American Journal Of Biomedical Science & Pharmaceutical Innovation

VOLUME Vol.05 Issue10 2025
PAGE NO. 77-79
DOI 10.37547/ajbspi/Volume05Issue10-15

Immunobiotics: Novel Approaches To Strengthening The Immune System Using Microorganisms

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Received: 29 August 2025; **Accepted:** 25 September 2025; **Published:** 27 October 2025

Abstract: The discovery of immunobiotics has opened a new era in microbiology and immunology, combining microbial biotechnology with immune system regulation. Immunobiotics—specific strains of probiotic microorganisms—can stimulate or modulate host immunity by interacting with mucosal cells, cytokines, and immune receptors. They have demonstrated potential in strengthening host defense, improving vaccine responses, and reducing inflammatory and allergic diseases. This article discusses the mechanisms of immunobiotic action, recent advances in immunobiotic research, and their application prospects in preventive and therapeutic medicine.

Keywords: Immunobiotics, probiotics, microbiome, immune modulation, cytokines, host defense, microbial biotechnology, gut–immune axis.

Introduction: In recent decades, a growing body of research has emphasized the role of the human microbiome in maintaining health, particularly its interactions with the immune system. The concept of immunobiotics—a term derived from "immune" and "probiotic"—has emerged as a distinct scientific field aimed at understanding and utilizing specific microorganisms to regulate immune responses. Unlike conventional probiotics, whose primary focus lies in promoting gut health, immunobiotics specifically target the immune system through molecular communication between microbial cells and host immune receptors.

The immune system is a complex network that depends heavily on the interaction between the gut microbiota and immune cells. Immunobiotics act as modulators that can enhance or suppress immune activity depending on the physiological state of the host. When consumed, these beneficial microorganisms interact with intestinal epithelial cells and antigen-presenting cells, such as dendritic cells and macrophages. Through these interactions, immunobiotics influence the secretion of cytokines and the differentiation of immune cells like T-helper and regulatory T cells, leading to balanced immune responses and improved resistance to infections.

A critical mechanism underlying immunobiotic function involves pattern recognition receptors (PRRs), especially Toll-like receptors (TLRs) located on immune cell surfaces. When microbial molecules—such as peptidoglycans, lipoteichoic acids, or exopolysaccharides—bind to TLRs, a signaling cascade is triggered that results in the activation of nuclear factor kappa B (NF-κB) and other transcription factors responsible for immune gene expression. These molecular interactions lead to increased production of protective cytokines like interleukin-10 (IL-10) and interferon-gamma (IFN-γ), which are essential for maintaining immune homeostasis and controlling inflammation.

Recent studies have identified several bacterial species with significant immunobiotic potential. Among them, Lactobacillus rhamnosus, Lactobacillus plantarum, Bifidobacterium longum, and Streptococcus thermophilus have shown the ability to regulate both local and systemic immunity. For instance, L. plantarum can enhance mucosal IgA production, contributing to improved antiviral defense in the respiratory and gastrointestinal tracts. Similarly, B. longum has demonstrated the capacity to increase anti-inflammatory cytokine production, which helps to mitigate allergic reactions and autoimmune responses.

Immunobiotics have also gained attention in the context of respiratory viral infections, including influenza and SARS-CoV-2. Some clinical studies indicate that probiotic supplementation may reduce the duration and severity of upper respiratory infections by modulating immune cell activity and reducing inflammatory cytokines such as TNF-α and IL-6. Moreover, immunobiotics may act synergistically with vaccines, enhancing antigen presentation and antibody generation, thus improving vaccine efficacy. Such findings make immunobiotics promising tools for pandemic preparedness and public health resilience.

Beyond infectious diseases, immunobiotics have shown beneficial effects in autoimmune disorders, metabolic syndromes, and oncological applications. For example, certain Lactobacillus strains can modulate immune checkpoints and affect the tumor microenvironment by enhancing the activity of cytotoxic T cells. In metabolic diseases, immunobiotics influence the gut–brain axis, contributing to improved glucose tolerance and reduced systemic inflammation. These multifaceted benefits illustrate that immunobiotics bridge the gap between nutrition, microbiology, and immunotherapy.

Nevertheless, despite the substantial progress, several scientific and technical challenges remain. One major limitation is the strain specificity of immunobiotic effects. Each microbial strain may interact differently with host receptors, and results obtained from one strain cannot be generalized to others. Furthermore, host genetics, dietary patterns, and environmental factors all play crucial roles in shaping the microbiota composition and, consequently, immunobiotic performance. To ensure reproducibility and safety, standardized methods for strain characterization, genome sequencing, and clinical validation are essential.

Another promising direction is the integration of omics technologies—genomics, proteomics, metabolomics, and transcriptomics—into immunobiotic research. These approaches allow for the identification of bioactive compounds and immune-regulating genes within microbial genomes. Advances in synthetic biology are also enabling the design of engineered microbial strains that can deliver therapeutic molecules, vaccines, or immune modulators directly in the gut environment. Such innovations point toward the emergence of next-generation immunobiotics, which will combine natural microbial properties with targeted biotechnological enhancements.

The potential applications of immunobiotics extend to functional foods, nutraceuticals, and pharmaceutical formulations. Food-based immunobiotics could serve as preventive agents for immune deficiencies, while medical-grade preparations may be used as adjunct therapies for chronic inflammatory or infectious diseases. The safety profile of most lactic acid bacteria and bifidobacteria makes them suitable candidates for long-term consumption without significant side effects, increasing their attractiveness for both clinical and commercial use.

In the context of global health, the development of immunobiotics aligns with the principles of sustainable medicine. Instead of relying solely on chemical immunostimulants and antibiotics, which may contribute to antimicrobial resistance, immunobiotics offer an ecological and biologically compatible solution. Their use supports the natural equilibrium between the host and its microbiota, promoting immune resilience and overall health stability.

In conclusion, immunobiotics represent an innovative and environmentally safe strategy for strengthening the immune system through the use of beneficial microorganisms. As scientific understanding of host–microbe interactions deepens, immunobiotics are expected to play an increasingly important role in modern medicine, preventive healthcare, and biotechnology. Continued interdisciplinary research combining microbiology, immunology, and systems biology will be essential to fully unlock the therapeutic potential of immunobiotics and translate laboratory findings into practical medical applications.

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