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Exploring the Potential of Probiotics and Fecal Microbiota in Maintaining a Healthy Gut Microbiota

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Probiotics are live microorganisms that offer numerous health benefits, particularly in maintaining gut health and reducing the incidence of gastrointestinal diseases. They can be found in fermented dairy products, in the form of pills, capsules, powders, and sachets. This paper explores the advantages of using commercial probiotics, including alleviating gastrointestinal pain, preventing gastrointestinal disorders, and enhancing immunity. Probiotics are associated with other axis systems; including gut-skin, gut-lung, gut-heart, and gut-metabolism, further highlighting their significance. It is evident that maintaining a balanced gut microbiota is crucial for overall health and any alteration in its composition can lead to the development of local or systemic disorders. In

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addition, fecal microbiota transplant has also shown promise in treating gastrointestinal disorders in animals. Therefore, this paper emphasizes the role of probiotics and fecal microbiota transplant in preserving gut health and reducing the occurrence of gastrointestinal diseases.

Keywords: Dysbiosis; fecal microbiota transplant; gut health; gut microbiome; probiotics; health benefits.

1. INTRODUCTION

The term "microbiota" (formerly known as "microflora") refers to communities of bacteria found on mucosal surfaces, with or without microorganisms in the surrounding environment, as well as on other areas of the body like the skin. The gut microbiota, gut microbiome, or gut flora encompasses a diverse collection of microorganisms, including bacteria, archaea, fungi and viruses, residing in the digestive tracts of animals. These microorganisms inhabit the gastrointestinal system and contribute to its overall ecosystem [1]. The gut microbiota plays crucial role in preserving the well-being of the host by supporting host cell differentiation, safeguarding against pathogen colonization, and influencing the immune system [2]. Bacterial byproducts or metabolites (short-chain fatty acids (SCFAs), organic salts, amines, alkaloids) can enter the bloodstream and engage in intricate physiological and biochemical processes at various locations, such as interfering with nerve signal transmission and hormone secretion [3]. The presence and composition of gut microbiota play a crucial role in defending against harmful pathogens and facilitating various metabolic processes [4]. The composition and function of gut microbiota can be influenced and altered by factors like antibiotic usage, age, changes in diet, invasion by pathogens, pregnancy, living environment, and metabolic disorders [5,6]. When the gut microbiota is altered, it leads to the proliferation of harmful pathogens and a decrease in the diversity of beneficial bacteria, it is referred to as intestinal dysbiosis [6]. During intestinal dysbiosis, both pathogens, which are bacteria capable of harming the host through virulence factors, and pathobionts, which are normally harmless bacteria that can become detrimental under specific conditions, experience an increase in their population. This abundance of pathogens and pathobionts disrupts the host's homeostatic and metabolic processes [7]. During a state of dysbiosis, pathogenic bacteria generate inflammatory metabolites, such as proinflammatory compounds, detrimental secondary bile acids like deoxycholic and lithocholic acid, as well as hydrogen sulfide. These substances collectively contribute to the worsening of inflammatory conditions in the gut epithelium [8]. The modified gut microbiota can engage in communication and interaction with the immune system via the release of these detrimental metabolites [6]. As a result, there is an increase in the population of proinflammatory cells, cytokines, and metabolites that enter the bloodstream. These substances then reach distant organs such as the brain, lungs, heart, and skin, where they contribute to the inflammatory conditions of these organs [6]. There is now strong evidence supporting the crucial role of gut microbiota in either promoting or alleviating diseases in organs beyond the intestinal tract. The gut microbiota can serve as an alternative mechanism for exacerbating inflammation or improving symptoms in these specific organs.

2. PROBIOTICS AND GUT HEALTH

Probiotics are live microorganisms that, when administered in adequate amounts, confer a health benefit on the host [9]. Probiotic agents commonly used include organisms belonging to the *Lactobacillus* or *Bifidobacterium* genera. However, other organisms such as *Escherichia* coli, *Bacillus subtilis*, *Saccharomyces boulardii* and *Enterococcus faecium* are also utilized as probiotics, among others [10,11] (Fig. 1). They are commonly used to alter the composition of the intestinal microbiota and influence the immune response of the host. Probiotics work in different ways, such as producing substances that fight against harmful microorganisms, helping beneficial bacteria grow, competing with harmful bacteria in the gut, and influencing the immune system. Probiotics offer benefits through diverse mechanisms, such as producing antimicrobial peptides, fostering the growth of beneficial native microorganisms, competing for colonization sites on the intestinal lining, and modulating immune functions [12]. They also generate antimicrobial substances, including fatty acids, lactic acid, and acetic acid [13], and potentially enhance the production of various metabolites [14]. In simple terms, Probiotics possess the capacity to modify gut bacteria and

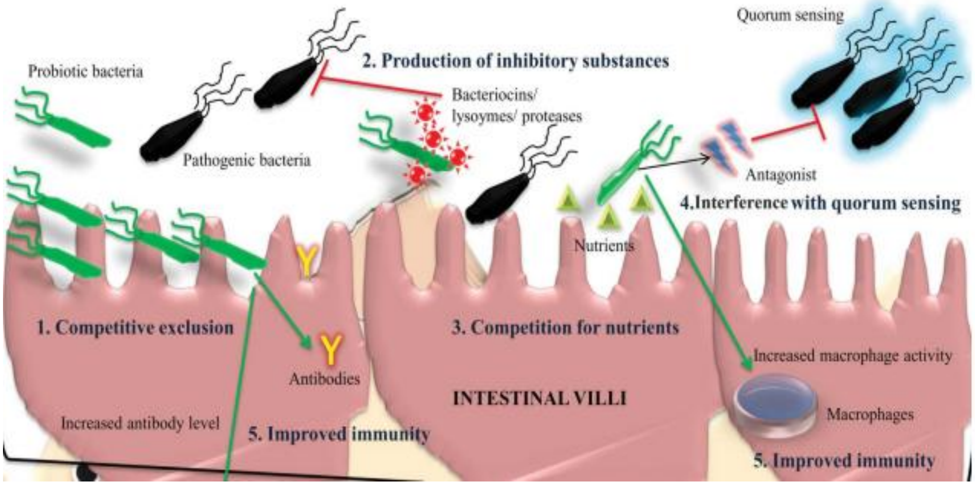

Fig. 1. Mechanism of action of probiotics; immune modulation, competition with pathogens, enhancement of barrier function, production of antimicrobial compounds and modulation of microbial composition and activity [11]

exert influence on the immune system through various mechanisms. Beneficial microflora produce antibacterial substances, stimulate specific antibody production, and contribute to the development of a protective mucus layer [15]. Probiotic microorganisms, including lactic acid bacteria (LAB) and other anaerobes, positively impact the composition of the gut microflora. They promote the production of secretory IgA, facilitate the targeted transportation of luminal antigens to Peyer's patches, and enhance the production of interferon-gamma (IFN-γ). LAB also support the activity of both non-specific and specific immune cells while maintaining intestinal wall integrity [16]. Similarly, research demonstrates that intestinal colonization of germ-free piglets with non-pathogenic *E. coli* O86 results in elevated presence of IgM, IgG, and IgA-secreting lymphocytes in the spleen, mesenteric lymph nodes, and Peyer's patches compared to germ-free piglets [17]. However, it is important to note that there is currently a lack of sufficient scientific evidence to substantiate their benefits for various conditions.

3. FECAL MICROBIOTA TRANSPLANTATION

Fecal microbiota transplant is a procedure that involves the transfer of fecal material from a healthy donor to an unhealthy recipient's gastrointestinal tract (GIT). The purpose of the transplant is to introduce a diverse and healthy community of bacteria and microorganisms into the recipient's gut, with the aim of restoring or improving the balance of their gut microbiota [18]. Fecal transplants have primarily been used to treat conditions such as *Clostridium difficile* infection, which is characterized by severe recurrent diarrhea and is often resistant to antibiotics [19]. The process typically involves a healthy donor providing a stool sample, which is then processed to isolate the fecal microbes [20]. These microbes are usually transferred to the recipient through various administration methods, including colonoscopy, enema, or oral capsules [21,22].

Fecal Microbiota Transplant (FMT) has also shown promise in treating gastrointestinal disorders in animals. Similar to humans, animals can experience imbalances in their gut microbiota, leading to conditions such as diarrhea, inflammatory bowel disease, and antibiotic-associated diarrhea [23]. The goal of FMT is to introduce a healthy and diverse community of microorganisms, restoring the balance of the recipient's gut microbiota and improving their gastrointestinal health. Studies have demonstrated the effectiveness of FMT, particularly in cases of enteropathogenic infections and antibiotic-associated diarrhea in various animal and human species [24]. The potential mechanisms of FMT include competitive niche exclusion and the production of antimicrobials [25] (Fig. 2). In competitive niche exclusion, certain strains of fecal donors may outcompete the pathogenic strains present in the recipient's intestines by successfully occupying the same niches. By doing so, the donor fecal material displaces the resident microbial communities of the recipient [26]. Another

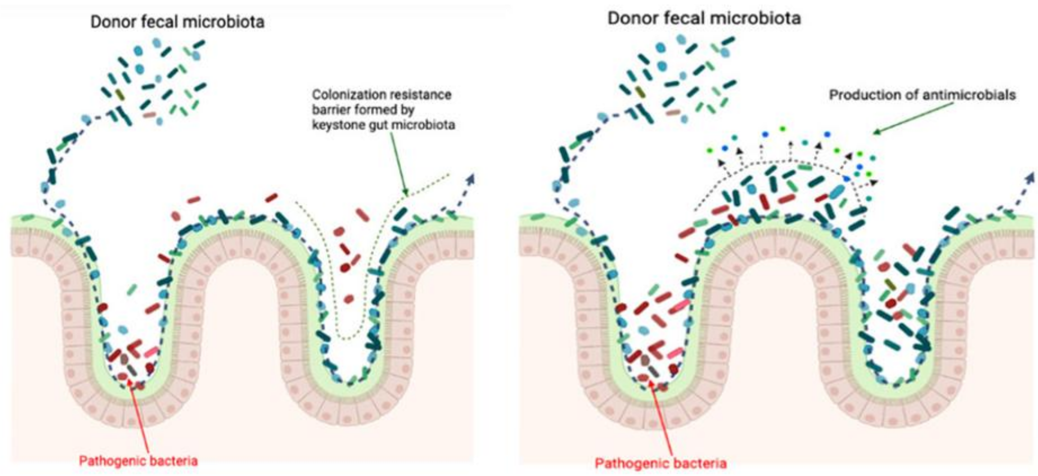

Fig. 2. Potential mechanisms of Fecal Microbiota Transplantation (FMT); Competitive Inhibition and production of Antimicrobials [25]

mechanism is the production of antimicrobials, which can be seen as a competition-based strategy as well. In this mechanism, the donor microbiota produces antimicrobial substances that inhibit the growth and survival of pathogenic microorganisms in the recipient's gut. This competition between the antimicrobial-producing donor strains and the pathogenic strains helps restore a healthier microbial balance in the recipient's gut [27]. The use of antibiotics leads to a reduction in the diversity of the gut microbiome, further disrupting its balance. This disruption creates an opportunity for pathogenic bacteria like *Clostridial difficile* to colonize the gut. Paradoxically, the treatment for *C. difficile* infection often involves the use of antibiotics like metronidazole. While these antibiotics can eliminate *Clostridial difficile*, but spores of clostridia may persist in the gut. This not only increases the risk of recurrence of infection, but also poses a threat of contamination in soil, food, and water through feces. Restoring a healthy gut microbiota can be therefore achieved by transferring fecal bacteria from a healthy donor into the gastrointestinal tract of the patient.

While FMT holds promise for treating animal gastrointestinal disorders, further research is necessary to establish standardized protocols, determine optimal donor selection, and evaluate long-term effects.

4. CONCLUSION

This paper presents a comprehensive overview of the significance of probiotics and fecal transplantation in preserving gut health. Recognizing the significance of probiotics in different axis systems and their influence on overall well-being, researchers and healthcare experts can explore their potential as therapeutic interventions for various conditions. However, additional research is required to unravel the mechanisms of action and optimize the utilization of probiotics and fecal transplants to maximize their advantages in enhancing gut health and preventing neurodegenerative disorders.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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