Chapter 14

# The Beneficial Role of Probiotics and Prebiotics for Control of Zoonotic Parasitic Diseases

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## ABSTRACT

Zoonoses are infections that humans can contract from animals in a reversible manner. The zoonotic helminths are a significant health hazard, infecting one-third of the world's population. There is currently no reliable human vaccine available to prevent helminth infections. As a result, in the past few years, probiotics and prebiotics have gained attention due to their possible uses as a preventative or treatment strategy towards parasites. During the previous decade, probiotics have been reported to be effective in controlling parasitic infections, which were described as involving primarily gastrointestinal disorders as well as certain non-gut infections, all of which are crucial for both humans and animals. The probiotic strains have been shown to have anti parasitic effects on parasites in the gastrointestinal tract at both the egg and larval stages of development. In the majority of case studies, the animal models provided the majority of data for beneficial effects. The *Lactobacillus, Bifidobacterium* and *Enterococcus* are most frequently used microbes. Still, these beneficial microbes' effects on helminth infections are mostly understudied. There is a full discussion of the most recent research on the beneficial effects of bacteria against helminth infections, as well as the suggested mechanism of action in this chapter.

**KEYWORDS**
Parasitic zoonosis, Probiotics, Prebiotics, Immunomodulation, Control

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## INTRODUCTION

When a parasitic organism spends a particular phase of its life cycle living on or inside another host in tight biological and environmental circumstances, this is termed as parasitism. The zoonotic parasites are specific parasites to which animals are the primary hosts, although they can also invade and inflict illnesses in individuals. Globally, animal and human parasites represent a major risk to the production and health (Omeragic et al., 2022).

Nearly 60% of newly discovered infections affecting humans are considered to be zoonotic. Animals are the source of the majority of illnesses that harm people. Companion animals including sheep, goats, cattle, horses, cats and dogs are susceptible to zoonotic infections and transfer them to people. Examples of few most frequent zoonotic parasitic diseases that are present in the world are Toxocariasis, Schistosomiasis, and Trichinellosis (Rahman et al., 2020).

These zoonotic diseases can be transmitted from diseased animals to individuals through several ways such as eating of raw feed, direct contact with feces and touching of companion animals. The helminth infections caused by parasites have become major frequent zoonotic illnesses, infecting roughly one third of people internationally. The helminths often have complicated life cycles with several phases and hosts. Throughout their entire life cycle, the majority of parasitic helminth species belong to many niches in their living hosts, and the majority of them lead to persistent infections. It is acceptable to avoid the outbreaks of zoonotic parasitic diseases with routine deworming and anti-parasitic drugs as well as basic sanitation and good hygiene practice (Reda, 2018).

Still, the elimination of parasitic infestation remains an issue, requiring the development of novel potential strategies because there are no appropriate immunizations as well as anthelmintic resistance of different parasites to medications

has emerged. Hence, in the past few years, there has been a noticeable increase in the interest in using probiotics as a medicine supplement (Saracino et al., 2021).

As a matter of fact, the scientific community's keen interest in analyzing the connections between parasites like cestodes, trematodes and nematodes and the microbiota of gastrointestinal tract has increased recently, primarily due to the desire to gain more knowledge of how host malnutrition is impacted by variations in the microbial population composition brought about by parasites. Several studies have investigated the immunomodulatory characteristics of commensal bacteria and gastrointestinal parasites to better understand the function of helminth-induced variations in the gut microbiota in parasite-driven inflammation reduction (Duarte et al., 2016).

The human and animal digestive tract helminths represent some of the most common infections worldwide, contributing extensively to mortality as well as morbidity, especially in developing countries. According to data from the WHO, gastrointestinal parasitic infections, such as *Trichuris trichiura*, *Ascaris lumibricoides*, and *Necatar americanus*, ultimately affect 24% of the world's population (Rooney et al., 2023).

The probiotics have been defined in a number of ways in the scientific literature. Therefore, ten years ago, probiotics were defined as live microbes that improve the intestinal microbiota balance of the host and had a positive impact on the host's health. The probiotics that are currently most frequently utilized include *Bifidobacterium, Lactobacillus* and *Saccharomyces cerevisiae, Boulardii* (Yeast). The prebiotics, as an idea, have also changed dramatically in the recent years. A prebiotic was initially described as a non-digestible food component that improves health of the host by specifically promoting the growth or activity of one or a small number of microbes in the colon. Insulin, fructooligosaccharides, galactooligosachharides are the most commonly utilized prebiotics (Figueroa-González et al., 2011).

Still, the role of probiotics and prebiotics in avoiding the spread of zoonotic parasitic infections is neglected. In this chapter, we are going to address the most recent research on the beneficial usage of probiotics and prebiotics towards specific zoonotic parasites.

**Use of Probiotics against Zoonotic Parasites**

The zoonotic infections caused by parasites continue to be a global concern, affecting health of the public, food security, and agribusiness (Torgerson and Macpherson, 2011). The resistance frequencies to anthelmintic medications are increasing day by day, indicating the need for novel therapeutic techniques. For that reason, probiotics are becoming more prevalent as a prophylaxis and medicinal strategy for a variety of diseases. The current studies on the use of beneficial live microbes, their impact on parasites and immune response in the GI tract have produced positive findings. For further information on investigating the mechanism of action and positive effect of probiotics against parasites, it is necessary to acknowledge the current developments in helminth research.

**Role of Probiotics to Control Giardiasis**

According to WHO, giardiasis is one of the most prevalent zoonotic parasitic infection globally is caused by *Giardia doudenalis*, also referred to as *Giardia lamblia* and *Giardia intestinalis*. It affects approximately 280 million individuals annually (Ankarklev et al., 2010). This single cell aquatic parasite is capable of infecting a variety of species. Almost, ten environmentally resistant cysts must infect individuals for clinical infection to begin. During GIT transportation, cysts release trophozoites, which are both replicative and motile. The presence of trophozoites in the digestive tract can cause symptoms such as epigastric pain, discomfort, abdominal cramping, watery diarrhea, vomiting, and reduced appetite within 6-15 days of cyst intake. However, 50% of the infections may remain undiagnosed. The medications include metronidazole and nitroimidazole, but infections can frequently cure on their own (Darwesh and El Sayed, 2022).

Broadly, introducing probiotic strains like *Lactobacillus* and *Saccharomyces* proved to decrease the severity of GIT symptoms and repair the damage, particularly in people with giardiasis. The probiotics have the capacity to regulate the balance and composition of intestinal microbiota, which has a positive medical impact. Many probiotic strains have the ability to boost antioxidant levels, eliminate oxidative products, control chronic inflammation, trigger mucosal immune system responses, and shorten the duration of gastrointestinal symptoms. These actions help to prevent harm to the gut triggered by parasites. Furthermore, they may decrease the *G. duodenalis* percentage burden by directly attacking the parasite itself (Dashti and Zarebavani, 2021). The *in-vitro* and *in-vivo* efficacy of *L. acidophilus* and *L. palantrum* bacteriocin trophozites of *Giardia lamblia* has been proved (Amer et al., 2014).

**Role of Probiotics to Control Toxocariasis**

*Toxocara canis* is the common cause of toxocariasis, which is defined by the movement and infestation of parasitic larvae in men. This zoonotic parasite is prevalent in the intestine of dogs (Avila et al., 2013). The *Toxocara* species accidentally infect people when they consume infectious eggs or raw meat or viscera from hosts that are infected (Ruiz-Manzano et al., 2019). The researchers also looked into how *Lactobacillus rhamnosus* (ATCC 7469) and *Lactobacillus acidophilus* (ATCC 4356) affected the *Toxocara canis* infection in a single trial. Prior a parasitic trial using an embryonated *Toxocara canis* egg, the probiotic therapy was started. The use of these probiotics effectively decreased the overall quantity of migratory larvae seen in the hepatocytes at forty-eight hours post-infection (58% decrease for *L. acidophilus* and 52% for *L. rhamnosus* (Cadore et al., 2021; Walcher et al., 2018).

**Role of Probiotics to Control Cryptosporidiosis**

The *Cryptosporidium parvum* is a highly prevalent zoonotic parasite of veterinary and medical importance, affecting the health of both humans and animals. It is known that around 15 different types of *Cryptosporidium* species can infect humans. The transmission occurs via the oro-fecal route (Ali et al., 2024). One study investigated the treatment of *C. parvum* infection in immunosuppressed mice by administration of *E. faecalis* (CECT 7121) as an oral probiotic strain. The impact of *Cryptosporidium parvum* infection on the intestinal mucosa was evaluated at each site of the intestine. The results revealed that when both *C. parvum* and *E. faecalis* were found in the same intestinal area, they competed with each other. The effects of *Cryptosporidium parvum* infection on the intestinal mucosa were assessed in each part of the gut. The findings demonstrated that when *C. parvum* and *E. faecalis* were identified in the same intestinal location, they competed with one another. Moreover, supplementation with *E. faecalis* can reduce the negative effects of *C. parvum* infection (Del coco et al., 2016).

**Role of Probiotics to Control Scabies**

Scabies is an infection of the skin that poses a serious threat to the human health around the world. The symptoms of scabies in people are hives, vesicles, and papules. Rubbing can cause excoriation and crusting of the skin. Regularly used topical scabies lotion can cause itching and dermatitis, as well as secondary infections by bacteria *Streptococcus pyoderma*, thus an adequate plan should be developed to address this issue. The probiotics in goat milk soaps may work as an antiseptic on the surface of the skin, due to the inclusion of lactic acid bacteria, which can kill harmful microbes. The *Pediococcus pentosaceus* is a probiotic that has been known to suppress both pathogenic and spoilage microbes. It can also restrict contamination of pathogenic microbes and a toxin generator because of its capacity to make lactic acid and reduce the pH level of the substrate (Mawarti et al., 2014).

**Role of Probiotics to Control Trichinellosis**

The trichinellosis is a zoonotic illness triggered by nematodes of the genus *Trichinella,* which belong to the most common parasites class of domestic and wild omnivores. The probiotic strains may protect from zoonotic *Trichinella spiralis* infection, as part of a new treatment approach for controlling parasitic zoonoses. Eating raw meat might lead to infection of the hosts. The anthelmintics do not efficiently treat all developmental stages of human trichinellosis, only targeting adult worms. The probiotics are now being utilized in experimental models to treat parasitic infections, as the research community is still in its early stages. The probiotics impact on *Trichinella* species beyond *T. spiralis* remains unknown. The beneficial effects of probiotic bacteria decrease parasitic burden and pathogenic modifications in the experimental trichinellosis by stimulating local as well as systemic immune responses has been observed in several studies (Boros et al., 2022; Ortega-Pierres et al.,2015).

Worms mature in the intestine of pig. Then, enter the bloodstream and lymphatic system, eventually ending up in striated muscles. The larvae movement can harm host tissue and trigger inflammatory reactions, perhaps leading to mortality. Treatment with albendazole and mebendazole has varying degrees of effectiveness. The oral administration of *Lactobacillus casei* ATCC7469 to mice showed a considerable reduction in both adult worms (58% and 44%, respectively) and larvae per gram of muscle (up to70%), showing an immune response. Treatment with *Lactobacillus casei* culture supernatant had a significant impact (32% decreased adult worms), although being less effective (Travers et al., 2011).

**Role of Probiotics to Control Schistosomiasis**

Schistosomiasis is a zoonotic parasitic disease triggered by infected trematode worms of the genus *Schistosoma*, affecting 240 million individuals globally (Inobaya et al., 2014). *Schistosoma mansoni* and *Schistosoma japonicum* are the most common causes of intestinal schistosomiasis, while *Schistosoma haematobium* causes urogenital schistosomiasis. *S. mansoni* infection causes fibrosis and impaired function of gastrointestinal tract systems. The intensity of symptoms depends on the parasitic load and the response of the host's immune system (Dejon-Agobé et al., 2022). The recommended drug for treating schistosomiasis is praziquantel (da Paixão Siqueira et al., 2017).

Probiotics protect the intestinal mucosa against dysbiosis from opportunistic infections such intestinal parasites. Biovicerin®, a probiotic containing *Bacillus cereus* GM, modulates the immunological response of *S. mansoni* infected hosts. The decrease in parasite load, the quantity of eggs within the liver, and the morphology of schistosomal granuloma are indicators of infection progression. Mice administered with *Bacillus cereus* had significantly lower worms compared to the control group (Dos Santos et al., 2024).

Two *Lactobacillus* strains named as *Lactobacillus bulgaricus* DSM 20080 and *Lactobacillus acidophilus* ATCC 4356 have reduced the worms load in animals treated for a week prior to *S. mansoni* infection by 67.8% and 59.8%, respectively (El-khadragy et al., 2019). The mice treated with *Bacillus clausii* (Enterogermina®) prior *S. mansoni* infection showed a 41.4% reduction in overall worms load. Following 38 days of infection, the treated group showed a 30.1% decline, according to the same study (Cruz et al., 2022).

**Mechanism of Action of Probiotics against Parasites**

**1) Modulation of Intestinal Microbiota**

The probiotics can alter the intestinal environment by inhibiting the growth of bacteria or competing for a common biotope (Gupta and Garg, 2009). The probiotics can compete for iron, a limiting nutrient required by the majority of microbes. The *Lactobacillus* can make iron un-accessible for pathogens. The Microbes can bind ferric hydroxide on their surfaces (Elli et al., 2000).

**Table 1:** Effects of probiotics against parasites

| Parasites | Probiotic used | Studied Model | Mechanism of Action | Effects | References |
|---|---|---|---|---|---|
| *Trichinella spiralis* | *L. plantrum* | Mice | Increase serum IFN-γ | Increase larval count | (El Temsahy et al., 2015) |
| *Trichinella spiralis* | *L. casei* | Mice | Increase IgA and IgG | Increase protection | (Martínez-Gómez et al., 2011) |
| *Toxocara canis* | *S. boulardii* | Mice | increase IL12andIFN-γ | Increase protection | (de Avila et al., 2016) |
| *Schistosoma mansoni* | *L. plantrum* *L. acidophilus* *L. reuteri* | Mice | Increase IgM, Decrease AST,LDH and gGT | Decrease weight of spleen and liver Decrease parasitic complications | (Ghanem et al., 2005) |

The imbalance of the gut microbiota is a major contributor to a variety of diseases. The probiotics help human health since they are live microorganisms that have the potential to significantly control the microbial composition of the GI tract. The VSL#3, a probiotic mixture made up of eight live bacterial strains, is crucial for preventing and curing gastrointestinal disorders in humans as well as animals. It can increase tight junction protein activity, alter the makeup of microbiota in the gut as well as modulate immune-related cytokine release (Cheng et al., 2020).

**2) Production of Active Substances**

The bacteriocins, free fatty acids, antibiotics, and hydrogen peroxide ($H_2O_2$) can regulate the development and survival of bacteria. The bacteriocins are released as protein or peptide molecules that typically kill closely associated microbes by permeabilizing their cell membranes. The probiotics also produce lactic acid bacteria that lower gut pH (Wohlgemuth et al., 2010).

**3) Immune Modulating Effects Towards Helminths**

Effects on the immune response are caused by reactions among microbes and the cell receptors. The dendritic cells, which exude cytoplasmic processes into the GI tract, are located in the epithelial and immune cells and play a crucial role in regulating the effects of probiotics (Sánchez et al., 2017). The probiotics alter the gut microbiota and immune receptor targets, influencing the immune system's innate as well as adaptive responses. These modulations occur at both systemic and local levels (Sivan et al., 2015). The interleukins (IL)-4, IL-5, IL-9, IL-10, and IL-13 production are indicative of type 2 immunity response, and this is the usual immunological response to helminth infections (Allen and Maizels, 2011). The innate lymphoid cells (ILCs), innate immune cells, including mast cells, basophils, and eosinophils, and adaptive immunity cells like $CD^{4+}$ $Th^2$ cells and B-cells are both significant effector cells and providers of type 2 cytokines (Gause et al., 2020).

**Use of Prebiotics and Immunity against Helminths**

The prebiotics have a long history of safe use and have been shown to improve human health by increasing mineral bioavailability, modulating the immune system, preventing gastrointestinal infections, modifying inflammatory conditions, and regulating metabolic disorders. The prebiotic substances can influence microbial composition and activity on the luminal and mucosal surfaces, promoting positive host-microbe interactions (Roberfroid et al., 2010). Although all prebiotics are fibers, not all fibers are prebiotics. The prebiotics must have demonstrated health benefits for animals. The prebiotics for animal health and disease prevention are equally important as for people (Gibson et al., 2017).

Innovations in knowing about the prebiotic effects of dietary chemicals and GM-dependent modifications to mucosal immune system function highlight an issue regarding how prebiotic dietary components, such as dietary fiber, can influence anti-helminth immunity. The host GM undergoes significant alterations during parasitic infection; however a consistent set of taxa has yet to be identified (Walk et al., 2010). Transferring GM from helminth-infected mice to mice without germs replicated immune function, including the Treg response, indicating that helminth-induced alterations in the GM may contribute to the immune-mediated effects resulting from infection (Su et al., 2018).

Healthy mice administered inulin had an enriched gut microbiota with *Actinobacteria* and *Akkermansia muciniphila*, as well as higher short-chain fatty concentrations, indicating the beneficial effects of prebiotic carbohydrates. Regarding this, serological tests revealed that administration of insulin during *Trichuris muris* infection had significantly reduced the type-2 immune response, showing that the prebiotic fiber inhibited instead of increasing the immune response against infection. However, in one study, mice infected with the parasite *Trichinella spiralis* and fed β-glucans were observed to be protected by β-glucan-mediated proliferation of *Akkermansia muciniphila* within the GM, activating the TLR2-dependent immune response to promote worm expulsion (Jin et al., 2022).

One study found that giving malnourished mice prebiotic insulin before or during *Giardia* infection decreased the degree of severity of giardiasis, increased the mass of the body and small intestine, and raised the number of lactobacilli in the feces in comparison to mice that were not infected with *Giardia*. More precisely, compared to starved Giardia-infected mice, administration of prebiotics markedly raised anti-giardial IgA along with IgG antibodies, anti-inflammatory cytokines IL-6 and IL-10, and decreased the pro-inflammatory cytokine TNF-α in both the intestinal fluid and serum. The nitric oxide levels were also higher. This study is the sole effort to show that prebiotic therapy improves immunological function and gut morphology in malnourished Giardia-infected mice (Shukla et al., 2016).

**Future Perspectives of Probiotics and Prebiotics**

The scientific and methodological advancements offer great opportunities for the probiotic and prebiotic studies as well as applications. The real-time investigations in humans, monitoring microbes as they integrate into the microbiota, and measuring health levels will advance this field of study. Monitoring the microorganisms, how they interact with the host, and factors related to the environment (e.g., medications, nutrition) will become standard for the future physical examination. The innovative techniques for sampling will reveal how probiotics and prebiotics affect the immune system, metabolism, and the gut microbiome. As early career scientists, we aim to contribute to a society that utilizes helpful microbes to address global issues such as disease prevention and toxin removal from food and the environment. These will prove to be dynamic moments, with various job options. The probiotics and prebiotics can be used in various fields, including science (Spacova et al., 2020).

**Conclusion**

This chapter highlighted the favorable effects of probiotics and prebiotics on the immunity and digestive tract health of humans as well as animals. The probiotics are commonly utilized in human aquaculture, livestock, and poultry to improve health and prevent intestinal diseases. To address the financial impact of zoonotic helminth infections and anthelmintic treatment resistance, novel control measures, such as probiotics and prebiotics, are urgently needed. The probiotics and other treatments are crucial for reducing parasitic infections. The analysis suggests that probiotics may be a more effective therapy option for gastrointestinal parasitic infections, as current care options are inadequate. The probiotics as a therapy for helminth infections is a significant, newly investigated field. The probiotic strains from *Lactobacillus*, *Bacillus clausii*, and *Enterococcus* have been extensively studied for their effectiveness in treating giardiasis, cryptosporidiosis, schistosomiasis, trichinellosis, and toxocariasis. The probiotics can benefit hosts through several modes of action, including immunomodulation, if administered properly. To fully understand the benefits and drawbacks of probiotics, high-throughput confirmation methodologies and solid clinical, *in-vivo*, and *in-vitro* investigations are necessary.

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