Probiotics: Classification And Therapeutic Role in Human Health

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***Abstract*—Probiotics are live microorganisms that, when administered in adequate amounts, confer health benefits to the host. In recent years, advances in microbiome research have significantly transformed the understanding of human health, highlighting the central role of gut microbiota in physiological regulation. Probiotics are now recognized not only for their role in gastrointestinal health but also for their systemic effects on metabolic, immunological, neurological, respiratory, cardiovascular, and oncological conditions. These beneficial microorganisms act through multiple mechanisms, including modulation of gut microbiota composition, strengthening of intestinal epithelial barrier function, production of antimicrobial compounds, and regulation of immune responses. This review provides a comprehensive overview of probiotic classification, major microbial strains, mechanisms of action, and their therapeutic applications. Special attention is given to Lactobacillus, Bifidobacterium, Bacillus, Streptococcus, Enterococcus, and Saccharomyces species. Current scientific evidence suggests that probiotics represent promising adjuncts in the prevention and management of various diseases, particularly those associated with gut microbiota imbalance.**

***Index Terms*—Probiotics, Microbiota, Therapeutic benefits, Gut health.**

I. INTRODUCTION

The human body harbors a complex microbial ecosystem composed of trillions of microorganisms collectively known as the microbiota. Among these, the gastrointestinal microbiota plays a crucial role in maintaining physiological homeostasis, influencing digestion, metabolism, immune responses, and even neurological function. Disruption in this microbial balance, known as dysbiosis, has been associated with multiple disease conditions ranging from gastrointestinal disorders to metabolic and neuropsychiatric diseases.

Probiotics, defined as "live microorganisms which when administered in adequate amounts confer a health benefit on the host" [1], have emerged as an important therapeutic approach for restoring microbial balance. Historically, fermented foods such as curd, yogurt, and fermented milk products have been consumed for their health-promoting properties. However, scientific validation of these benefits has only recently been established through microbiological and clinical research.

Probiotics exert beneficial effects through multiple biological pathways including competitive inhibition of pathogens, enhancement of mucosal barrier integrity, production of bioactive metabolites such as short-chain fatty acids (SCFAs), and modulation of host immune responses. Importantly, their effects are not restricted to the gastrointestinal tract but extend to systemic physiological systems, including the nervous system, cardiovascular system, and immune system.

II. CLASSIFICATION OF PROBIOTICS

Probiotics are broadly classified based on their genus and species. The most commonly used probiotic microorganisms are presented in Table 1.

Table 1: Classification of Common Probiotic Microorganisms

Genus	Species
Lactobacillus	acidophilus, rhamnosus, fermentum, johnsonii, lactis, reuteri

Bifidobacterium	breve, infantis, longum, bifidum, lactis, thermophilum
Bacillus	Coagulans
Streptococcus	Thermophilus
Enterococcus	Faecium
Saccharomyces	cerevisiae (S. boulardii)

These microorganisms differ in their physiological properties, oxygen tolerance, acid resistance, and therapeutic potential, but collectively contribute to maintaining gut microbial equilibrium and host health.

III. GENERAL CHARACTERISTICS OF PROBIOTIC MICROORGANISMS

3.1 Lactobacillus species

Lactobacillus species are Gram-positive, facultative anaerobic bacteria that produce lactic acid as a major metabolic end product. They are commonly present in the gastrointestinal tract, oral cavity, and urogenital system. These organisms contribute to improved digestion, enhanced mineral absorption, and protection against pathogenic microorganisms. Certain strains also exhibit cholesterol-lowering, anti-inflammatory, and anticancer activities [2].

3.2 Bifidobacterium species

Bifidobacteria are anaerobic, Gram-positive, pleomorphic bacteria that produce acetic acid and lactic acid. They are among the dominant bacterial groups in the infant gut microbiota and play a vital role in immune system development, intestinal barrier function, and protection against infections [3].

3.3 Bacillus coagulans

Bacillus coagulans is a spore-forming bacterium that exhibits high resistance to heat, acid, and environmental stress. Although not a permanent gut resident, it helps restore microbial balance and suppress pathogenic bacteria after germination in the intestine [4].

3.4 Saccharomyces boulardii

This probiotic yeast is widely used in the management of diarrhea and gastrointestinal infections. It is resistant to acidic conditions and temperature variations and plays a protective role in intestinal health [5]. The details of probiotic information tabulated in table2.

Table 2: General Characteristics of Probiotic Microorganisms

Genus	Species	Key Characteristics	Major Therapeutic Functions
Lactobacillus	L. acidophilus, L. rhamnosus, L. fermentum, L. johnsonii, L. lactis, L. reuteri	Gram-positive, rod-shaped, lactic acid–producing bacteria; anaerobic/microaerophilic; improve mineral absorption and gut barrier integrity	Maintain gut microbiota balance, inhibit pathogens, improve digestion and immunity, anti-inflammatory, anti-cancer and hypolipidemic effects
Bifidobacterium	B. breve, B. infantis, B. longum, B. bifidum, B. lactis, B. thermophilum	Gram-positive, anaerobic, pleomorphic bacilli; produce acetic and lactic acid; dominant in infant gut microbiota	Improve gut health, IBS management, immune modulation, anti-inflammatory effects, prevention of diarrhea, support

			in ulcerative colitis and allergic diseases
Bacillus	Bacillus coagulans	Spore-forming, gram-positive, highly resistant to heat, acid, and bile; survives harsh GI conditions	Restores gut microbiota, inhibits pathogenic bacteria, improves digestion and immunity, used in functional foods
Streptococcus	Streptococcus thermophilus	Gram-positive cocci; widely used in dairy fermentation; lactose-utilizing bacteria	Improves lactose digestion, enhances yogurt texture, supports immunity, reduces gastrointestinal inflammation
Enterococcus	Enterococcus faecium	Gram-positive cocci; gut-resident bacteria; survive gastrointestinal transit	Maintains gut microbial balance, supports digestion and immunity when safe strains are used
Saccharomyces	Saccharomyces cerevisiae, S. boulardii	Yeast probiotic; resistant to acid and temperature stress; isolated from fermented fruits	Treatment of diarrhea, restores gut flora, anti-inflammatory effects, inhibits intestinal pathogens

IV. MECHANISM OF ACTION OF PROBIOTICS

Probiotics exert beneficial effects through multiple interconnected mechanisms. One of the primary mechanisms is competitive exclusion, where probiotics prevent pathogenic bacteria from adhering to intestinal epithelial surfaces. They also enhance intestinal barrier integrity by strengthening tight junction proteins.

Additionally, probiotics produce antimicrobial compounds such as bacteriocins, hydrogen peroxide, and organic acids, which inhibit pathogen growth. A key metabolic product of probiotics is short-chain fatty acids (SCFAs), which play a crucial role in maintaining gut health, regulating inflammation, and providing energy to colonocytes.

Furthermore, probiotics modulate both innate and adaptive immune responses by influencing cytokine production and enhancing antibody synthesis. These combined mechanisms contribute to maintaining intestinal homeostasis and overall systemic health [6].

V. IMPORTANT PROBIOTIC STRAINS AND THEIR FUNCTIONAL PROPERTIES

5.1 Lactobacillus acidophilus

This strain is known for its strong adhesion to intestinal epithelial cells and resistance to bile and acid. It has been shown to reduce cholesterol levels and improve cardiovascular health. Commercial

strains include LA-1, LA-5, NCFM, DDS-1, and SBT-2026 [7].

5.2 Lactobacillus rhamnosus
L. rhamnosus is widely studied for its ability to survive gastrointestinal conditions and modulate immune responses. It is effective in treating IBS, allergies, eczema, and respiratory infections [8].

5.3 Lactobacillus fermentum
This strain exhibits antimicrobial, antioxidant, and immunomodulatory properties and plays a role in cholesterol metabolism and gut epithelial adhesion [9].

5.4 Lactobacillus johnsonii
It enhances immune responses and inhibits pathogen colonization, thereby reducing gastrointestinal infections.

5.5 Bifidobacterium breve
This species is abundant in infants and supports digestion, immune development, and respiratory health [10].

5.6 Bifidobacterium infantis
It is effective in reducing symptoms of irritable bowel syndrome and restoring microbial balance.

5.7 Bifidobacterium longum
A dominant gut microorganism with anti-inflammatory, anticancer, and immunomodulatory properties.

5.8 Bacillus coagulans
This strain enhances gut health and immune response under extreme environmental conditions [11].

VI. THERAPEUTIC APPLICATIONS OF PROBIOTICS

6.1 Cancer Prevention and Therapy
Probiotics play an important role in reducing cancer risk by modulating gut microbiota composition and suppressing pathogenic bacteria. They enhance production of short-chain fatty acids that inhibit tumor growth and promote apoptosis in cancer cells. Clinical studies have demonstrated reduced side effects of chemotherapy and radiotherapy in cancer patients receiving probiotic supplementation [12].

6.2 Gastrointestinal Disorders
Probiotics are widely used in the management of diarrhea, irritable bowel syndrome, ulcerative colitis, and Crohn's disease. They compete with pathogens for epithelial binding sites and enhance intestinal barrier function. Saccharomyces boulardii is particularly effective in treating acute and chronic diarrhea [13].

6.3 Diabetes Mellitus
Probiotics regulate glucose metabolism by influencing gut hormones and improving insulin sensitivity. They also reduce adipocyte accumulation and metabolic inflammation.

6.4 Urinary Tract Infections
Lactobacillus species help maintain vaginal microbiota balance by lowering pH and preventing pathogen colonization, thereby reducing UTI recurrence [14].

6.5 Obesity
Probiotics regulate lipid metabolism, adipokines, and energy balance. They reduce LDL, triglycerides, and body fat accumulation.

6.6 Neurological and Psychiatric Disorders
The gut–brain axis plays a critical role in mental health. Probiotics such as Lactobacillus rhamnosus and L. helveticus reduce anxiety, depression, and autism-related symptoms by modulating neurotransmitter production and inflammatory pathways.

6.7 cardiovascular diseases
Certain probiotic strains inhibit angiotensin-converting enzyme (ACE), thereby reducing hypertension and improving cardiovascular health.

6.8 respiratory diseases
Probiotics exhibit immunomodulatory and antimicrobial effects that help in reducing respiratory infections such as pneumonia, bronchitis, and sinusitis.

6.9 Inflammatory Diseases
Probiotics are effective in reducing inflammation in ulcerative colitis and Crohn's disease by restoring microbial balance

VII. GUT–BRAIN AXIS AND SYSTEMIC HEALTH

The gut–brain axis represents a bidirectional communication system between the gastrointestinal tract and the central nervous system. Probiotics influence this axis by modulating neurotransmitter synthesis, immune signaling, and microbial metabolites. This interaction is associated with regulation of mood, behavior, and cognitive function, and has implications in depression, anxiety, autism, schizophrenia, and neurodegenerative disorders [15].

VIII. SYNBIOTICS AND FUTURE PERSPECTIVES

Synbiotics, which combine probiotics and prebiotics, enhance microbial survival, colonization, and functional activity. They improve gut health, immune responses, and metabolic regulation. Future research is focusing on personalized probiotic therapies based on individual microbiome profiles to achieve targeted therapeutic outcomes.

IX. CONCLUSION

Probiotics represent a rapidly expanding field in natural and biomedical sciences with wide-ranging therapeutic applications. Their ability to modulate gut microbiota and influence systemic physiological processes makes them valuable adjuncts in disease prevention and management. Further clinical and mechanistic studies are required to optimize strain-specific applications and therapeutic outcomes in human health.

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