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The Role of Probiotics in Modulating Gastrointestinal Physiology in Laboratory Animals

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Abstract
Probiotics, which are live microorganisms as defined by Food and Agriculture Organization (FAO) and the World Health Organization (WHO) that confer a health benefit to the host organism when delivered in adequate amounts during an oral route of delivery, have attracted considerable interest for their potential role in altering gastrointestinal physiology. Probiotics have been used as experimental tools in laboratory animals to gain insights into mechanisms of gut homeostasis, immune regulation, and host–microbiota interactions. This review analyses the literature to date concerning the role of probiotic supplementation on gastrointestinal function in experimental animal models, such as rodents and other laboratory species. Major physiological effects include improvement of mode profile intestinal barrier integrity, modulation of gut motility, regulation of mucosal immunity responses, change in gut microbiota composition, and suppression of inflammatory pathways. Probiotic strains like *Lactobacillus*, *Bifidobacterium* and *Saccharomyces* species exerted strain-specific effects on epithelial tight junction expression, short-chain fatty acid production and cytokine balance. Moreover, administration of probiotics has demonstrated therapeutic significance in experimental models of inflammatory bowel disease, antibiotic-associated dysbiosis, metabolic disorders and stress-related intestinal dysfunction. While promising, heterogeneity of strain selection, dosing and experimental design underlines the need for standardized protocols and mechanistic explorations. Knowing how probiotics interact with their host in the laboratory can inform translational applications for use in veterinary and human medicine. Future studies need to elucidate the molecular pathways involved and long-term safety, as well as optimal precision probiotic strategies for gastrointestinal health.

Keywords: Probiotics, gastrointestinal physiology, gutmicrobiota, laboratory animals, immune response modulation

INTRODUCTION

Probiotic consumption is also commonly consumed via gut/microflora health [1]. Traditional laboratory animals (mice, and rats) and poultry are prototypical laboratory animals are systematically use to elucidate the physiologic exemption of probiotics and therapeutic impacts, such a model is kept edge bid environment as well as homologous genetically [2]. Hence, this review aims to depict the abnormalities of probiotics in great structural qualities incurred by probiotics within distinct experimental rats and/or lamb/poultry gastrointestinal regions, together with a special focus on the advantage for biomedical studies that could be found these particular data from rodents. In veterinary medicine, Probiotics is a new issue due to increased health-conscious and environmentally-friendly way of utilizing the pet & livestock, people now search for important information related to probiotics [3]. Probiotics are live microorganisms that improve host health when administered in sufficient amounts. For companion and food-producing animals, probiotic is very important in improvement of animal performance immunity and general care[4] [5]. The three groups of probiotic taxa *Lactobacillus*, *Bifidobacterium* and *Enterococcus* plus *Saccharomyces boulardii* yeast work together symbiotically with the GI microbiome for optimum benefit [6]. Prebiotics are preferred because they prolong promote the growth of gremial flora for instance *bifidobacterial* and will found favorable bacteria due to larger modification in health condition of gut flora compared to probiotics, that report solely transient however not permanent change [7].Probiotics applications may alter the kinetics of rumen fermentation patterns for ruminants [8].For instance, it has shown that probiotics could promote the synthesis of rumen microbes with crude protein and digestibility of rumen fibers without affecting a fermentation level and microbial viability in rumens [9].This implies that microbiome-informed probiotic strategies can be applied to customize a balance of productivity and ecological sustainability. Probiotics have multiple modes of action ranging from competitive exclusion of pathogenic bacteria, production of antimicrobials, stabilization of epithelial barriers and modulation of host immune response [10]. Probiotics are practical and economical additives/alternatives to antibiotics for growth enhancement due to their association with enhanced feed conversion ratio, reduced prevalence of gastrointestinal disease and improved animal growth rate performance at the production level [11]. New strategies in microbiome research that could be used to reduce host-microbe interactions and along with probiotics manage microbial micro-induction and metabolism, positively linked to improved resistance against the pathogens [12]. Probiotics present a solid substitute for the most problematic antibiotics that have been prohibited or restricted in many areas since they are effective bioactive formulations to boost production in poultry industry. Supplemental treatment has been shown to improve

1) nutrient metabolism,
2) decrease in pathogen populational levels
3) gut health all of which are associated with improved sustainable fills.

It is reported that the population of *Lactobacillus plantarum* and *Propionibacterium freudenreichii* in ruminant feeding has led to lower methane production during fermentation and better assimilation sharing along with the feed, which gives them a potential role in limiting ruminant farm output [15]. Probiotics usage in pigs may mitigate Mitigating post-weaning diarrhea PWD. Because of lifestyle factors, these dog disorders have made probiotics a major area of study, exploring the effect on immune system and microbiota disorders. Probiotics for treating the gastrointestinal tract of cats, and relieving diarrhea. A few recent studies have reported that similar immunomodulatory effects observed in dogs may also occur in cats[16,17,18]. Psychobiotics can confer psychological benefits, as shown also in experimental mouse models of stress. For instance, orally introduced L. plantarum D-9 suppressed depressive-like and anxiety-like behaviors via enhancement of tryptophan metabolism, hypothalamic-pituitary-adrenal axis activity and inflammation as well as gut microbiota [19] (Figure 1). Probiotics have demonstrated promise for various applications, yet barriers remain in their widespread deployment. These problems come from strain-dependent effects, non-standardized dosages and no clear understanding of how various probiotics behave in different hosts. For example, in some comparison studies on cattle, different probiotics had varying effects on rumen fermentation and production [20]. Administration of probiotics at different doses also has diverse effects on growth response and microbiota modification abilities in chicken [21]. Recent similar discrepancies have also been reported on piglets and probiotics efficacy on treating diarrhea and other clinical conditions varies among domesticated animals[13,22]. Probiotics other uses coupled with economic benefits are not to be ignored. As these products improve animal performance, probiotics can be an economical choice for pet owners and livestock farmers by reducing their expenses related to treating diseases [24]. For example, the feeding of dairy cattle resulted in increased milk production and reduced costs for veterinarians on checking bills while it has been reported that poultry improves feed conversion efficiency [25].

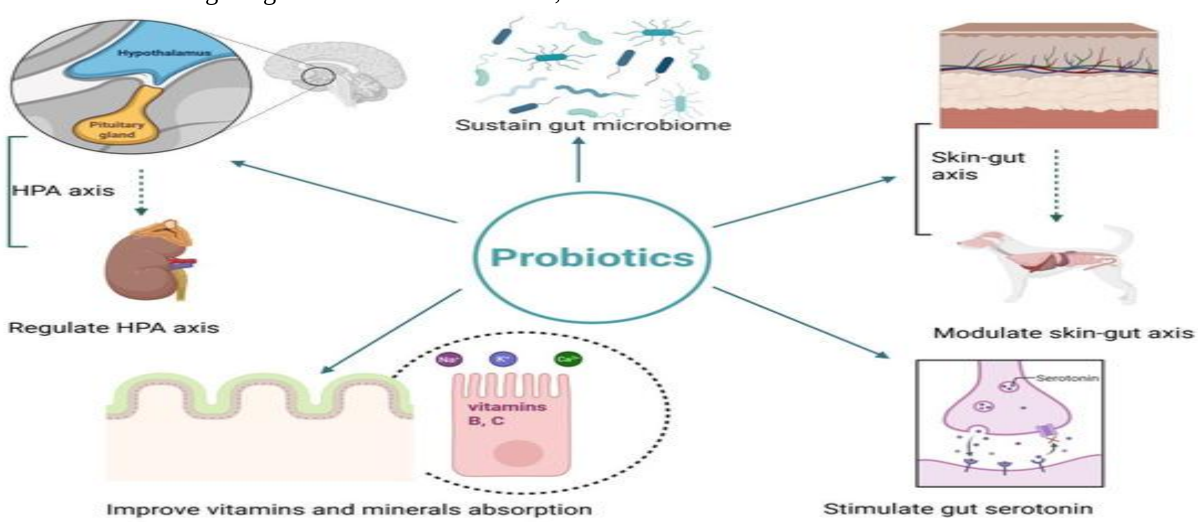

Figure 1. The roles played by probiotics in animals are specific and essential for maintaining an animal's health at all levels. Probiotics help maintain the gut flora that are necessary for a healthy internal environment. Another important stress-reducing system that probiotics help regulate is the Hypothalamic-Pituitary-Adrenal HPA axis [26].

Probiotics and inflammatory bowel disease in laboratory animal

Extensive evidence founded on animal models has shown the potential of probiotics to affect inflammatory bowel diseases (IBD) through determining mechanisms of host-microbiota interactions. The role of probiotics under certain physiological and environmental conditions, as well as the inflammatory response itself, can be quantified in an experimental environment using animal models [27]. Studies indicate that administration of probiotics to lab animals can mitigate intestinal inflammation by modulating innate and adaptive immune responses. Probiotics change the composition of gut microbiota by reducing the risk of opportunist infection and promoting growth of beneficial bacteria. Indeed, the modulation of gut microbiota balance composition in animal models with IBD have demonstrated benefits on restoring intestinal functionality and lower severity of disease. Overall, the results from animal models will of course be crucial and are expected to present further insight into translational research in GIT physiology as potential resolution of inflammatory disease of enteric organs. ScienceDirect Probiotics in IBD: Combined use of in vitro and in vivo models for selection of strains with anti-inflammatory potential and gut epithelial barrier restoring capacity.

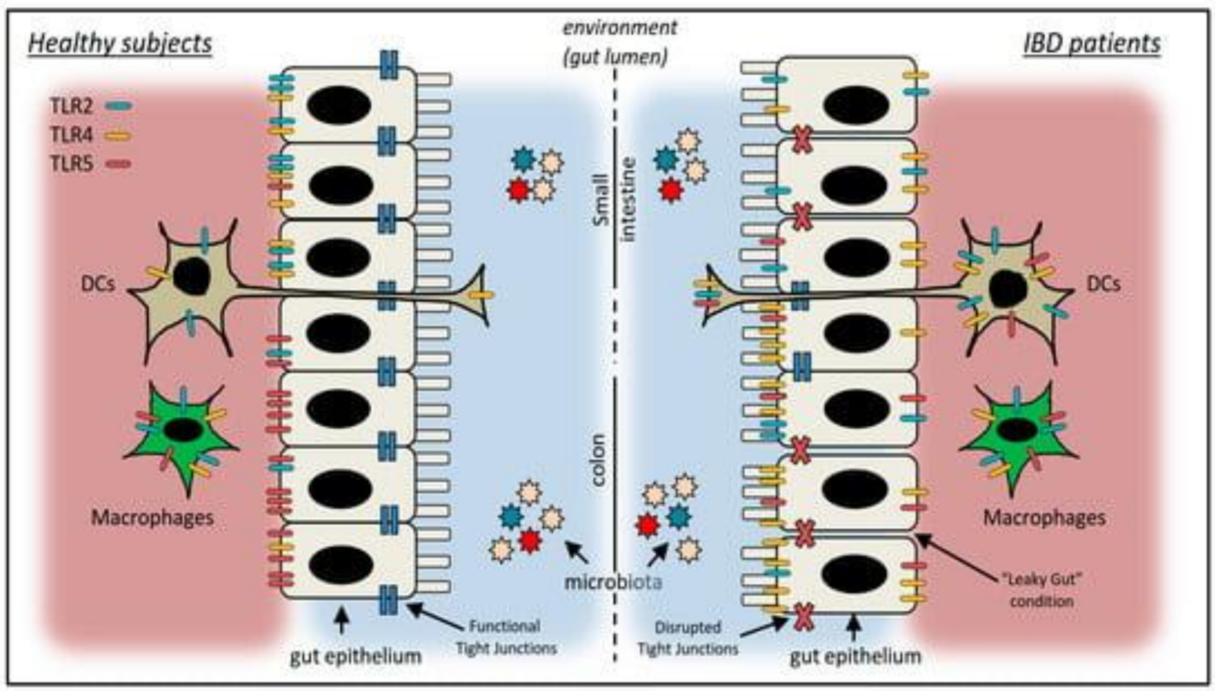

Figure 2. Toll-like receptor (TLR) communities on the human gastrointestinal tract (GIT) of normal versus inflammatory bowel disease (IBD). The Gut epithelium shows immune system and microorganisms' interaction in GIT lumen. In a healthy status, gut epithelium is established as a barrier made of tight junctions between cells [28].

Enhancement of Intestinal Barrier Function

To prevent the translocation of toxic elements and pathogenic microorganisms, intestinal barrier intact is required. Probiotics play an important role in the maintenance of the intestinal barrier through mucus production, fortification of tight junction proteins and reduction of epithelial permeability. Laboratory studies have demonstrated that these probiotics enhance the epithelial barrier by enhancing the expression of occludin and claudin tight junction proteins [17]. This defense mechanism also reduces inflammation and promotes overall intestinal health. The intestinal microbiota, which can be pro- or anti-inflammatory, is essential for maintaining the integrity and function of the intestinal barrier. Both direct and indirect mechanisms are involved in which intestinal commensal bacteria play important roles in maintaining barrier integrity and health [29]. Intestinal symbionts and probiotics affect the intestinal barrier of the host using surface molecules and metabolites[30,31]. So, Probiotics can reduce inflammation and restore the integrity of epithelial barrier.

Immunomodulatory Effects of Probiotics

The GI tract is an essential organ of the immune system and probiotic intake may modulate innate and acquired immunity. Probiotics have been shown to elevate the production of anti-inflammatory cytokines and suppress the release of pro-inflammatory mediators in vitro [18]. Probiotics have also been found to enhance the function of immune cells such as macrophages, dendritic cells and regulatory T cells [30] . This mechanism of action has shown a protective effect in preventing infections and decreasing the rates of ulcerative colitis. Various physical barriers and immune cells, along with mediators, contribute to forming an integrated immune system in all tissues, including the gut and lungs, that controls homeostasis but also manages infections [31]. Gut commensals also have significant immunobiological importance through modulation of inflammatory processes and interactions with the host.

The gut microbiome is another important immune system regulator and it has been suggested that dysbiosis (malfunction of the gut microbiota) contributes to diseases like inflammatory bowel disease (IBD) and irritable bowel syndrome (IBS) [32], as shown in Figure 3.

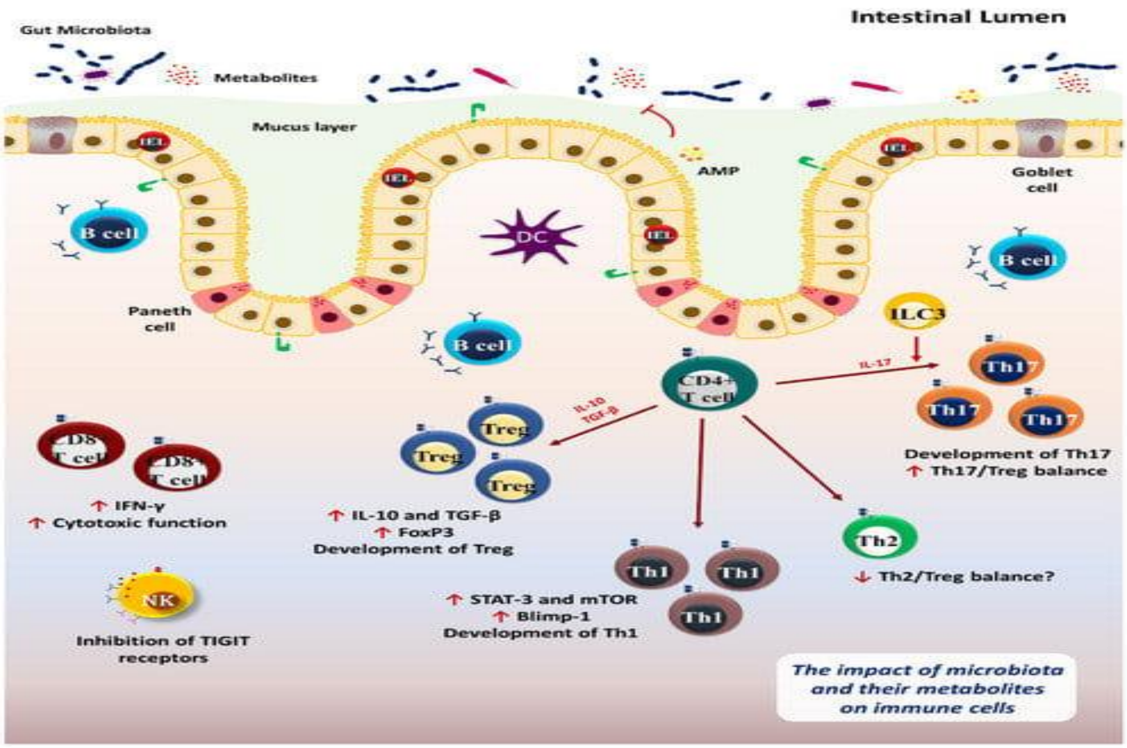

Figure 3. interactions between gut microbiota and immune system The gut microbiota and its antigentic products such as SCFAs promote the differentiation of T cell with a systemic immune response aimed at targeting the dominating Treg, Th1 and Th17 cells. Gut microbiota modulates Th1 differentiation from CD4+ T cell through cooperation of mTOR and STAT-3 pathway, in addition IL-10 and TGF-β secreted by gut microbiota effects on Treg differentiation [33].

Impact on GI metabolism and Motility

Gut microbiota and immune system interactions F1. The gut microbiota and its products, as SCFAs for the example accelerate T cell differentiation which serves a broad immunological pathway aimed against predominant Treg, Th1 and Th17 cells[35]. The mTOR and STAT-3 pathway cooperation by gut microbiota in shaping Th1 differentiation from CD4+ T cells In addition, IL-10 and TGF-β secrete the gut microbiota that induce the increase of Treg differentiation [34].

How Probiotics Work in the Gut

Nevertheless, the positive impacts of probiotics exert through different but linked modes including microbial metabolic processes, host–microbe interaction and gut cell regulation activation [35]. One of the main mechanisms is the fermentation of non-digestible carbohydrates, leading to production of microbial metabolites, especially short-chain fatty acids (SCFAs), including acetate, propionate and butyrate. These metabolites provide energy to colonocytes and maintain the integrity of intestinal epithelium. Butyrate can inhibit HDAC activity to further regulate gene expression involved in inflammation suppression and mucosal healing. SCFAs also function as agonists of G-protein-coupled receptors, including GPR41 and GPR43, which are critical for immune and metabolic regulation. [36].

The second mechanism is the production of antimicrobial compounds by probiotic bacteria, such as bacteriocins, organic acids and hydrogen peroxide. These substances restrict the development of pathologically active microorganisms by decreasing luminal acidity and preventing the adhesion and colonization of bacteria. Probiotics employ competitive exclusion to colonize niches in the gut environment and prevent pathogenic overgrowth, restoring the microbial community to homeostasis [37]. Impeding quorum sensing mechanisms by probiotics for microbial communication networks regulation. Probiotics can prevent virulence factors produced by pathogenic microorganisms from regulation by binding to their bacterial signal molecules.

Gut-Brain Axis and Psychobiotic Actions

Recent studies have shown that probiotics can influence the gut-brain axis, the system by which our intestines and central nervous systems communicate with each other (in both directions). Probiotic microbes have also action on neurochemical mechanisms via modulation of the tryptophan metabolism pathway which is pre-cursor for serotonin synthesis. Serotonin plays an important role in the gut's clearance and mental-behavioral modalities control according to its higher levels [38].

The hypothalamic-pituitary-adrenal (HPA) axis has been modulated by probiotic therapy, thereby decreasing stress responses of laboratory animal models. For example, probiotics have reduced blood corticosterone release and intestinal barrier dysfunction induced by stress. Microbial metabolites and inflammatory mediators induced by probiotics can also influence vagus nerve signaling to various brain areas.which are capable of modulating behavioral changes of modeled experimental animals

Sensitive Responders to Probiotic Supplementation in Laboratory Animals

The physiological impact of probiotics is not the same because gastrointestinal structures, microbiota and dietary patterns of experimental animal species are diverse. In IBD pathogenesis, the immunomodulatory properties of probiotics have been demonstrated in common mouse models by dampening inflammatory mediators and promoting epithelial barrier integrity. Since we developed the rat model in an experimental setting where conditions are better controlled than they would be in a natural host, it provided us an opportunity to characterize host-microbe interactions on a global level[39]

Translational Relevance of the Experimental Data to Human and Veterinary Medicine

Our better understanding of the promise of probiotics has been based on laboratory animal research. Such experimental models have paved the way for insights into the probiotic treatment for inflammatory bowel diseases and metabolic disorders, and potential therapeutic effects in antibiotic-induced dysbiosis. Lab research is inherently governed, which allows you to identify individual pathways that could then be followed as medicinal drugs.

That also contributed to the comparative research of microbiome-assisted therapies for curing human diseases, which are aimed at correcting gut homeostasis and minimizing antibiotic use. Given the rapid advancement of both precision medicine and personalized nutrition, it is likely that probiotics will become key components in the design of tailored treatments based on each individual's microbiota.

Experimental and Biomedical Significance

The use of probiotics in lab animals also has important ramifications for experimental research. Probiotics supplementation enhances animal welfare, reduces experimental variability, and improves replicability in scientific studies. Moreover, these models provide important information that will aid in the future therapeutic use of probiotics against gastrointestinal diseases in humans.

Conclusion

There are significant implications for experimental work where probiotics are administered to laboratory animals. Supplementation of probiotics can have beneficial effects on animal health and they can reduce variation and improve the reproducibility in experimental studies relating to this topic. These models influence the therapeutic application of probiotics for gastrointestinal diseases in human patients.

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