

Chapter 13

Gut Health in Avian Coccidiosis and its Prevention using Probiotics

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ABSTRACT

The poultry industry as a key player in food industry saw tremendous growth since its establishment. However, this growth was not free from various types of type's challenges including diseases and management of birds. The challenge of controlling and eradicating diseases mainly focused on bacterial and viral diseases for most of the time. Later on, several other types of ailments were also observed among poultry birds. The most prominent out these was the problem of coccidiosis among birds. Coccidiosis is a disease marked by bloody diarrhea, loose droppings and is caused by protozoan species of *Eimeria*. Coccidiosis markedly affected the production of birds led to severe economic losses as it directly affected the GIT tract. Various types of drugs were introduced for treating coccidiosis. At later stages these drugs became ineffective as resistance against them developed in the pathogens. This trend soon led rise of consideration among researchers to find medicinal alternatives against coccidiosis beyond traditional drugs.

KEYWORDS

Eimeria, Coccidiosis, Poultry industry, Pathogens, Protozoan, Economics losses

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INTRODUCTION

One of the key protozoan ailments in poultry is coccidiosis. Coccidiosis is reported to occur due to the infection of the *Eimeria* genus including a number of notable species ranging up to seven (Blake and Tomley, 2014; Abbas et al., 2019; Khater et al., 2020). In terms of pathology the infection severity depends on the site of infection in the alimentary tract and the impact of infection on the efficiency of the host's immune response. The effect of infection is predominantly seen locally on the immune response state of the intestine (Alnassan et al., 2014; Ali et al., 2015). Parasitic infestation can be seen in the lumen of the intestine of the host. Their presence in the intestine leads to sloughing of intestinal epithelial cells. Sloughing of epithelial cells in turn results in impairment of nutrient absorption from the intestinal lumen. Lack of nutrients reaching body cells can consequently induce diarrhea, weight loss and weakness (Bozkurt et al., 2013; Bachaya et al., 2015; Abbas et al., 2017a; Abdel-Saeed and Salem, 2019). Studies conducted by some researchers in the past estimated (Peek and Landman, 2011; Seddiek, 2015), that USD 3 billion were lost due to coccidial infections in the poultry industry all across the globe. The utilization of drugs used against coccidiosis as feed additives or feed supplements in drinking water became a regular habit for the farmers to treat and save their birds from avian coccidiosis (Lillehoj et al., 2008; Arczewska-Włosek and Świątkiewicz, 2013). This strategy that was useful for some time turned out to be even more damaging than the disease itself as the frequent use of coccidiostats lead to the rise of resistant strains against anticoccidial drugs among *Eimeria* species. This problem was global as these drugs were available all over the world and were being commonly used by farmers (Abbas et al., 2019; Zhang et al., 2020). A few steps were taken to replace the commonly used anticoccidial drugs, most effective of them being use of vaccines (Khater et al., 2020), utilizing extracts drive from plants and essential oils (Idris et al., 2017; Abbas et al., 2017b), antioxidant species (Markowiak and Śliżewska, 2017), probiotic chemicals (Ritzi et al., 2014) and prebiotic compounds (Hutsko et al., 2016). Vaccination takes the central stage in terms of controlling a

disease like coccidiosis effectively controlled (Dalloul et al., 2005). Vaccines also enhance the health status of birds by improving their overall immunity strength against parasites like the *Eimeria*. Although, there is also a chance that if a flock is poorly managed the administration of live vaccines may lead to severe reactions that can ultimately lead to coccidiosis becoming an outbreak (Chapman, 2000). On the other hand, the high production costs may make the attenuated vaccines seem like a less attractive alternative but they also have lower chances of starting a reaction outbreak among birds (Sharman et al., 2010). Essential oils are another useful alternative that can have a serious impact on the viability of coccidiosis in poultry flocks, hence effectively controlling the disease (Christaki et al., 2012; Idris et al., 2017). The catch with use of essential oils is that they may induce cytotoxic effects of the cells leading to destruction of cell membrane of the birds (Christaki et al., 2004). Another approach considered best for control of enteric problems is the use of probiotics that can help in treating various maladies including coccidial infections (Christaki et al., 2004; Eckert et al., 2010; Ritzi et al., 2014). Probiotics contain live microorganisms, that are useful for gut health and help in maintaining the populations of intestinal microbes that are essential for proper functioning of intestines (Ohimain and Ofongo, 2012; Abdou et al., 2019; Mousa and Marwan, 2019; Sarwar et al., 2019). Probiotics can be utilized effectively in various ways against coccidiosis infection among poultry birds. Some of the effect aspects for use of probiotics include immunomodulation (Ritzi, 2015), antioxidant effect (Wang et al., 2017), reduced shedding of oocyst, lowered number of lesion (Ritzi et al., 2014) and enhanced intestinal health (Sen et al., 2012).

Probiotics

The term prebiotic were first used by two scientists named Gibson and Roberfroid in year 1995 (Kechagia et al., 2013). For the production of prebiotic, several species of bacteria are used, for example *Lactobacillus* (Fioramonti et al., 2003; Markowiak and Ślizewska, 2017). The mechanism of action of prebiotic has not been explained completely, how they work as immunity stimulating agents and how they help to enhance the phagocytic activity (McNaught and MacFie, 2001; Guarner and Malagelada, 2003). The mode of action of probiotics has been divided into three classes:

1. Stimulating the immune response of the host hence enabling the skill of survival against diseases.
2. Actively in reducing the infection level through creation of competition against the pathogenic agents in epithelium cells of the intestine while also participating in the activities that help in restoring balance of beneficial microbes in intestinal tract.
3. Detoxification of the toxic substances residing in the GIT lumen, improving the overall metabolism in body metabolism through microbial action (Oelschlaeger, 2010).

There are several possibilities through which probiotics can approach and act against pathogenic agents whose infection produces disease. The mode of actions for resisting against pathogens include:

1. Activating biological molecule production through probiotics like bacteriocins, oxygen peroxide, antibiotics, free fatty acids having antibacterial properties,
2. Regulation of the environment in intestine (nutrients, pH, enhancing state of beneficial intestinal microbiota, simulating immunity, reducing inflammation activity, increased presence of epithelial cell receptors,
3. Regulating the immune system by maturation of dendritic cells to Th1 and Th2 or Tregs (Regulatory T cells) lymphocytes, consequently cytokines induction and activation of immune response of humoral nature via production of IgA, IgG and IgM,
4. Working as antioxidation agent by reducing the number of reactive oxygen species produced by enzymes, chelating metal ions, stimulation of production of antioxidases. These include catalase and superoxide dismutase, improving formation of antioxidation metabolic agent like folate and GSH (glutathione), increasing productive capacity for other probiotics while also having a positive impact on the physicochemical environment of the host's intestine. A key role can be played by probiotic substances for the regulation of cell signaling pathways such as Protein Kinase C, which consequently lead to the significant role of probiotics as antioxidant agents (Wang et al., 2017; Azad et al., 2018).

Therapeutic Effect

Probiotics containing live microbes help in maintaining the number and performance of the intestinal microflora. The use of antibacterial drugs comes with various adverse effects such as diarrhea is usually cause when antibacterial drugs are used against pathogenic bacteria. The probiotics have very excellent effects when used against diarrhea which usually caused by pathogenic agents like bacteria as these probiotics know to exhibit therapeutic effects and produced bacteriocins to fight against bacteria (Moslehi-Jenabian et al., 2011; Carter et al., 2016). Scientists have been working to find the true nature of probiotics and they revealed that probiotics have curative and therapeutic characteristics to treat coccidiosis in poultry. The probiotics give better results as an alternative of synthetic drugs used to treat coccidial infections. Probiotics containing multiple bacterial species for example PoultryStar® have been used by (Ritzi et al., 2014) in chickens feed at a dose rate of (1 g/kg) and obtain best results. The best outcomes of PoultryStar® includes decrease in number of oocysts and less lesions in birds having mixed *Eimeria* species infections. Another probiotic supplementation containing multiple bacterial species named ProLive® has been used against *E. tenella* in an experimental study. In this study, water infected with 1.1×10^{11} (CFU) live microbes was administered to the chickens. The impact of probiotics was checked in terms of feed conversion ratio and the health of the gut. The result of the study reveals that probiotics have beneficial effects on the FCR and health of the gut as compared to the synthetic antibacterial drugs such as salinomycin (ERDOĞMUŞ et al., 2019). Another evaluation study has been done to find out the therapeutic effects of Primalac®

(probiotic) and Fermacto® (prebiotic) at dose rate (1g/kg) against coccidial infections in broiler chickens. The evaluation was based on lesion score and number of oocysts in the fecal samples. The results show that the birds treated with probiotics has less lesion score and oocysts count in comparison with salinomycin. So it is concluded that the probiotic supplementation improves the performance of the bird against mixed infection of *Eimeria* in poultry birds (Behnamifar et al., 2019). The characteristic immune-regulatory and therapeutic effects of *Lactobacillus* and *Saccharomyces* based probiotics were used experimentally against *Eimeria* species. These probiotics were used for their actions in enhancing immunity responses by increasing antibody titers and proliferation of lymphocytes to enhance their responses. These probiotics done many other functions including lowering the lesion score, decreasing the fatality rate and increased number of oocysts in fecal samples in the chickens infected with *Eimeria* especially in broiler chickens (Awais et al., 2019). Another probiotics supplementation named Mitomax® has been used in poultry birds experimentally against infections of *Eimeria* which results in reduction of oocysts number and increased antibody count (Lee et al., 2007a). Another probiotic product called as MitoGrow® also gives similar results of increased antibody production level against *Eimeria* infections in broiler chickens (Lee et al., 2007b). The continuous used of PoultryStar® probiotic and vaccine (Immucox) against coccidiosis in poultry birds help in improving the health and performance of the bird also protect the birds from leading infections of different *Eimeria* species (Ritzi et al., 2016). In a recent research study, a probiotic containing four different strains of lactic acid bacteria were used in broiler chickens which helps in decreasing intestinal ulcers caused by *E. tenella* (Chen et al., 2016).

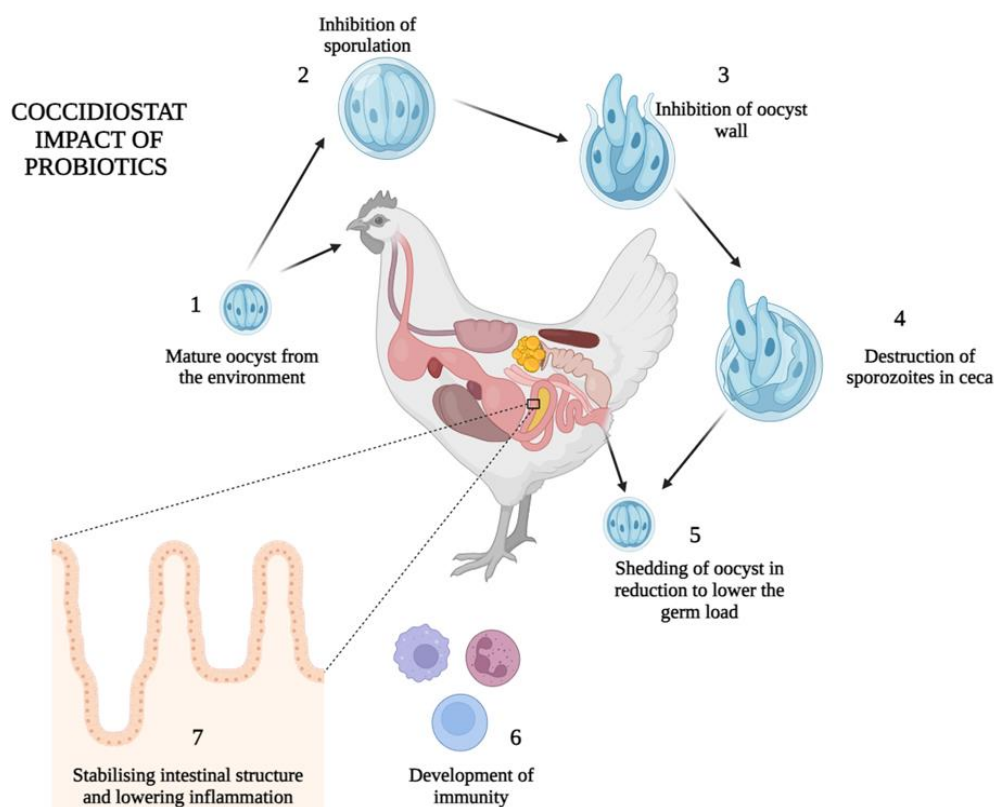


Fig. 1: Coccidiostatic impact of probiotics.

Antioxidant Effect

In the mechanism of poultry coccidiosis, free radical formation results in the necrosis of the enteric tissue. In the chicken infected with the coccidiosis, the oxygen species of reactive nature (ROS) causes cytotoxicity and alterations in the enteric route (Georgieva et al., 2011). The unregulated production of oxygen as a result of oxidative stress causes serious damage to the de-oxy ribonucleic acids, fat and amino acid products. A number of different ROS production for example radical of hydroxyl, hydrogen peroxide and superoxide anion radicals damage the host body at the level going deepest to the individual cells (Abbas et al., 2013). ROS are of two types, exogenous and endogenous. Exogenous ROS are produced due to some external factors for example ultraviolet light, ionizing radiation, cytokines and pathogens but endogenous ROS are produced inside the body of organisms including Cytochrome p450 and NADPH (Wang et al., 2017). Probiotics play a major role in treating poultry coccidiosis as they act as antioxidants and decrease the oxidative stress by triggering the antioxidant system of the host body (Wang et al., 2017). Antioxidant nature of probiotics can be observed in many ways which include formulation of various enzymes with antioxidant properties. Examples of such enzymes include antioxidant enzymes (superoxide dismutase (SOD)), and through metabolism products. The role of probiotic chemicals as antioxidants has a vital part in treating several intestinal infections such as poultry coccidiosis as probiotics also possess therapeutic action (Georgieva et al., 2011). Acting as antioxidants, probiotic compounds have a very desirable effect on the performance of the poultry birds as they help in fighting against coccidiosis and maintain the gut environment of the birds (Azad et al., 2018). By improving the antioxidants status of the host body, probiotics help in improving the healthy state of

the poultry birds. The mechanism of activity of probiotics is explained as improvement of intestinal health by enhancing the antioxidants capacity, decreasing the pH level of the gut, triggering the immune responses associated with intestinal tract and stimulation of intraepithelial lymphocytes. Many research studies proved the role of probiotics as antioxidants, inhibition of excessive production of ROS to stop destruction of cell (Wang et al., 2017).

Immunomodulator Effect

The immunity mechanism of birds is classified into two types: innate and adaptive immune systems. In the innate immunity system, the immune response happens by the action of the immune system immediately after an invading body or cell gets entry in the body of the bird, without any specific mechanism of action, immediate protection is provided to the host. The innate immune responses occurred before the adaptive immune responses and the innate immunity reaction have a crucial part in protection of chickens through different mechanics including complement component system, gastric secretions, and phagocytosis (by engulfing the foreign body of cell or bacteria). The heterophils in chickens play the same role as neutrophils in the mammalian body. The heterophils provided the first line of defense (innate immunity) through the mechanism of degranulation and oxidative burst. It has been observed that the chicken feeding with probiotics feed supplementation shows heterophilic activity for example chain of oxidation reactions or granule removal process (Stringfellow et al., 2011). During another research it has been proved that the birds supplemented with Poultrystar® (probiotics supplementation) show oxidative bursts of heterophils (Stringfellow et al., 2011). As soon as the bird gets infected with coccidia infection, it triggers the adaptive immune responses which decrease the number of parasites in the body through the production of antibodies. It has been proved that the birds with probiotics addition to feed have increased the number of antibodies produced including IgG, Ig A, IgM against several infections and health problems (Ritzi, 2015). The probiotic supplementation enhances the number of immunoglobulin against *E. acervulina* (Lee et al., 2007a; Lee et al., 2007b). The mode of action of antibodies in protecting the host against microorganisms is still not clear but humoral immune responses helps in decreasing the number of pathogens not removing from the body (Dalloul et al., 2005; Ali et al., 2015). Not only the humoral immune responses, probiotics also helps in enhancing the cellular immune responses by improving the rate of proliferation of lymphocytes at the site of infections at the end protecting the body of host from coccidiosis (Dalloul et al., 2005). Probiotics help in enhancing the number of lymphocytes at the intestinal epithelium cells and play an important role in improving cellular immune responses. Poultry birds having *E. acervulina* infections, have different levels of cytokines due to the different rates of doses of probiotics and strains utilized (Dalloul et al., 2005).

Anticoccidials Effect

The mechanism of action against poultry coccidiosis is difficult to explain as there are a number of biological actions involved. These biological actions are controlled by genes, in some cases many genes producing small effects or fewer genes exhibiting greatest (Lee et al., 2007a). To control the tissue damage and improve the health conditions of the chickens, genes and biological pathways play a significant role and also provide protection against *E. maxima* infection. Probiotics helps in enhancing the performance of antibody and act as antioxidants, which results in decreased number of oocysts in poultry droppings while the bird is infected with *E. acervulina* and *E. tenella* (Dalloul et al., 2005; Lee et al., 2007a; Lee et al., 2007b). The use of probiotics with Bacillus species helps in decreasing the rate of infection of *E. maxima* in chickens. To diagnose the degree of infection, lesion scoring is the best parameter as less number of lesions indicates the higher possibility of recovering in infected chickens (Ritzi et al., 2014). Chickens supplemented with Bacillus species containing probiotics show fewer lesion scores in case of *E. maxima* infection (Lee et al., 2007b).

Gut Health and Performance

The major symptom of *Eimeria* is stunted growth which results in less feed utilization and lowered rate in weight gain which causes major economic losses (Dalloul et al., 2005). The obvious signs of coccidial infection in poultry is decreased body weight and weight gain due to the huge damage to the intestinal epithelial which causes malabsorption of nutrients ultimately resulting in poor performance. Use of probiotics helps in improving the intestinal health by controlling the damage due to disease through the stimulation of local immune responses (Dalloul et al., 2005). Use of probiotics containing Bacillus subtilis species helps in enhancing the growth and size of intestinal villi and cells of gut in chickens (Markowiak and Ślizewska, 2017). Increased size of villi result in increased absorption of nutrients and intestinal crypts helps in generation and replacement of cells as a result of any intestinal infection (Awais et al., 2019). The consumption of *Lactobacillus*-based probiotics have been observed to enhance the number of intraepithelial lymphocytes in the intestine which helps in protecting the birds against coccidiosis. Chickens infected with *Eimeria acervulina* were fed with probiotics which afterwards observed that improve the local immune responses by the alterations of lymphocytes subpopulations which helps in reducing the number of oocysts in droppings (Dalloul et al., 2005). Many studies proved that the probiotics help in enhancing the health aspects of chickens which includes balancing the intestinal microflora, increased weight gain, carcass yield and feed conversion. There are some evidences that shows that probiotics have no significant effect on birds infected with *Eimeria* parasites (Ritzi et al., 2016). This difference may be due to different strains of bacteria present in probiotics, formulation protocols, and the dose rate of probiotics (Peek and Landman, 2011).

Conclusion

With its progress the poultry industry became exposed to various kinds of challenges. One of such problems was the spread of protozoan caused GIT ailment coccidiosis. Coccidiosis is caused by *Eimeria spp.* This disease soon became a matter of grave concern for researchers and farmers alike as it resulted in grave economic losses in the poultry industry. Soon, various drugs found their use as effective weapons against this disease. However, this victory was short lived because the *Eimeria spp.* soon started gaining resistance against these drugs. This problem was soon observed as a threat to poultry industry and was met by alternative solutions like use of essential oil, vaccines and prebiotics. The solution like prebiotics were seen as effective measures as they not only countered coccidiosis but also other problematic issues like oxidation and toxicity. However, the proper application of prebiotics still requires thorough research and comprehension.

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