Probiotics: Definition, Mechanisms of Action and Key Species

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Abstract

In this chapter, probiotics, their species and mechanism of action are discussed. Probiotics are beneficial living microorganism, that when administrated in right amount provide positive health benefits to the host. These characteristics enable them to survive in the gastrointestinal tract, so promoting a balanced and healthy intestinal environment. The most prevalent probiotic microorganisms are from genera *Lactobacillus*, and *Bifidobacterium*. Other genera that include probiotic bacteria are *Bacillus, Propionibacterium, Streptococcus*, and *Escherichia*. Probiotics, naturally part of the gut microbiome and are available as foods, supplements, and medications approved by the FDA. Probiotics are commonly found in milk-based products, fermented foods, and other sources include juices and plant-based drinks. Probiotics include wide range of microbes varying from bacteria to yeast/fungi. Probiotics have following health benefits: improved gut health, lower serum cholesterol, neuroprotective, antioxidant, antidiabetic, and anti-carcinogenic. Several methods have been proposed to explain how probiotics work against diseases. These mechanisms of action include improving intestinal barrier function, enhancing adhesion to the intestinal mucosa, competitively excluding pathogens, modulating the immune system, and synthesizing neurotransmitters. The aim of this review is to discuss the major probiotic strains and various mechanisms of actions focusing on how gut microbes influence the host.

Keywords: Probiotics, *Lactobacillus, Bifidobacterium,* Gut microbiome, Mechanism, Health benefits, Fermented products

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Introduction

Probiotics have gained an immense importance in recent decades for their health benefits especially due to the therapeutic potential. The word probiotic derived from the Greek word pro meaning “for” and biotic meaning “life” (El-Sayed, 2020). Food and Agriculture Organization of United Nation (FAO) and World Health Organization (WHO) defined probiotics as “the beneficial living microorganism, that when administrated in right amount provide good health effects for the host” (Sanders et al., 2018).

The human body is populated by trillions of dynamic and distinctive microbial communities that influence the host's physiology, generally known as the "Microbiome" (Malard et al., 2020). These host friendly microbes support digestive system by strengthening the gut microbiota. Probiotics have unique properties that increase their efficiency, such as resilience to acidic pH, tolerance to bile and pancreatic enzymes, and the capacity to stick to and interact with intestinal epithelial cells. These characteristics enable them to survive in the gastrointestinal tract, so promoting a balanced and healthy intestinal environment. The most prevalent probiotic microorganisms are from genera *Lactobacillus*, and *Bifidobacterium* (Stavropoulou & Bezirtzoglou, 2020; Shafique et al., 2023).

Other genera that include probiotic bacteria are *Bacillus, Propionibacterium, Streptococcus*, and *Escherichia*. These probiotic microbes are named according to their genus, specie and strain designation. Like *Bifidobacterium longum GH8 Bifidobacterium* is the genus, *longum* is the species and *GH8* is the strain designation (Sanders et al., 2018).

Probiotics are naturally the part of gut microbiome, but can be supplemented through extra source. Probiotics are mostly found in three major categories recognized by FDA in the global market: foods, dietary supplements, and medications (Plaza-Diaz et al., 2019). For the product to be licensed as a probiotic it should contain significant number of bacteria. Uncertainty surrounds the regulatory classification of several more recent probiotic-containing products. Probiotic cosmetics, for instance, are now available. Chewing gums, throat sprays, and probiotic lozenges are examples of products that don't clearly fall under the food or supplement category (Sanders et al., 2018; Shafique et al., 2022).

Evolution of term Probiotics

In 1907, Metchnikoff observed improved health and increased longevity among Bulgarian citizens, which he ascribed to their habitual intake of yogurt rich in live lactic acid bacteria (LAB). It was the first scientific idea that claimed that bacteria possess health benefits. This discovery highlighted the potential health benefits of probiotic-rich foods and sparked further research into probiotics and their function in human health. Metchnikoff further claimed that LAB in yogurt contributes to the host heath by suppressing the activity of toxin producing bacteria in intestine and encouraging the growth of gut friendly microbiota (Ma, 2018).

Over time, studies have produced scientific proof to back up Metchnikoff's assertions regarding the health advantages of probiotics, especially lactic acid bacteria (LAB) in yogurt. Metchnikoff's for his work in probiotic is awarded noble prize and regarded as a "grandfather of modern probiotic".

By 1950, researchers found the bifidobacteria promoting factors in breast milk. Breastfeeding has been linked to bifidobacteria dominance in the gut microbiota of infants, indicating that milk components are a selective colonization factor (Wong & Xiao, 2018).

In 1953, German physicist Werner Kollath coined the word "probiotic." He described probiotics as a substance made by one microbe that promote the growth of another (Rajiv Gandhi et al., 2019). The concept changed over time to emphasize live microorganisms that are beneficial to the host's health. The FAO/WHO defines probiotics in 2001 as "live microorganism, that when taken in right amount provide positive health benefits to the host". This established the term's and set the basis for modern probiotic research (Fig. 1).

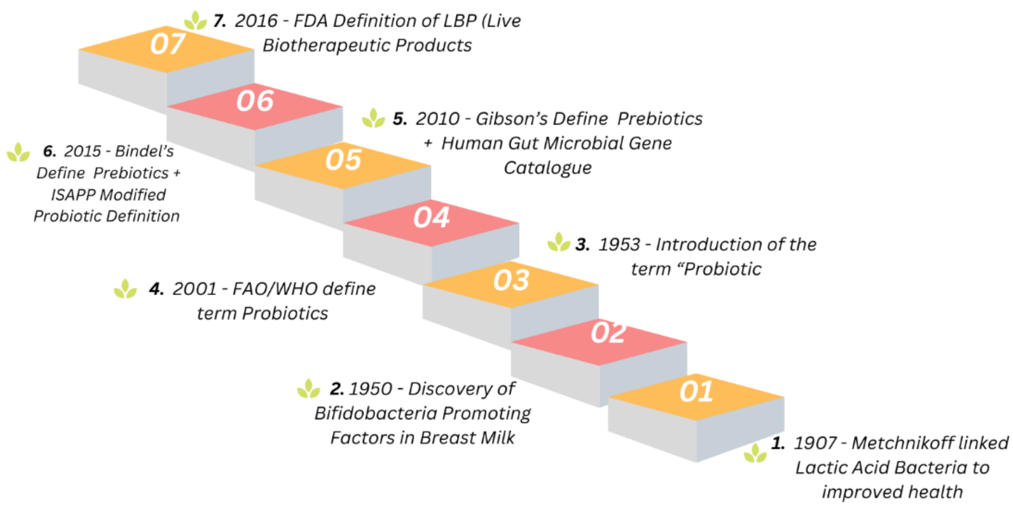

Fig. 1: Timeline of Key Milestones in Probiotic and Prebiotic Research.

Probiotic Selection Criteria

Probiotics include wide range of microbes varying from bacteria to yeast/fungi. For food application, the ideal probiotic strain should therefore be of human origin, acid resistant and bile resistant, and most importantly safe for human consumption (Tegegne & Kebede, 2022). Microorganism should possess following characteristics to meet selection criteria as a probiotic: (Venkatesh et al., 2024).

i. Offers health benefit to host
ii. Survive the transit through intestinal tract
iii. Possess good adherent power for intestinal epithelial cells.
iv. Encourage the growth stable intestinal microflora.
v. Inhibit infection by production of antimicrobial compound.
vi. A good competitor to pathogenic bacteria
vii. No transfer of antibiotic resistance gene

Types of Probiotics

At present probiotics have been broadly classified in to three major groups: *Lactobacilli, Bifidobacteria,* and others.

Lactobacillus

Lactobacillus spp. is the rod shaped; gram-positive bacteria belong to phylum *Firmicutes* (Rastogi, & Singh, 2022). The genus *Lactobacillus* has earned its name due to its ability to ferment glucose to lactic acid. Based on this, property *Lactobacillus* species are predominantly used in production of fermented dairy products such as cheese, yoghurt (Widyastuti et al., 2021). They are the inhabitant of colon, gut and vagina. *Lactobacilli* have been approved as safe for food purposes and have been classified under "Generally Recognized as Safe" (GRAS) status by the U.S. FDA, and "Qualified Presumption of Safety" (QPS) status by the European Food Safety Authority (EFSA). Therefore, such economic importance has called for research, especially on their genomics and interactions with human health and disease, which makes *Lactobacilli* an ideal candidate for probiotics (Ameer et al., 2020; Dempsey & Corr, 2022). *Lactobacillus* species are appreciated for their anti-inflammatory effects, which may reduce symptoms caused by several diseases, including asthma, COPD, neuroinflammatory disorders such as multiple sclerosis, Alzheimer's disease, and Parkinson's disease; cardiovascular diseases; inflammatory bowel disease (IBD); and persistent infections (Rastogi & Singh, 2022).

Bifidobacterium

Bifidobacterium species are gram-positive, anaerobic bacteria that are frequently found in the intestines of humans and other animals. They are members of the *Actinobacteria* phylum. Found in breast milk, oral cavity, colon and vagina. *Bifidobacterium* was initially isolated by Tissier from the feces of breastfed infants in 1899. In infants 90% of intestinal microbiota is comprised of *Bifidobacteria* as compared to adult that account for 3-5% only. The breastfed infant had higher level of *Bifidobacteria* than formula fed infant, this evident difference is due to fact that breast milk contains bifidogenic factors that promote growth of *Bifidobacterium* in intestine. Particularly during the early phases of life, these bacteria are regarded as essential components of the human microbiome (Tian et al., 2022). Because of their many health advantages, they are frequently referred to as probiotics. They are essential for preserving gut health and regulating the immune system (Sadeghi et al., 2024). In a study (Liu *et al.,* 2020), stated that there are 32 known species of *Bifidobacterium*, and have nine subspecies, among these 14 have been isolated from human gut.

Bifidobacterium longum BL-10 significantly contributes to improving intestinal immunity by lessening intestinal damage brought on by lipopolysaccharides (LPS). It increases helpful immune cells like CD4+ T cells and IgA plasma cells while decreasing pro-inflammatory cytokine levels (e.g., TNF-α, IL-6) and myeloperoxidase activity. By downregulating TLR4 and NF-κB signalling, it modifies inflammatory pathways and improves the intestinal barrier by upregulating tight junction proteins (Claudin1, Occludin) (Dong et al., 2022). *Bifidobacterium* synthesize essential vitamins and amino acid in intestine and increase the calcium bioavailability, an important mineral for bone health (Theorin, 2024).

Other Bacterial Species

Besides *Lactobacillus* and *Bifidobacterium*, there are different other microbes that have probiotic properties. The genus *Saccharomyces* includes many species, but well-known being *Saccharomyces boluardaii* and *S. cerevisiae*. Probiotic yeast *S. boulardii* has demonstrated effectiveness in treating gastrointestinal disorders, particularly when administered in conjunction with antibiotic therapy. Additionally, *S. boulardii* yeast helps maintain the equilibrium of the normal microbiome and is important in regulating the secretory processes of intestinal epithelial cells, which benefits the host's nutritional needs. (Pais et al., 2020).

The probiotic strain *Saccharomyces cerevisiae* is found in various sources including tropical fruits lychee and mangosteen and in fermented products like kombucha and dairy-based beverages such as kefir (Ansari et al., 2019). Nowadays, probiotic foods are produced commercially using *Saccharomyces cerevisiae*, a well-known non-pathogenic and selective probiotic One important characteristic of *Enterococcus* strains as probiotics is their capacity to live, compete, and adhere to intestinal host cells (Malik et al., 2023; You et al., 2022).

Enterococci probiotics can be used to treat and prevent a number of illnesses in both humans and animals, including the prevention of various functional and chronic intestinal diseases and the alleviation of symptoms associated with irritable bowel syndrome and antibiotic-induced diarrhea. Numerous probiotic products contain strains like *E. faecium M74* and E. *faecium SF-68* as dietary supplements (Hanchi et al., 2018). Different genus and their probiotic strain are listed in Table 1**.**

Table 1: Microorganism commonly used as probiotics

Probiotic	*Phylum*	*Species*
Lactobacillus	Firmicutes	*Lactobacillus Acidophilus*
		Lactobacillus Rhamnosus
		Lactobacillus Bulgaricus
		Lactobacillus Reuteri
		Lactobacillus Casei
		Lactobacillus Johnsonii
		Lactobacillus Plantarum
Bifidobacterium	Actionbacteria	*Bifidobacterium Bifidum*
		Bifidobacterium Animalis
		Bifidobacterium Breve
		Bifidobacterium Infantis
		Bifidobacterium Lactis
		Bifidobacterium Longum
Streptococcus	**Firmicutes**	*Streptococcus Thermophiles*
		Streptococcus Sanguis Streptococcus Oralis
		Streptococcus Mitis
Saccharomyces	Ascomycota	*Saccharomyces boulardii*
		Saccharomyces cerevisiae
Enterococcus	**Firmicutes**	*Enterococcus faecalis,*
		Enterococcus faecium
Propionibacterium	*Actinomycetota*	*Propionibacterium jensenii*
		Propionibacterium freudenreichii
Bacteroides	Bacteroidota	*Bacteroides uniformis*

Fermented Food as Probiotic

Fermentation is the biochemical process that changes the biochemical properties of food by breaking large complex molecules in to simpler one by action of microorganism. The fermented foods can be more advantageous to consumers than basic foods. Fermented foods had more antioxidants potential, peptide synthesis, organoleptic properties, and probiotic qualities, and antibacterial action, than simple foods available commercially. Fermented food contains live bacterial or yeast culture, these microbes increase the food probiotic potential and these probiotic properties provide health benefits by boosting digestive health, and increases bioavailability of several vitamins such as B, C, and K, polyphenols and other bioactive compounds (Zohreh Abdi-Moghadam et al., 2023).

Probiotics are commonly found in milk-based products and other sources include juices and plant-based drinks. Natural sources of probiotic include:

1. Yogurt

Yogurt is an important dairy product, which is obtained by the bacterial fermentation of the milk by *L. bulgaricus and S. salivarius* sub-spices (thermophilic bacteria) (Farag et al., 2021). Health benefits of yoghurt include helps in managing gastrointestinal disorders such as treat diarrhea, constipation, ulcers irritable bowel syndrome, reduce risk of osteoporosis, improve heart health by reduction of blood pressure and lower blood cholesterol levels. Moreover, enhances immune health by modulating gut associated lymphoid tissue, reduces risk of infection and inflammation (Zohreh Abdi-Moghadam et al., 2023; Pannerchelvan et al., 2024).

2. Cheese

Cheese is an important source of probiotic. In fact, one of the best foods for calcium, which is essential for healthy bones, is cheese. It is commercially sold in market with the label on their packaging as "probiotics," "active culture," or "live culture." Live cultures of *Bifidobacterium* and *Lactobacillus acidophilus* are used to inoculate certain cheeses. Blue cheese and aged cheeses are additional cheeses that are high in bacteria (Maftei et al., 2024).

3. Buttermilk

Buttermilk is the probiotic rich fermented dairy-based beverage it contains live lactic acid bacterial culture. Lactose intolerant individual can tolerate buttermilk better than other dairy products because fermentation process significantly reduces the lactose content. Sweet or cultured and whey buttermilk are the two major types of buttermilk (Ali, 2018).

4. Kefir

Kefir is a fermented milk drink; physical appearance is much like thin yogurt. The main ingredient is kefir grains. It is produced by fermenting kefir grains with milk. Key probiotic involved in kefir fermentation are strains of lactic acid bacteria (*L. plantarum*, *L. kefiri, L. kefiranofaciens*), acetic acid bacteria (*Acetobacter lovaniensis,* and *Acetobacter orientlis*) and yeast (*Saccharomyces cerevisiae*) (Milanda et al., 2021).

5. Miso

Miso is fermented paste widely used in Japanese food and had a unique umami taste. Soybeans are fermented with salt, koji, and occasionally rice, barley, seaweed, or other ingredients to create this thick paste. Miso contains the microorganisms *Tetragenococcus halophilus* and *L. acidophilus* (Kusumoto et al*.,* 2021).

6. Soy Sauce

Soy sauce, a famous Asian condiment, is produced by fermenting soybean paste with enzymes and salt. Molds of *Aspergillus oryzae* or *Aspergillus sojae* are combined with water and salt to ferment soybeans. In addition to having several health advantages, including reducing blood cholesterol and having anti-hypertensive, anti-cardiovascular, anti-diabetic, and anti-neuro inflammatory properties, Lactic acid bacteria are also abundant in soy sauce (Jang et al*.,* 2021).

7. Kimchi

Kimchi is a traditional Korean dish. Kimchi is a fermented chines cabbage in combination with other vegetables that include onion, raddish, carrots and garlic. Probiotic microbes used in kimchi fermentation are lactic acid bacteria (LAB) genus *Lactobacillus, Leuconostoc*, and *Weisella* (Cha et al*.,* 2023).

Health Benefits of Probiotics

Probiotics have gained significant importance in the field of health and medicine. The body's resistance can be weakened by a variety of circumstances, leading to degenerative conditions, inflammatory, viral, and neoplastic disorders. Different therapies, such as immunosuppressive therapy, radiation therapy, and antibiotics, may change the stomach's normal flora composition and weaken the immune system. Administrating probiotics as powders, capsules, or beverages alleviate beneficial gut microflora, enhancing the immune function and general well-being (Tegegne & Kebede, 2022).

The health benefits are strain-specific. The following genera are significant for obtaining effective probiotic strains: *Lactobacillus, Bifidobacterium, Escherichia coli, Enterococcus, Saccharomyces, Streptococcus, Pediococcus, and Leuconostoc*.

The most frequently used probiotics are *Bifidobacteria* and Lactic acid bacteria (LAB) (Rajiv Gandhi et al., 2019). The Chinese sourdough-derived *Lactobacillus plantarum* ZJUFT17 shows great promise as a probiotic with anti-obesity properties (Liu et al*.,* 2020).

LAB-driven microbial fermentations frequently yield by-products with a variety of health-promoting impacts, including protection against pathogenic microbes, anti-allergenic effects, anti-anxiety effects, immunomodulatory properties, anti-obesity effects, anti-oxidant effects, increasing the bioavailability of vitamins/minerals, and others (Mathur et al*.,* 2020).

S. cerevisiae has traditionally been utilized as a neuroprotective, antioxidant, antidiabetic, immunological booster, and anti-inflammatory (Farid et al., 2019).

The probiotic *Escherichia coli* strain *Nissle 1917,* along with several *Lactobacilli* specie, is one of the most well-studied probiotic strains. It was observed that this strain of *E. coli* is effective against gastrointestinal and urinary infections (Schultz, 2008).

In Germany, a gram-negative strain of *E. coli* called *EcN* was effectively utilized to treat colitis and chronic constipation (Behnsen, 2013). Probiotic bacterium *Escherichia coli Nissle 1917* or *Lactobacillus GG* used to treat inflammatory bowel diseases (Stavropoulou & Bezirtzoglou, 2020). Among the various probiotic, species known today, many have demonstrated significant health benefits.

It has been claimed that *Bifidobacteria* limit intestinal colonisation by pathogenic bacteria, have anti-carcinogenic, anti-diarrheal characteristics, and can help alleviate lactose intolerance in people (Russell et al., 2011).

Table 2: Food sources, inhabitant and health benefits of some important probiotics

Genus	Inhabitant	Food Source	Health benefits
Lactobacillus	Colon, gastrointestinal tract and vagina	Yogurt cheese, kefir, Miso, kimchi buttermilk	Immunomodulatory properties, anti-obesity effects
Bifidobacterium	Breast milk, oral cavity, colon and vagina	Cheese, yogurt.	Anti-diarrheal characteristics, alleviate lactose intolerance
Saccharomyces	Tropical fruits (lychee & mangosteen) fermented products like kombucha and dairy-based beverages such as kefir, colon, and insects.	Yogurt, kefir	Antioxidant, antidiabetic
Escherichia Coli	Colon	Supplements	Treatment of IBD and chronic constipation, effective against gastrointestinal and urinary infections

Mechanism of Action of Probiotics

Studies on probiotics has made tremendous progress in selecting and investigating individual probiotic cultures and their impact on health. Probiotics have been linked to improved intestinal microbial balance, but recent research suggests they may improve immunological function (K Gogineni & Morrow, 2013).

Because the gastrointestinal mucosa is the first area of interaction with probiotics, it appears that the initial effects of probiotics are related to digestive function (Fioramonti et al., 2003). Probiotics can colonize the human gut in different ways based on the individual's microbiota, probiotic strains, and area of the GI tract. Probiotics' mode of action against infections can be explained by multiple mechanisms (Maftei *et al.,* 2024).

Whatever action a probiotic has is determined by its metabolic features, the chemicals at its surface, or the components released. Even fundamental components of the bacterial cell, such as DNA or peptidoglycan, may be important for its probiotic efficacy. The unique mix of such qualities in a probiotic strain determines its specific probiotic action and, as a result, its effectiveness in both the prevention and treatment of specific disease (Oelschlaeger, 2010).

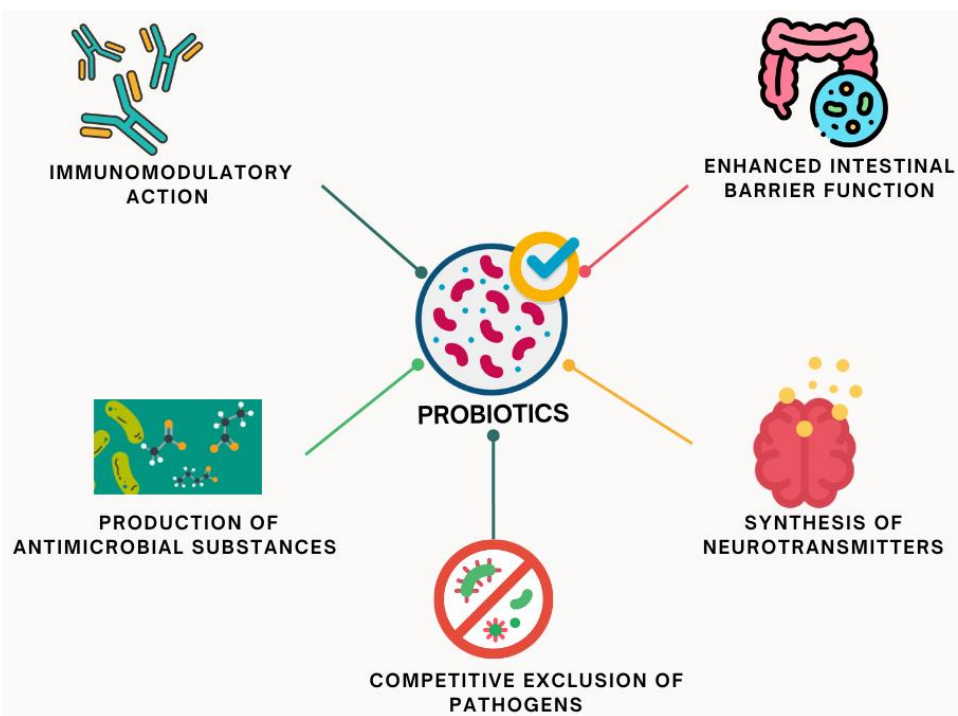

Fig. 2: Mechanism of action of probiotics

Probiotics have made significant advancements, however documenting of their mechanism of action remains a major challenge (Rajiv Gandhi *et al.,* 2019). Probiotics may not always populate the intestinal tract to achieve their intended effects. Certain probiotics, such as

Lactobacillus casei, have a temporary effect by influencing the already-present microbial flora, whereas others, such as Bifidobacterium longum, presents its action by becoming important part of human GIT microflora (Gogineni & Morrow, 2013).

Probiotics may benefit the human body by improving intestinal barrier function, improved adhesion to the intestinal mucosa, competitively excluding pathogens, immunomodulation, and neurotransmitter synthesis. These are some major mechanisms of action of probiotics (Rajiv Gandhi et al., 2019; Plaza-Diaz et al., 2019).

Some mechanisms of action of probiotics are given below and displayed in Fig. 2.

1. **Probiotics and enhanced intestinal barrier function**

Probiotics play major role in maintaining integrity of human intestinal barrier and mucosal barrier. Moreover, they improved the intestinal chemical barrier function in many ways such as, stimulating mucin proteins production and regulating intestinal pH (Chang et al., 2021). A study (Liu et al., 2023) demonstrated that *Lactobacillus plantarum* repairs the intestinal barrier in ulcerative colitis by exerting excellent preventive and therapeutic effects. It performs this activity primarily by improving gut flora composition, promoting mucin production, increasing the levels of short-chain fatty acids (SCFAs), and reducing the apoptotic activity of intestinal epithelial cells.

Probiotics can enhance the expression of genes and proteins linked to tight junction (TJ) signaling, and encourage intestinal epithelial cells (IECs) proliferation to repair the intestinal mechanical barrier. *Lactobacillus reuteri* protects the intestinal barrier by increasing the expression of TJ proteins in IECs (Gou et al., 2022).

Zhao et al. (2021) found that combination of probiotics (*L. acidophilus, B. infantis, Bacillus cereus*, and *Enterococcus*) improved intestinal barrier impairment in neonatal necrotizing enterocolitis.

2. **Immunomodulatory action of Probiotics**

The gut microbial environment is critical for the growth and maturation of the GIT-associated immune system. Probiotics act to modulate a variety of immune cells, including, natural killer T cells, B cells, effector lymphocytes, dendritic cells (DCs), and epithelial cells. The immunomodulatory effects of probiotics are mediated by two key mechanisms: gene expression modulation and signalling pathways in host cells (Begum et al., 2021). Probiotics interact with intestinal epithelial cells, attract macrophages and mononuclear cells, and promote anti-inflammatory cytokines synthesis (Sajedi et al., 2021). *Lactobacilli* may transmit signals that enhance the activation of DCs. The DCs play an important role in the development of immunological responses generated by bacterial colonization of the gut, which probiotics stimulate (Yadav et al., 2022).

Probiotics help maintain gut microbial balance. They are regarded as one of the most beneficial options for restoring microbial diversity and treating illnesses caused by antibiotic-resistant bacteria or invading viruses (Youssef et al., 2021). A study was carried out to determine the immunomodulatory and ameliorative effects of *Lactobacillus* and *Saccharomyces* based probiotics against Eimeria infection (enteric disease) in broilers. It was concluded that probiotic supplementation was extremely beneficial in improving the immunological and performance potentials of broilers, resulting in protection against *Eimeria* infection (Awais et al., 2019).

Coating commensal bacteria (normal microflora) with SIgA (secretory IgA) promotes gut colonization and acclimates the infant's mucosal immune system to antigens. According to a study, the combination of a *Bifidobacterium* or *Lactobacillus* with non-specific SIgA increases probiotic adherence to Caco-2 cells (human intestinal epithelial cells) by more than threefold (Mantis et al., 2011). *Lactobacillus casei* is a crucial probiotic that is known to greatly improve the immune system, including interleukin and γ-interferon, and to promote the synthesis of immunoglobulin A (IgA) (Santacroce et al., 2019).

Many studies have shown that probiotics and their bioactive components, such as bacteriocins and short chain fatty acids (SCFAs), have unique immunomodulatory effects.

LAB strains produce lactic acid and include, *Leuconostoc, Enterococcus, Pediococcus, Streptococcus, Lactobacillus, Lactococcus, and Bifidobacterium*. They share metabolic properties, such as the ability to produce bacteriocins and SCFAs. Bacteriocins possess cytotoxic properties against cancer cells thus having immunomodulatory effects, which help to maintain a balanced interaction between gut microbiota and immunity (Thoda & Touraki, 2023).

3. **Production of Antimicrobial Substances**

Probiotics also act as anti-microbial agents by synthesis of substances; short chain fatty acids (SCFA), organic acids, hydrogen peroxide. The LAB produces antimicrobial chemicals that provide them a competitive advantage over other microbes. Lactic acid bacteria produce a wide range of antimicrobial compounds, including lactic and acetic acid, hydrogen peroxide, carbon dioxide, diacetyl, and bacteriocins or bacteriocin-like chemicals (Mishra & Lambert, 1996).

Lacticaseibacillus rhamnosus GG, *Saccharomyces cerevisiae var. boulardii*, and several probiotics demonstrated antiviral activity against rotavirus gastroenteric infections in children (Steyer et al., 2022). Nisin from *Lactococcus lactis* and Pediocin A from *Pediococcus pentosaceus* B-61 and L-7230 are active against a broad range of foodborne pathogens. Recently it was claimed that bacteriocins from *Pediococcus damnosus* and *Pediococcus pentosaceus* inhibited the growth of gram-negative organisms *Yersinia enterocolitica, Pseudomonas fragi* and *Pseudomonas fluoroscens* (Hurst, 1981).

The selected strains of *Bifidobacterium* and *Propionibacterium* are tested for antimicrobial activity against pathogenic and toxic microorganisms that can cause food poisoning and illnesses. It has been demonstrated that the reduction of viable cells of pathogenic microorganisms in mixed populations with probiotic bacteria is strain dependent, but the majority of them die after 72 hours of incubation. It was concluded that probiotic cultures produce short-chain acids (lactic, acetic, and propionic) that serve as antimicrobials (Denkova et al., 2013).

4. **Role of Probiotics in the Synthesis of Neurotransmitters**

Probiotics can synthesize neurotransmitters in the digestive tract via the gut-brain axis. Probiotic strains can regulate levels of gammaaminobutyric acid (GABA), serotonin, and dopamine impacting mood, gastrointestinal motility, behavior, and stress-related mechanisms (Srivastav et al., 2019).

The manipulation of gut microbiota can influence brain activity and behavior, making it a potential treatment for neuropsychiatric illnesses like autism spectrum disorder and depression (Kelly et al., 2016).

A study was carried out to investigate if a single microbe, *Bifidobacterium dentium*, can regulate key neurotransmitters. It was concluded that *B. dentium* might regulate intestinal tyrosine and GABA concentrations in-*vivo*. Furthermore, we discovered that *B. dentium* proliferation was associated with an increase in tyrosine levels across the entire brain tissue (Luck et al., 2021).

In the rat model, supernatants from *E. faecium, E. faecalis*, and *B. subtilis* can upregulate serotonin transporter (SERT) expression in intestinal epithelial cells and intestinal tissues (Chen et al., 2022).

5. Competitive Exclusion of Pathogens

Competitive exclusion occurs when bacterial species in the same biological niche struggle for limited resources (space and nutrients) using two strategies: interference and exploitation competition. Exploitation competition involves consuming resources quickly and investing in growth, while interference competition occurs when one organism directly affects another, for as by producing antimicrobial chemicals (Knipe et al., 2020). Probiotic flora affects the gut environment by decreasing the development of harmful microbes (e.g. quickening gastrointestinal transit while decreasing pathogens capacity to reside and attach to the GIT mucosa) (Maftei et al., 2024).

Many probiotics have been demonstrated to inhibit colonization and shedding of *Salmonella* and *Campylobacter* in chicken (Revolledo et al., 2006). The research carried out to examine the adherence features of *Bifidobacterium longum and Bifidobacterium catenulatum* strains with enhanced acid resistance, as well as their capacity to inhibit adhesion of *Salmonella, Escherichia coli, Listeria monocytogenes, and Clostridium difficile* to human intestinal mucus. (COLLADO et al., 2006).

The *L. plantarum* enhanced the abundance of *Bifidobacterium* and *Lactobacillus* in the cecum of mice administered with cyclophosphamide while decreasing the abundance of *E. coli* and *Enterococcus* (Meng et al., 2019).

Conclusion

The most important requirement for healthy growth is the maintenance of a proper microbial ecology in the host environment. Probiotics are one such alternative that is given to the host, and *Lactobacillus, Bifidobacterium*, and *Saccharomyces* are the most common probiotics. Current and future breakthroughs in microbe research have led us to new areas of study for probiotics. Probiotics are vital to preserving the equilibrium of the human microbiota in the gut, and several studies have demonstrated their positive impact on human health. The innovative types, processes, and uses evaluated so far, as well as those now under investigation, have the potential to profoundly transform our knowledge of probiotic dietary uses and human disease management. Probiotics have shown great therapeutic potential for a range of ailments, but the processes underlying these effects have yet to be fully understood.

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