endogenous (schizogony and gametogony) and exogenous (sporogony) (Allen and Fetterer, 2002). The motile, banana-shaped sporozoite stage, which is the first stage of all *Eimeria* sp., has a special apical complex for invading host cells (Augustine, 2001). The infectious stage is sporozoites, which are expelled from sporulated oocysts (Bowman, 2008). The tough-walled oocysts, which differ in size and shape among species, are expelled in feces. Unsporulated oocysts go through sporogony to produce sporocysts and sporozoites when the right environmental parameters are met, which include oxygen, moisture, and 16–30°C (Chapman, 2014). Usually, sporulation takes one to two days.

Table 1. Species of *Eimeria* and their predilection site in the host

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

Source: Abebe and Gugsa (2018)
Affected chickens are illustrated in Table 1.

By altering the Stieda body inside the host, bile salts and digestive enzymes cause sporozoites to be released from sporocysts (López-Osorio et al., 2020a,b). With the help of amylopectin metabolism, sporozoites actively enter intestinal epithelial cells (Müller and Hemphill, 2013). They change into trophozoites and start merogony inside host cells. In order to create merozoites – motile, spindle-shaped cells that infect new epithelial cells – the parasite must go through several nuclear divisions during schizogony (Deplazes et al., 2016).

Parasites enter gamogony after a number of merogony cycles. A lesser percentage of merozoites develop into motile microgametes (male), whereas the majority differentiate into macrogametes (female). The zygote formed after fertilization matures into a sporont surrounded by a resilient oocyst wall (Deplazes et al., 2016). The cycle is then restarted when mature oocysts are discharged into the environment along with feces, where they sporulate (Chartier and Paraud, 2012).

This cycle mostly results in disease during gamogony, when intestinal epithelial cell death causes diarrhea, poor absorption, and decreased poultry production (Levine, 1961; Deplazes et al., 2016).

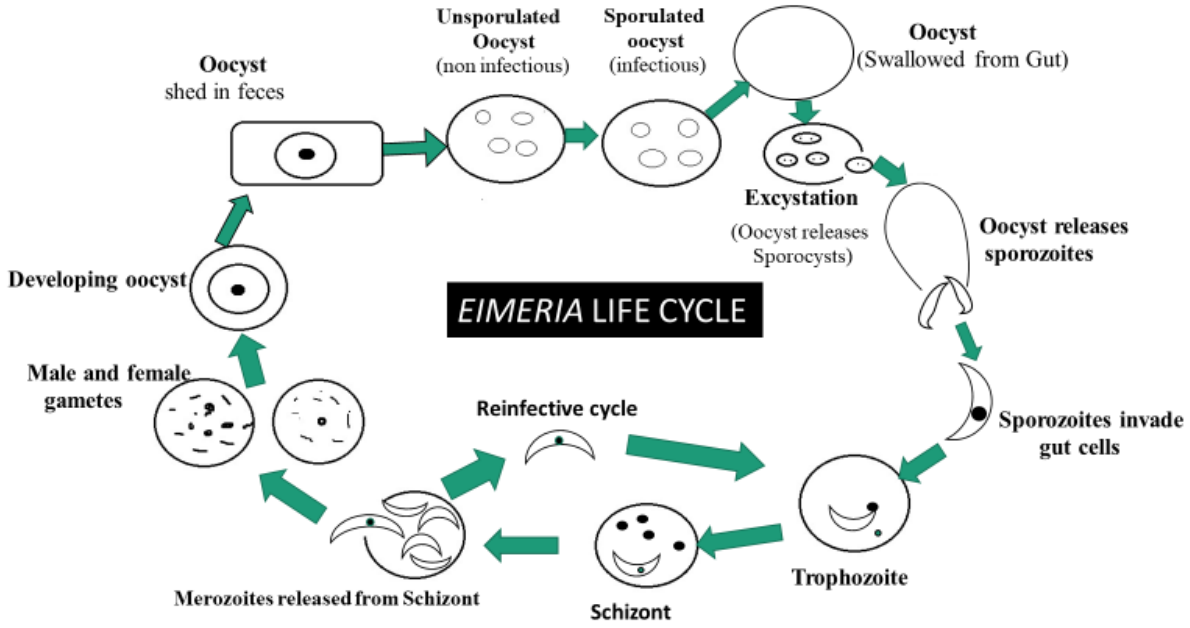


Figure 1. Life cycle of *Eimeria*

Molecular diagnosis

Morris and Gasser (2006) offer a great overview of *Eimeria* sp. coccidiosis diagnostics and genetic variation analysis. Molecular and biochemical approaches including southern blotting, pulsed-field gel electrophoresis, and multilocus enzyme electrophoresis have been used in research (Mares et al., 2023). Recently, polymerase chain reaction (PCR) has been used to identify *Eimeria* sp. involved in single or mixed infections (López-Osorio et al., 2020a,b). Because they employ *Eimeria* sp. genomic sequences, PCR tests are more popular than traditional techniques (Güven et al., 2013). These methods promote scientific research and practical applications like vaccine development and quality control. However, the lack of a fast, cheap, and quantitative diagnostic test hinders their wider application. Field diagnosticians mostly employ these methods to detect neglected species like *E. praecox* and *E. mitis.*

Furthermore, field diagnosticians mostly rely on traditional procedures like lesion scoring and coproscopic inspection, seldom employing molecular technologies in their daily work. Despite their lack of sensitivity and specificity, these techniques continue to be the mainstay of field diagnosis since they are straightforward and reasonably priced. Despite the widespread use of ionophores, which allow delicate parasites to grow, the lack of quantitative data in the approaches inhibits a clear knowledge of coccidia species (De Gussem, 2007).

Clinical signs

Poultry sector coccidiosis is clinical and subclinical. Death, morbidity, diarrhea or bloody feces, dehydration, reduced feed intake, weight loss, pallor, huddling, feather-ruffling, and sadness are the main symptoms (Taylor et al., 2007). Coccidia-infected hens get sick and weak, and after four to five days, immature birds sometimes bleed in the face, lose their wings, and stop breathing

(Julie, 1999). Pathogenicity of *Eimeria* sp., age of infected poultry, management strategy, and amount of sporulated oocysts swallowed by birds affect clinical coccidiosis incidence. Coccidiosis dramatically reduces chicken production and performance. Laying chickens will produce fewer eggs (Nematollahi et al., 2009). Subclinical coccidiosis causes the most economic loss because of poor feed conversion efficiency and weight loss (Nematollahi et al., 2009).

Methods for prevention of coccidiosis

Since 1948, when the American Food and Drug Administration initially approved nitrofurazone and sulphaquinoxaline, a number of anticoccidial medications have been developed. The majority of anticoccidial products are now authorized in various parts of the world to prevent coccidiosis in hens (Peek and Landman, 2011).

Table 2. Anticoccidial products (Peek and Landman, 2011)

Method	Description	Advantages	Limitations
Chemoprophylaxis	Use of anticoccidial drugs in feed or water	Easy to administer, effective short-term	Drug resistance, residue concerns
Vaccination	Live or attenuated vaccines administered to chicks	Long-term immunity	Costly, requires precise application
Biosecurity Measures	Hygiene, controlled entry, litter management	Prevents multiple infections	Requires strict compliance
Probiotics/Prebiotics	Beneficial bacteria to enhance gut health	Natural, improves gut flora	Variable efficacy
Essential Oils/Herbal Extracts	Plant-derived compounds (e.g., oregano, thyme) with anticoccidial activity	Natural, residue-free	Less standardized, slower onset
Genetic Selection	Breeding for coccidiosis-resistant poultry strains	Long-term solution	Time-consuming, limited availability
Enzymes & Organic Acids	Improve gut health and reduce Eimeria development	Promotes digestion, non-toxic	Supportive, not curative alone

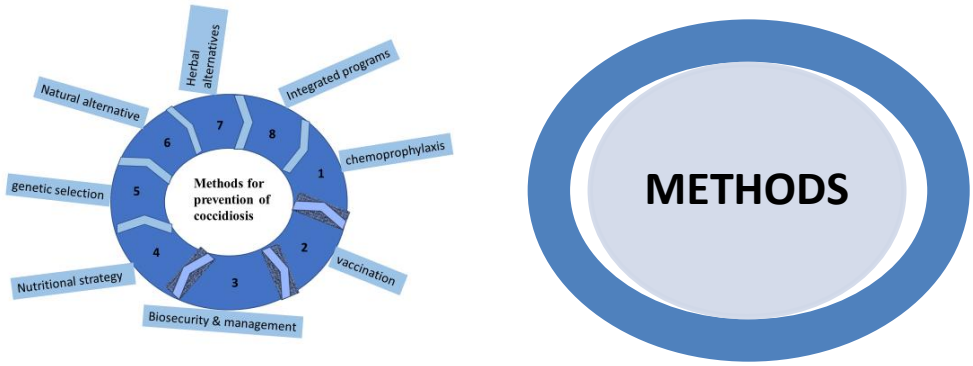


Figure 2. Prevention and control of coccidiosis

Chemoprophylaxis and anticoccidial drugs use

Fifty years of successful anticoccidial medication usage have expanded the chicken sector and given consumers economical, high-quality poultry products. Many of the items developed then are still used. However, rising drug resistance is a concern (Chapman, 1997). There are two types of

anticoccidial drugs: 1) synthesized drugs and 2) polyether ionophores. Sulphamides and similar medicines compete with folic acid for incorporation and metabolism inhibition. Similar medications compete with parasites for thiamine absorption. Through the cytochrome system, clopidol and quinoxaline suppress *Eimeria* sp. energy metabolism. Quinoline and ionophores kill sporozoites or early trophozoites, nicarbazin, robenidine, and zoalene kill first- or second-generation schizonts, while sulphonamides kill growing and sexual schizonts. Ionophores, which alter sodium and potassium balance, kill coccidia. Ionophores prevent parasites from controlling these ions. Chemoprophylaxis with anticoccidial medications is still one of the most used methods.

1. Synthetic drugs: After these drugs were introduced, ionophores became essential for coccidiosis treatment. Coccidiosis is treated with diclazuril and toltrazuril (Chapman, 1999). Toltrazuril in potable water as the only anticoccidial drug is best given for two days, between days 10 and 14. Coccidiosis would be controlled well (Mathis et al., 2004). It was found that toltrazuril protects chickens against all *Eimeria* sp. (Peek and Landman, 2010) and effectively inhibits all intracellular developmental phases, including schizogony and gametogony. Toltrazuril may boost natural immunity despite its great effectiveness, according to certain findings. Toltrazuril proved successful as a single anticoccidial drug and as an adjuvant to certain regimens (McDougald et al., 1990; Greif, 2000). It was found that diclazuril has broad-spectrum, robust anticoccidial action against *Eimeria* sp. with specific effectiveness against the six most important pathogenic species (*Eimeria acervulina*, *Eimeria maxima*, *Eimeria tenella*). Roxarsone is effective against *E. tenella*, *E. brunetti*, *E. necatrix*, and *E. mitis* (Chapman et al., 2004). It also synergizes well with ionophores. Coccidiostats are still often used in poultry feed as preventive measures. Growth enhancers like bacitracin and anticoccidial combinations like salinomycin and roxarsone are frequently used in growth diets (Chapman and Johnson, 2002). Resistance to all anticoccidial drugs, including ionophores, is obvious (Chapman, 1997). To reduce resistance, chicken breeders rotate anticoccidial usage across flocks. This involves using several medication classes on one bird crop. One class may be used in starting feed and another in growers. The finisher diet reinstates the starting class before a withdrawal diet (Sangster, 2001).

2. Polyether ionophores: Since 1971, ionophore antibiotics have combated coccidiosis. Salinomycin, narasin, monensin, lasalocid, maduramicin, and semduramicin are effective unless parasites are a major problem. It has also been shown that certain ionophores can be used with live virulent vaccines, so resistant strains tolerant to ionophores may be more useful in developing coccidiosis vaccines. These ionophores prevent infection in the first three to four weeks of life when immunity is growing. This reduces the danger of coccidiosis by minimizing infection pressure induced by field strain multiplication during immunity development (Chapman, 1997). The interaction between *Clostridium perfringens* and damaged intestinal mucosa and *Eimeria* parasite growth has been shown to worsen coccidiosis. This may be solved by ionophores' antimicrobial capabilities. Live virulent vaccines (Nobilis COX ATM) and ionophores like monensin, narasin, and salinomycin help protect poultry against necrotic enteritis and coccidiosis (Vermeulen et al., 2000). The method is said to protect against broad-type coccidiosis during the period before effective immunity develops, species not included in the vaccine, and bacterial diseases like necrotic enteritis due to the ionophores' additional properties. (Chapman et al., 2002; Vermeulen et al., 2000).

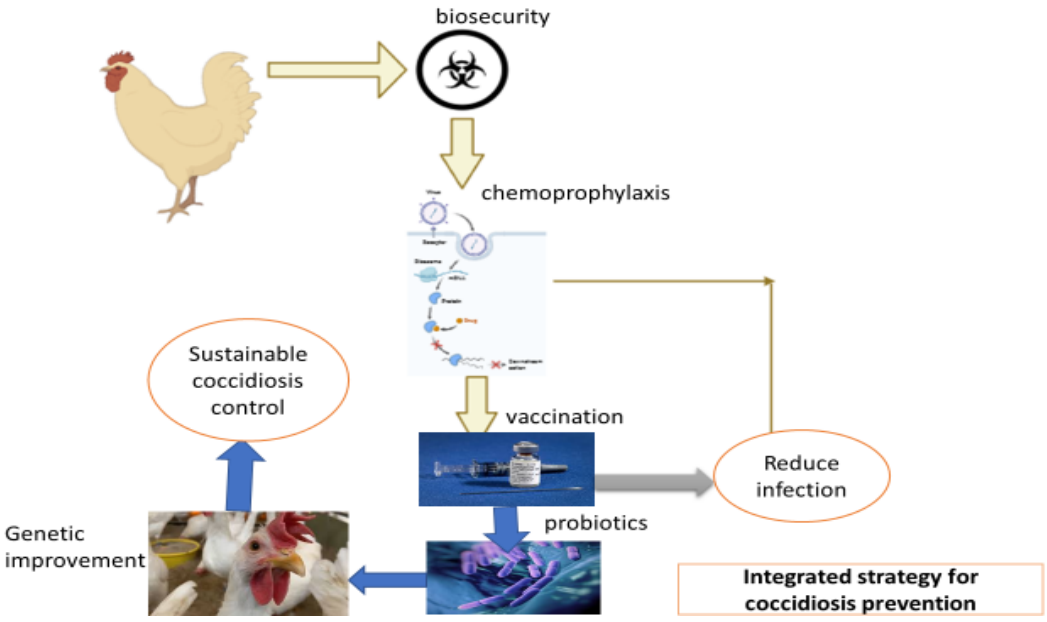


Figure 3. Integrated strategy for coccidiosis prevention

Vaccination and immunization

Public concern about chemical residues in poultry products, environmental pollution, and anticoccidial drug resistance has led to research into alternative control methods, such as early vaccination or drug development (Yim et al., 2011). Currently, poultry vaccinations are attenuated or virulent (Allen and Fetterer, 2002). Attenuated vaccinations, derived from the original strain, lack asexual reproductive cycles. These vaccinations have reduced pathogenicity and reproduction (Chapman and Jeffers, 2014). This improves virulent coccidial vaccine performance, but attenuated vaccines have lower reproductive potential and greater manufacturing costs. Some virulent vaccines include anticoccidial-sensitive strains and others contain resistant strains. Live anticoccidial-sensitive strain vaccinations may change coccidial population resistance (Mathis and Broussard, 2006). Live vaccines made of attenuated or virulent oocysts of several *Eimeria* sp. may replace anticoccidial medications for chicken coccidiosis management. Several of these vaccines are commercially marketed worldwide. However, *Eimeria* sp. elicits significant immunity to homologous challenge, and its immunological diversity may explain why geographically separated isolates lack cross-protective immunity (McDonald and Shirley, 2009). Many vaccine techniques have been used to eliminate avian coccidiosis. Many nations, including Europe, have successfully adopted the Paracox vaccination in non-caged poultry systems for reproduction and egg laying (Shirley and Harvey, 2000). Attenuated vaccines, like *E. tenella* Livacox vaccines, are produced by passing through embryonated eggs, whereas the other species and Paracox vaccines are produced by selection for precocity (Arabkhazaeli et al., 2014). A coccidiosis in poultry may be managed using a live attenuated vaccination instead of coccidiostats. This includes selected precocious strains of each poultry-affecting coccidia species. These strains grow quickly *in viv*o, cause little intestinal damage, and provoke a strong immunological response. Many countries now provide live or attenuated coccidian vaccinations (Taylor et al., 2007).

Vitamins

Vitamins boost chicken immunity and help them withstand a variety of challenges (Khan et al., 2010; Ajakaiye et al., 2011). Vitamins and other nutrients may affect humoral and cellular immunity. Vitamin A helps epithelial cells differentiate, protecting the intestine's mucosal surface (Chew and Park, 2004). Vitamin A deficiency weakens broiler poultry's gastrointestinal lymphoid tissues' local immune responses and raises the risk of enteric illnesses such as coccidiosis (Dalloul et al., 2002). This caused intraepithelial lymphocyte subpopulations, mostly $CD4^+$ T cells, to decline. Intraepithelial lymphocyte subpopulation alteration lowers *E. acervulina* resistance. Dalloul et al. (2002) found that vitamin A deficiency reduces IFNgamma release via decreasing splenic T cells' ability to respond to *in vitro* mitogen stimulation. Vitamin A intake affects broiler chicken intestinal immunity. Vitamin A deficiency may cause immunosuppression in some areas, making birds more susceptible to coccidiosis.

Probiotics

The FAO defines probiotics as "living microorganisms that bestow a beneficial effect on the host's health when administered in sufficient quantities" (2002). The chicken industry uses probiotics to restore intestinal microbiota after enteric illnesses or antibiotic treatment (Dalloul et al., 2003; Rajput et al., 2020). They have also been used to treat allergies and immunological problems by boosting the immune system (Kabir et al., 2004; Lee et al., 2007). Lee et al. (2007) found that *Pediococcus*-based commercial probiotic MitoGrow® somewhat protected chickens against growth retardation and coccidiosis. Probiotics from *Saccharomyces* and *Pediococcus* (MitoMax®) were given to birds exposed to 5000 *E. acervulina* or *E. tenella* oocysts in another study. Probiotic-fed pregnant birds had better antibody response and less oocyst discharge. Through humoral immune response activation, MitoMax® in chicken diets may increase coccidiosis resistance (Lee et al., 2007). *Lactobacillus*-derived probiotics also boost cellular immunity (Sayed et al., 2023).

Prebiotics

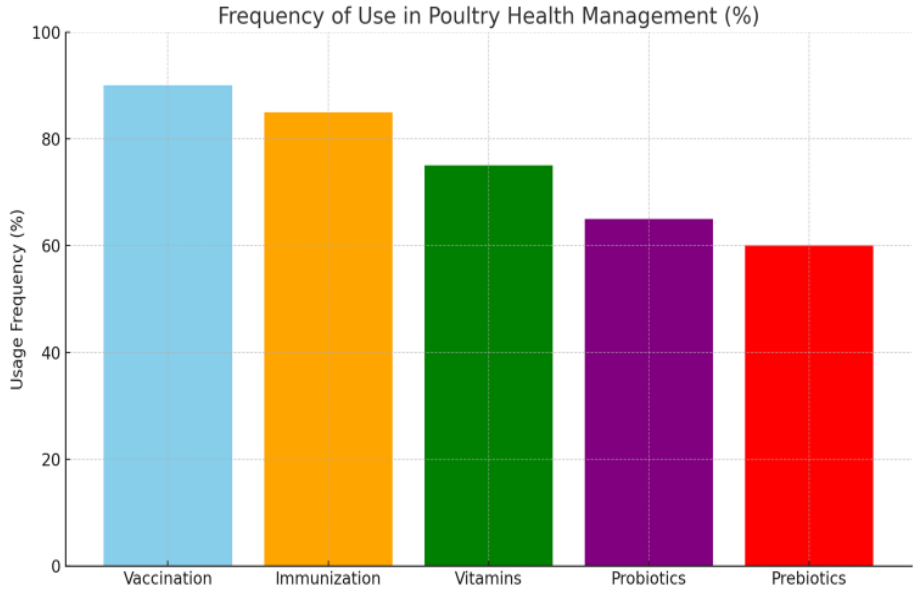
Prebiotics are indigestible dietary components that selectively stimulate a limited number of colonic microorganisms to improve host health (Spring, 1996). Several studies have shown that prebiotics benefit intestinal flora (Ahmed et al., 2023). Mannan oligosaccharides (MOS) from *Saccharomyces cerevisiae* yeast cell walls are widely used as prebiotics to improve performance and gastrointestinal health (Ricke et al., 2023). MOS inhibits microbe adhesion to mucosal mannan receptors, triggering an immunological response (Spring et al., 2000). MOS increases *Bifidobacteria* and *Lactobacillus* species in young chickens' digestive tracts while suppressing *Enterobacteriaceae* (Fernandez et al., 2002). Dietary MOS (1 g/kg feed) prevented an experimentally produced light infection of *E. tenella* (Elmusharaf et al., 2006). Later studies found that MOS as a food supplement at 10 g/kg feed reduced oocyst excretion and *E. acervulina*-induced lesions (Yan et al., 2023). However, subclinical sporulated oocysts also caused mild infections with this anticoccidial action (Dalloul et al., 2001; Elmusharaf et al., 2007). MOS may provide anticoccidial efficacy when paired with greater challenge dosages and feed concentrations (Griggs and Jacob, 2005).

A comprehensive strategy incorporating biosecurity, natural supplements, genetic selection and dietary approaches is needed to prevent and control coccidiosis in poultry. Biosecurity measures are essential to stop the introduction and spread of oocysts. According to Peek and Landman (2011), these include keeping your litter clean and dry, avoiding overcrowding, using all-

in/all-out production and disinfecting facilities in between flocks, managing vectors like insects, rodents, and untamed birds, and limiting guest access and cleaning the equipment.

In addition to these methods, using phytogenic chemicals has become a viable substitute for traditional anticoccidials. Products made from plants such as garlic extract, oregano oil, neem (*Azadirachta indica*), and *Artemisia annua* have inherent anticoccidial qualities through immunomodulation, antioxidant action and disruption of parasite metabolism. Benefits include the possibility of synergy with other measures and the low danger of chemical residues (Abebe and Gugsa, 2018). The use of genetic selection in breeding operations to create chicken breeds with innate resistance to coccidiosis is another viable approach. In order to contribute long-term disease resistance, desirable characteristics include less oocyst discharge, decreased lesion scores, and sustained performance under stress (Rossi et al., 2024).

Moreover, by increasing food digestibility and decreasing undigested substrates in the stomach, feed enzymes (xylanases, β-glucanases, and proteases) lessen the favorable circumstances for *Eimeria* sp. growth. They could also strengthen the effects of organic acids and probiotics (Reuben et al., 2021). Furthermore, by reducing intestinal pH, preventing the growth of pathogenic microorganisms, boosting the integrity of the intestinal barrier, and cutting down on secondary bacterial infections that exacerbate the symptoms of coccidiosis, organic acids such as butyric, propionic, and formic acids support intestinal health (Madlala et al., 2021; Bedford and Apajalahti, 2022).



Conclusion and future directions

This study examined the complicated relationship between coccidiosis and the use of drugs in commercial poultry. Coccidiosis is a growing chicken industry issue. Due to bird production and health issues, it costs the business money. Coccidiosis is caused by *Eimeria* sp. protozoan parasites. They are a major danger to the poultry business and need a solid plan to address it. Antibiotic

therapy was our aim to combat coccidiosis. Different medications and vaccinations from different sources may help poultry birds stay healthy. Birds' guts and immune systems benefit from prebiotics and probiotics. This study found that adding medications, vitamins, or vaccinations to poultry birds' diets reduces coccidiosis damage. These synthetic medications reduce illness and preserve poultry bird production. Immunization is crucial to avian health. The poultry birds' immune systems are strengthened by vaccination, so they can fight coccidiosis more effectively. These methods also promote intestinal health, lowering illness risk. Healthy guts prevent coccidian parasites from thriving. We also observed vaccination-induced oocyte loss. We can limit coccidian parasites' influence on chicken productivity this way. We have seen how medications affect poultry birds. Now further study is needed on dose and flock health. Research must show how various methods sustain production and how much of a certain medicine is needed for optimal effects. We must also understand coccidia and their resistance to various actions. Understanding all this improves illness management.

Summarizing, the research involves studying coccidian parasites' intestinal proliferation in birds and suggesting approaches to limit their impacts. Coccidiosis is reduced by medications, vitamins, and vaccinations. It also inhibits coccidian growth. This study lays the groundwork for understanding how medications affect coccidian parasites. Since medications might harm chicken flocks, the poultry industry wants biological management of coccidian parasites. We found that these strategies promote poultry bird health and economic productivity.

Authors' contribution

Adeeba Naseer & Rida Sattar: Conceptualization, Investigation; Formal Analysis, Writing –original draft, Visualization, Data Curation. Noman Waheed: Data Curation, Review and editing. Ghulam Mustafa: Review final draft.

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Data availability

All data generated or analyzed during this study are included in this published article.

Conflict of interest

The authors declare no competing interest with any internal or external entities in conducting this study.

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