Chapter 16

Role of Probiotics in Prevention of Avian Coccidiosis

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ABSTRACT

Coccidiosis is one of the most economically important protozoal diseases of avian which is caused by the protozoan genus *Emeria spp*. The probiotics have an important effect on the genus *Emeria*, also helping in the growth of beneficial microbiota in the gut. These have an incredible role in managing the gut microbiota and improve the immune potential of the host against pathogens in the gut. The probiotics are beneficial prokaryotes like bacteria which help in the control of coccidiosis in the avians. The key insight of this very chapter is to discuss how the probiotics acts and help to reduce coccidiosis by preventing the colonization of the *Emeria spps*. in the poultry gut. The prevention against coccidiosis is through competitive exclusion, immunomodulation, and formation of antimicrobial compounds in the gut. This chapter also sheds light on the role of coccidiostats, immunization against coccidia, bioactive compounds and natural alternative in the control of avian coccidiosis. The vaccine helps in the development of the body immunity which last longer and thus reduce the use of antibiotics for the disease control. The mentioned strategies will help in the prevention of coccidiosis and will lead to healthy chicken and food safety and security.

KEYWORDS
Coccidiosis; Probiotics; Poultry; Vaccine; Immunity

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INTRODUCTION

Poultry production is the source for the provision of chicken meat which is a cheap source of animal protein around the globe (Govoni et al., 2021; Nkukwana, 2018). The USDA reported that 102.9 million tons of poultry meat was produced in January 2020, which was reflected as a 3.9% increase as compared to the previous year (Mesa-Pineda et al., 2021). An increase in the population is expected to reach nine billion by 2050, which is a horrifying sign to produce sustainable and safe protein (Watson et al., 2018). A high stocking density is the predisposing factor for stress and disease prevalence, and it affects the poultry industry (Ahmad et al., 2022). Hence, a disease that impairs the productivity of the earlier indicated production system could be dangerous for the whole food chain (Aganovic et al., 2021).

The poultry sector faces significant losses due to coccidiosis, a hidden enemy caused by intracellular parasites (Blake et al., 2020). In the US, 127 million USD is invested in coccidiosis-related costs annually, with China exceeding 73 million USD, accounting for almost 30% of the total (Geng et al., 2021; Lahlou et al., 2021). Seven species of *Eimeria*, including *Emeria tenella*, *E. acervulina, E. maxima, E. necatrix*, and *E. mitis,* are associated with coccidiosis in poultry. These species attack the bird's intestines and exhibit specific cytotoxicity, preventing the body from metabolizing proteins and nutrients (Kers et al., 2018). The preventive immunization is crucial for the poultry industry's development and income (Hamid et al., 2018). In Europe, antiparasitic drugs with feed are used for broiler chickens, simplifying EU regulations for poultry health and wellbeing (Martins et al., 2022).

Since 1930, synthetic anticoccidial medications and ionophores have been used to combat dangerous parasites in chickens (Nogueira et al., 2009). However, antiparasitic resistance develops due to drug metabolites, negatively impacting human health (Nahed et al., 2022). The coccidiostats, synthetic drugs that inhibit Emeria's growth, are widely used. Coccidiosis, which is the major economic disease of poultry, is caused by the protozoan called *Emeria* (Noack et al., 2019). There are two classes of about ten coccidiostats which function as a feed additive approved by the European union for the use in poultry. Probiotics are initially provided to the birds from their first day of life to seven days to prevent the disease caused by the protozoan oocyst before they are marketed as meat for human consumption. This managemental procedure is very applicable and this helps the birds from coccidiosis. The probiotics which fortified the beneficial microorganisms including yeast and fungi have proved to boost performance and immunity of the intestine in the host and improve the gut microflora that reducing the risk of coccidiosis in the birds (Ahmad et al., 2022). Additionally, probiotics also can reduce the growth of other infectious agents in the gut and hence protect the birds' intestinal villi from damage by the toxins producing organism in the feed. In another study it has been found that the use of *Bacillus* strain orally has a significant effect on reducing the colonization of *Emeria* in the intestine of broiler birds and hence the use of bacillus strain is indispensable in the broiler feed (Gururajan et al., 2021).

The actual mechanism of action of probiotics bacterial strains acts as a competitor with *Emeria* for attaching to the intestinal epithelium receptors and thus occupy the receptors and inhibit the attachment of the *Emeria* to the epithelium its replication and oocyst shedding to the environment. Sometimes in case of acute coccidiosis the effect of probiotics and prebiotics are not proficient and so in such a case alternative needs to be identified (Nesse et al., 2019).

Probiotics and Gut Microbiota

The probiotics are compounds which play a key role in the composition of the microflora in the gastrointestinal tract. These beneficial microbes bind with the receptors in the intestinal mucosa and compete with the pathogens including *Emeria* and thus produce antimicrobial compounds which inhibit the growth of these pathogenic organisms (Abd El-Hack et el., 2020). The probiotics work as an antagonist by producing organic acids, change the gut pH and immunomodulation and have a significant positive effect on the epithelial cells, transduction pathways of microflora, intestinal surface integrity and immunity (Arif et al., 2021; Rajput et al., 2020).

The use of different molecular techniques like, metagenomic sequencings, *in-vivo* assay and culture have revealed the effect of the probiotics on the shift, function, and arrangement microflora of the GIT. Nevertheless, the effective and efficient method of getting the beneficial effect is the application through *in-vivo* method (Foligne et al., 2007). The *in-vivo* administration of the probiotic's strains like *Bacillus bifidum*, *B. animalis*, *Bifidobacterium longum* and *Bifidobacterium infants*. The *Lactobacillus* and *Bifidobacterium* have improved the bacterial population of the ileum by enhancing the intestinal colonization fermentation and reducing the coliforms bacteria (El-Moneim et al., 2020).

Mode of Action (Probiotics)

The unique mode of action of probiotics in gastrointestinal tract is competition with other pathogens by covering the specific receptors for their attachment in the intestinal epithelium that help eliminate the other pathogens to enter the epithelium and damage the gut microflora by bacterial belligerence or competitive exclusion. Interestingly this mode of action mostly possesses all the probiotics, prebiotics and symbiotics (Abd El-hack et al., 2020). Apart from this there is another concept called "Nurmi" in which resistance is developed in the gut microbiota by injecting the infectious agent into the chicken GIT (Bajagai et al., 2016). Similarly, probiotics attached to the epithelial surface both inner and outer and help in development and improve the digestion which is mostly investigated in the caeca and intestine of the avians (Ahmad et al., 2022; Agyare et al., 2018; Zaefarian et al., 2016).

The *Bacillus amyloliquefaciens* (BAP) accelerates digestion, nutrients absorption and availability in GIT, thus BAP mixed feed for 35 days (20g/kg) drastically accelerated the growth of broilers. The oral administration of spores of the genus *Bacillus* is one technique of competitive exclusion that may strengthen and promote host defense against coccidiosis.

Approaches to Control Avian Coccidiosis

To prevent the coccidiosis in the farm, there are different strategies implied like coccidial vaccination, use of feed additives, prophylactic use of anticoccidial drugs and farm management especially the litter and beddings (Broom, 2021). To ensure healthy poultry it is important to follow all the handling and managemental to minimize the stress and to produce a high-quality healthy poultry product (Dhaka et al., 2023).

The proper management of the farms' birds includes provision of stress-free environment, superior quality feed, water, feed supplements, optimum lighting, proper ventilation, and temperature. To control and prevent coccidiosis in the poultry farm it is utmost important to practice farm biosecurity. Maintaining litter conditions, reducing oocyst sporulation, and using anticoccidials (prophylaxis) are also essential for producing high-quality chickens. Regular cleaning, regular disinfection, and clean water usage are also essential for maintaining a healthy poultry farm (Tilli et al., 2022; Abebe and Gugsa, 2018).

Use of Coccidiostats

Since the 1950s, poultry and turkeys have been fed anticoccidial feed additives to prevent growth. Agri Stats Inc reports that 99% birds were administered anticoccidial drugs in the late 1900s (Chapman, 2009). However, 60% of broiler meat in the US is produced without these agents (Mesa-Pineda, et al., 2021). Anticoccidial agents are categorized as coccidiostats or coccidiocides based on their mode of action. Coccidiostats limit microbe growth and reproduction, while coccidiocides destroy pathogens and cause irreversible damage (Nahed et al., 2022).

Coccidiostats are two types of antibiotics, primarily synthetic compounds and ionophores. Streptomycetacae family bacteria produce natural substances like polyether ionophores. Synthetic coccidiostats, also known as chemicals, change ion concentration ratios on cell membranes through dimerization and binding (Dembitsky, 2022; Clarke et al., 2014;

Muthamilselvan et al., 2016). They modulate ion concentrations, leading to less cytotoxicity and energy production (Miller and Zachary, 2017). The EU has authorized eleven coccidiostats, primarily synthetic compounds and ionophores, to prevent disease spread, reduce parasite multiplicity, and strengthen the immune system. Ionophores target sporozoites before host cell penetration, allowing some to survive and develop host immunity (Nesse et al., 2019; Noack et al., 2019).

Vaccines

The coccidiosis control strategies rely on vaccination, which stimulates the immune system to defend against *Eimeria* hazards (Lee et al., 2022; Shivaramaiah et al., 2014). The vaccinations are a crucial substitute for eradicating coccidiosis, but they must be effective and provide adequate protection to poultry. Vaccines contain oocysts from *Eimeria* strains, with *E. maxima* oocysts causing the highest immune response (Attree et al., 2021). The adaptive immune response can be stimulated in 3-4 weeks, depending on the host's genetic makeup, infection duration, and parasite concentration (Martins et al., 2022). However, the current vaccination program is challenging due to the uncertainty of exposure to the same amount of coccidian. The *in-ovo* immunization, administered to 18-day embryonated chicken eggs, is a recent advancement that ensures accurate and consistent administration of vaccines to the embryo's amniotic sac (Williams, 2005).

The *in-ovo* inoculation is a method that delivers chemicals directly to chicken embryos during incubation stages, potentially controlling their gastrointestinal growth. Introduced in 2003, it involves injecting nutrients and chemicals into embryonic amnion to stimulate growth (Arain et al., 2022). In a research investigation Lee et al. (2022) stated that a micronutrient, selenium can modulate the immune response of broilers exposed to the *E. maxima* and *C. perfreingens*. Because the high immune response against the exposed pathogen were recorded in the selenium treated group as compared to the control and hence very minute intestinal damage and small number of oocysts were recorded. Similarly in another study conducted by Stadnicka et al. (2020) reported that the use of raffinose from lupine seed has a significant effect on the growth of pathogenic bacteria *C. perfreingens* and *Emeria* oocyst shedding.

The use of probiotics *in-ovo* 17 days post incubation have significant effects on the colonization of all *Emeria* species and thus limit their pathogenesis (Pender et al., 2016). Another study by Sokale et al. (2017) reported that *in-ovo* vaccination before hatching against coccidiosis in broiler has a significant effect on immunity development and prevention against subsequent exposure. The use of live vaccines (Inovocox, Pfizer) during incubation produces protective immunity in the birds (Zaheer et al., 2022).

The use of recombinant DNA vaccine (EtMIC2) has also a significant effect on the boosting of immune response against the coccidiosis in the gastrointestinal tract of the poultry birds (Huang et al., 2020). Similarly, Yuan et al. (2022) found that the *in-ovo* use of recombinant protein based vaccines is highly effective immunity booster. The feed ionophores combination during inoculation in commercial poultry improve the bird’s performance (Hamid et al., 2018). The vaccines can be offered topically, directly, or in the hatchery (Blake et al., 2021). The EU initiated vaccination programs for laying pullets, commercial broilers, and replacement breeders in 1992 and 2000 (Abebe and Gugsa, 2018). Common vaccination forms include attenuated, non-attenuated, and recombinant (Arczewska-Włosek et al., 2022).

Natural Alternatives

Several alternative coccidiosis control techniques are accessible that capitalize on less veterinary drugs in the feed. Natural remedies such as prebiotics and probiotics, plant and fungal extracts and essential oils are examples of alternative pharmaceutical methodologies. Normally, natural compounds modify GIT flora and the immune system instead of tackling parasites (Abd El-Hack et al., 2022).

Garlic (*Allium sativum*), a medicinal herb, contains allicin, a significant organosulfur component, which contributes over 70% of all thiosulphates and gives it its scent (Kovarovič et al., 2019). It also contains diallyl sulfide and diallyl trisulphide, which offer garlic anti-inflammatory and antioxidant properties. Garlic's anticoccidial property is linked to its immune-suppressive activity (Kim et al., 2013). Aqueous garlic extract contains phenols, flavonoids, and other sulfur compounds, which alter the cytoplasmic membrane's permeability, affecting molecular physiological activities, reducing membrane potential, cellular loss, and cellular death (Bhavaniramya et al., 2019; Jang et al., 2018; Christaki, et al., 2004).

The anti-inflammatory, antiviral, immunomodulatory and antioxidant are the medicinal properties possess by the garlic powder and its different extracts including flavonoids, phenols, diallyl disulfhide, and essential oils (Ali et al., 2019; Alnassan et al., 2015).

The herbal and medicinal plant *Artemisia annua* belongs to the family *Asteracae* and is a perineal plant that has antimalarial and anticoccidial properties (Coroian et al., 2022; Hong 2014). On contrary to Artemisinin the plant ingredient combination does not reduce malaria (Li et al., 2018; Cai et al., 2017).

The supplementation of the *A. annua* improves the feed conversion ratio in the layer by reducing the body weight compared to the control group (Lang et al., 2019).

Another member of the family *Asteracae* is *Biden Pilosa* (BP) is a medicinal plant used for more than 41 types of infectious diseases including coccidiosis and it also promotes the gut microflora and inhibit the growth of pathogenic microbes in the GI tract of the poultry (Mtenga and Ripanda, 2022; Khater et al., 2020; Uysal et al., 2018).

The use of BP at dose rate of 0.025% significantly improves the growth performance of the birds by inhibiting the colonization of the *Emeria* and shedding of oocysts in the faces. The BP in combination with probiotics in the poultry feed significantly inhibit the colonization of the *Emeria* infection and thus function as potent coccidiostat (Memon et al., 2021).

Bioactive Compound

Prebiotics

The commonly used prebiotics like fructo-oligosaccharides, oxylo oligosaccharides, inulines and mannan oligosaccharides in the poultry is to control the coccidiosis, these prebiotics help promotes the multiplication and activation of probiotics bacteria which inhibit the growth of the *Emeria* infection. The actual mechanism by which these prebiotics are working is that they stimulate the gut associated inflammatory response and activation of tissue macrophages and thus limiting the infectivity and virulency of the *Emeria* in the intestine and help in the control of the coccidiosis in the poultry birds (Santos et al., 2022; Adhikari et al., 2020; Gadde et al., 2017; Assis et al., 2010).

Probiotics

The probiotics include beneficial bacteria, fungi and yeast have a significant effect on the *Emeria* species which are responsible for coccidiosis in the poultry. These beneficial microbes promote the growth of gut microflora, stimulate immunity, and enhance the bird's performance by reducing the feed conversion ratio of the flock (Ahmad et al., 2022). The report of the Yin et al. (2014) indicated that probiotics like *Pediococcus* showed significant protection against *E. tenella* in challenge study in birds. Similarly, if the probiotics are used in a combined form significantly modulate the immune system and protect the birds from the Emeria infection (Wang et al., 2019).

The unique mode of action of probiotics in gastrointestinal tract is competition with other pathogens by covering the specific receptors for their attachment in the intestinal epithelium that help eliminate the other pathogens to enter the epithelium and damage the gut microflora by bacterial belligerence or competitive exclusion. Interestingly, this mode of action mostly possesses all the probiotics, prebiotics and symbiotics (Abd El-hack et al., 2020).

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