Literature Review: The Potential Health Benefits of Lactiplantibacillus plantarum as a Probiotic and Its Applications in Human Health

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Abstract
Lactiplantibacillus plantarum is a versatile lactic acid bacterium frequently found in fermented foods and the human gut. Owing to its metabolic flexibility and adaptability, this species has become one of the most extensively studied probiotics. Recent developments in food biotechnology highlight its potential in advancing preventive and therapeutic healthcare through microbiome modulation and functional food innovation. This article provides a narrative review of current literature regarding the biological activities, probiotic mechanisms, and technological applications of L. plantarum. Data were synthesized from recent scientific publications, emphasizing innovations in formulation and health-related outcomes. The review summarizes that L. plantarum can regulate gut microbiota composition, exhibit antioxidant and anti-inflammatory effects, improve lipid metabolism, and enhance immune responses. Technological advances—such as microencapsulation, fermentation optimization, and genetic enhancement—further strengthen its functional stability and bioavailability. Through its wide-ranging health benefits and compatibility with modern biotechnological innovations, L. plantarum represents a promising next-generation probiotic contributing to the transformation of healthcare toward a more preventive and sustainable system.

Introduction

Food plays a crucial role in preventing disease and maintaining health. The main challenge for consumers is to meet the need for safe, healthy, high-quality food while also seeking new innovations that focus on preventing chronic diseases (Abdelazez et al., 2018). The consumption of functional foods (foods containing beneficial compounds or microorganisms) has been shown to enhance health benefits by preventing chronic degenerative diseases such as obesity, diabetes, cancer, and heart disease (Hassan et al., 2019). Organisms considered probiotics have traditionally been used as starter cultures in fermented foods (Abdelazez et al., 2018).

According to the FAO/WHO, probiotics are defined as live microorganisms that, when consumed in adequate amounts as food or supplements, confer beneficial effects on the host's bacterial flora (Abdelazez et al., 2018). The human body is inhabited by a dynamic variety of microbes, consisting of bacterial viruses, archaea, and other eukaryotic organisms, collectively referred to as the microbiota. The microbiota plays an essential role in various aspects of human health, including immunology, metabolism, and disease pathology. It helps maintain the body's ecological balance and combats pathogens by preventing their invasion through the digestive tract or mouth. The goal of probiotics is to prevent or correct dysbiosis and create a balanced microbiota that provides positive benefits to the host. Dysbiosis is a condition in which harmful or pathogenic bacteria become dominant, which has been associated with various diseases such as allergies, type 1 diabetes, and obesity (Abdelazez et al., 2018).Recent original studies have demonstrated clear associations between gut-microbiota dysbiosis and metabolic disorders. In a Mexican cohort, "dysbiosis signatures" reliably predicted progression to type 2 diabetes (Neri-rosario et al., 2023). Animal and human studies show that high-fat diets alter gut microbial composition, impair insulin sensitivity, and promote dysbiosis that mitigated by probiotic/prebiotic interventions or other microbiota-modulating strategies (Qi & Wang, 2023). Several original studies have demonstrated the diverse health-promoting properties of *L. plantarum* 299v from fermented milk improves gut and reproductive microbiota in humans and enhances product stability (Nordström et al., 2021). Meanwhile, *L. plantarum* LP33 in yogurt

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promotes heavy-metal excretion and reduces oxidative stress in mice, demonstrating strong detoxifying effects (Hu et al., 2020).

The successful application of probiotics requires consideration of several aspects, including timing of administration, species, strain, and composition of the probiotic product used. *Lactiplantibacillus plantarum* (formerly *L. plantarum*) is one of the most promising probiotic species, possessing favorable probiotic characteristics and the ability to survive in the human digestive system. Several studies have demonstrated that administration of *L. plantarum* can provide positive health benefits in humans. Therefore, *L. plantarum* has become an important focus of research in the field of probiotics (Fidanza et al., 2021).

Methods

This article employed a narrative review approach by collecting and synthesizing scientific literature on Lactiplantibacillus plantarum from databases including PubMed, Scopus, ScienceDirect, and Google Scholar, covering publications from 2010 to 2025. Keywords such as "Lactiplantibacillus plantarum," "probiotic," "functional food," "gut microbiota," and "biotechnology" were used to identify relevant studies. Only peer-reviewed articles focusing on the probiotic characteristics, health benefits, and technological applications of L. plantarum were included, while non-scientific reports and unrelated studies were excluded. Data were analyzed qualitatively to summarize findings on physiological traits, functional roles, and mechanisms underlying health-promoting effects, including antioxidant, anti-inflammatory, immunomodulatory, and metabolic regulation properties. All information was derived from previously published and ethically approved research.

Results and Discussion

Physiological Characteristics of Lactiplantibacillus plantarum

Lactiplantibacillus plantarum is commonly found in the gastrointestinal tract of humans and other mammals, saliva, and various food products. It is considered one of the most important Gram-positive microorganisms within the lactic acid bacteria (LAB) group, typically rod-shaped. *L. plantarum* is a facultative anaerobe, microaerophilic, non-spore-forming, and catalase-negative bacterium. This species, belonging to the genus *Lactobacillus*, is widely distributed in nature. During fermentation, it produces only lactic acid and is capable of surviving without oxygen when necessary. Initially classified as *Lactobacillus plantarum*, it has been reclassified as *Lactiplantibacillus plantarum* to standardize and clarify the taxonomy of probiotic bacteria (Abdelazez et al., 2018).

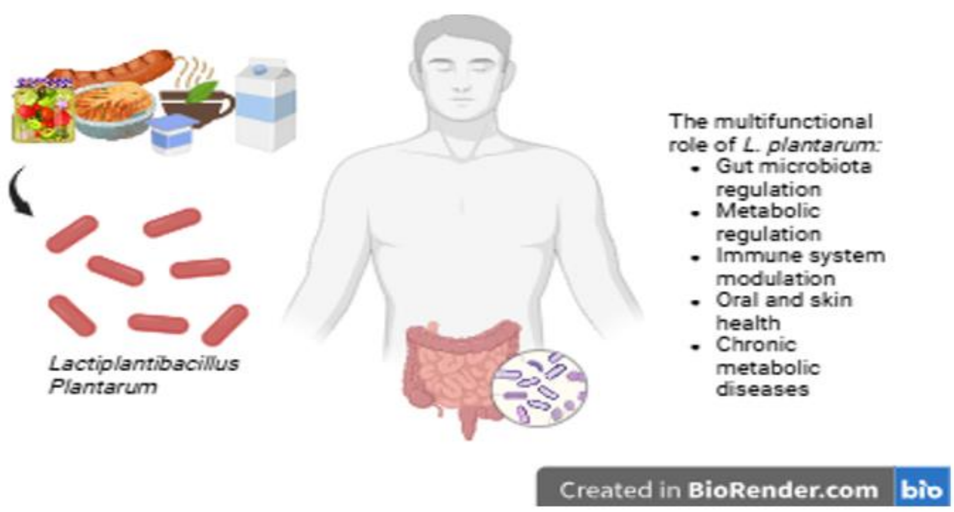

Figure 1. Multifunctional role of *L. plantarum,* generated withby Biorender.com

L. plantarum exhibits strong carbohydrate metabolism, salt tolerance, and synergistic interaction with other lactic acid bacteria. Morphologically, it appears as a long rod under an electron microscope, lacking flagella and spores. The bacterium can grow at temperatures between 15°C and 45°C, with optimal growth observed between 30°C and 37°C, and a preferred pH of approximately 6.5. It can be isolated from the digestive tracts of humans and animals, the urinary tract, and fermented foods such as sour porridge, sauerkraut, koumiss, and kefir. Due to these favorable characteristics, *L. plantarum* is regarded as a potential probiotic species (Hao et al., 2024).

Functional Roles of Commercial *L. plantarum* Probiotics

Dairy products are among the most common carriers for probiotics because milk provides essential nutrients required for bacterial growth. Probiotics are frequently incorporated into dairy-based foods such as cheese, yogurt, and ice cream. Several species within this genus—

including *L. brevis*, *L. acidophilus*, *L. delbrueckii*, *L. johnsonii*, *L. salivarius*, *L. rhamnosus*, *L. casei*, *L. paracasei*, *L. fermentum*, *L. plantarum*, and *L. helveticus,*serve as starter or non-starter cultures in food fermentation and preservation, as well as in the production of flavor compounds and bacteriocins, extending their use into biotechnological applications. *L. plantarum* is widely used in the fermentation of milk, meat, and plant products, and is also present in fermented foods such as yogurt, cheese, kimchi, sauerkraut, sourdough, and pickles. This bacterium contributes to the flavor and aroma of foods, depending on the balance between volatile (acetic acid) and non-volatile (lactic acid) compounds (Abdelazez et al., 2018).

Oxygen utilization and aeration during fermentation help manufacturers control acetic acid levels, such as in sourdough production. *L. plantarum* primarily contributes to dough acidification but also plays a role in fermentation processes. A notable example is sauerkraut, which undergoes spontaneous fermentation from cabbage through acid-tolerant LAB. However, the sensory characteristics of sauerkraut vary depending on the bacterial strains, fermentation substrate, salt concentration, and temperature. To standardize production, a two-stage fermentation process was developed: *Leuconostoc mesenteroides* is used in the initial phase to impart mild aromatic flavor, while *L. plantarum* dominates the second phase, contributing a more acidic and vinegar-like taste. The combination of these bacteria shortens fermentation time and inhibits the growth of undesirable microorganisms, thereby improving product quality and safety (Abdelazez et al., 2018).

Beyond fermentation, *L. plantarum* is employed in preserving fruit and vegetable juices, dairy products, cereal-based foods, and meats. It also serves as a natural preservative in the food industry and has medical applications in treating oral, skin, and veterinary conditions. Various applications of *L. plantarum* strains are summarized in Table 1 (Hao et al., 2024).

L. plantarum and Gut Microbiota

The host's intestinal flora constitutes a dense and competitive microbial ecosystem that provides essential metabolic activities and immune-stimulating molecules. Probiotics, such as *Lactiplantibacillus plantarum*, have been shown to play a significant role in regulating this intestinal microbiota. *L. plantarum* can enhance the balance of gut flora, positively influencing human health. Several studies have demonstrated that *L. plantarum* helps alleviate digestive problems such as diarrhea, constipation, inflammatory bowel disease (IBD), and irritable bowel syndrome (IBS) by restoring microbial balance. Furthermore, *L. plantarum* has been found to reduce pro-inflammatory cytokine levels while increasing anti-inflammatory cytokines, thus exerting beneficial effects on intestinal inflammation. Interventions involving *L. plantarum* have also been shown to modify the structure of gut microbiota and increase the abundance of beneficial bacteria. Both animal and human studies indicate that *L. plantarum* effectively corrects gut dysbiosis and alleviates symptoms of colitis. Additionally, *L. plantarum* is beneficial in preventing and treating antibiotic-associated diarrhea and promoting the growth and development of intestinal flora in animals (Hao et al., 2024).

Table 1. Functional Roles of Commercial *L. plantarum* Strains

Strain	Source	Physiological Function	Research Subject	References
L. plantarum ATCC 14917	Fresh tea leaves	Reduces atherosclerotic lesions, LDL, MDA, TNF-α, IL-1β	Mice	Hassan et al. 2019 (Hassan et al., 2019)
L. plantarum CJLP133	Kimchi	Anti-allergic effect	Mice	Won, TJ.et.al. 2012
L. plantarum CJLP243	Kimchi	Anti-allergic effect	Humans	Choi,SP.et.al. 2018 (Choi et al., 2018)
L. plantarum YIT0132	Fermented foods	Anti-allergic activity	Mice	Suzuki,S.et.al. 2020 (Suzuki et al., 2020)
L. plantarum LRCC5310	Kimchi	Antiviral activity; alleviates rotavirus-induced diarrhea	Mice	Kim,K. et.al. 2018 (Kim et al., 2018)
L. plantarum NCU116	Pickled vegetables	Improves type 2 diabetes; lowers cholesterol	Mice	Xie,J.et.al. 2015 (Xie et al., 2015)
L. plantarum SCS2	Chinese sausage	Decreases blood glucose, body weight, HbA1c, MDA, ROS	Mice	Wu et.al. 2021 (Wu et al., 2021)
L. plantarum DR7	Cow's milk	Relieves upper respiratory infections; modulates immunity	Humans	Chong,H.X. et.al. 2019 (Chong et al., 2019)
L. plantarum 299v	Fermented milk	Improves gut and reproductive flora; enhances storage	Humans	Nordstrm, E.A. et.al 2021 (Nordström et al., 2021)

L. plantarum LP33	Yogurt	Promotes heavy metal excretion; reduces oxidative stress	Mice	Hu, T. et.al. 2020 (Hu et al., 2020)
L. plantarum CCFM8724	Fermented milk wine	Reduces oral pathogens in children with dental caries	Humans	Zhang, Q. et.al. 2023 (Zhang et al., 2023)
L. plantarum Dad-13	Skim milk	Increases *L. plantarum* abundance	Mice	Rustanti,et.al. 2022 (Rustanti et al., 2022)

L. plantarum and Metabolism

Reduction of Cholesterol

Probiotics have become an attractive area of research in the management of hyperlipidemia, a major risk factor for several chronic metabolic diseases. While cholesterol is essential for human physiology, excessive intake can lead to health complications. Studies indicate that probiotics can lower cholesterol levels primarily through assimilation and regulation of cholesterol synthase enzyme activity. Certain probiotic strains, including *L. plantarum*, have been studied for their potential to reduce hyperlipidemia. Research findings suggest that regular consumption of *L. plantarum* can significantly lower LDL cholesterol levels. Animal and rodent studies also show that oral administration of *L. plantarum* reduces total cholesterol, triglycerides, and LDL levels in blood and liver tissues, highlighting its potential as a natural therapeutic for hyperlipidemia and related disorders (Hao et al., 2024).

Pomotion of Heavy Metal Excretion

Once absorbed, heavy metals can accumulate in soft tissues, with the liver being the most susceptible organ to heavy metal toxicity. The main mechanism of hepatotoxicity involves oxidative stress induction, which triggers abnormal inflammatory responses. In severe cases, heavy metal accumulation can lead to symptoms such as headaches, dizziness, and sleep disturbances, and in extreme conditions, may cause serious organ damage to the brain, kidneys, and skin. *L. plantarum* has been investigated for its ability to mitigate the negative effects of heavy metals by enhancing their excretion and reducing tissue accumulation. Studies show that *L. plantarum* can decrease blood concentrations of heavy metals such as methylmercury and cadmium while promoting their elimination via feces. When used in combination with *Bifidobacterium lactis*, *L. plantarum* was found to reduce lead levels in exposed mice by up to 90.7%. Moreover, *L. plantarum* alleviated liver damage, oxidative stress, inflammatory responses, and NF-κB activation in liver tissues of lead-exposed mice. It also improved memory function, reduced inflammatory cytokine levels, and restored gut microbiota balance disrupted by lead exposure (Hao et al., 2024).

L. plantarum and Immunity

Immunity refers to the body's ability to resist external invasion and maintain internal homeostasis. *L. plantarum* has been shown to significantly increase immunoglobulin levels (IgA, IgG, and IgM) on mucosal surfaces and in serum, thereby enhancing humoral immunity. Additionally, it stimulates T- and B-lymphocyte proliferation, strengthens cellular immunity, and enhances mononuclear phagocyte activity. Numerous studies indicate that various *L. plantarum* strains can alleviate respiratory tract infections, improve immune responses against pathogens, and modulate immune status in individuals with atopic dermatitis. *L. plantarum* also exerts beneficial effects on the immune systems of broiler chickens and fish, and offers protection against influenza virus through modulation of microbe-mediated immune responses. Furthermore, *L. plantarum* has been reported to enhance the absorption of trace elements such as iron. Supplementation with *L. plantarum* can increase iron absorption by up to 50%, as well as elevate ferritin and reticulocyte hemoglobin levels in individuals with low iron status (Hao et al., 2024).

L. plantarum and Oral and Skin Health

Oral Health

The oral cavity hosts a highly diverse microbial community, dominated by genera such as *Streptococcus*, *Veillonella*, and *Proteobacteria*. This microbial diversity reflects the state of oral and systemic health. Probiotic application has emerged as an effective strategy to improve oral health and reduce risks of dental caries, periodontitis, and halitosis. Probiotics have been shown to significantly reduce populations of cariogenic bacteria such as *Streptococcus mutans*, thereby improving oral health in individuals receiving regular dental care. From a microecological perspective, probiotics play a valuable role in both the prevention and treatment of dental caries in children and periodontitis in adults. For example, *L. plantarum* CCFM8724 has been demonstrated to reduce oral pathogens in children with dental caries and modulate their oral microbiota (Hao et al., 2024).

Skin Microbiota Enhancement

The human skin hosts a wide range of microorganisms, primarily *Actinomycetes*, *Proteobacteria*, and *Firmicutes*, along with a small proportion of fungi. The skin microbiome composition varies by site and environmental conditions. Recent studies indicate that skin health is closely linked to gut conditions through the gut–skin axis. *L. plantarum* has demonstrated the ability to reduce skin aging, prevent wrinkle formation and hyperpigmentation, and decrease acne lesions in clinical studies. Topical application of *L. plantarum* GMNL6 has been shown to lower *Propionibacterium* abundance and improve skin moisture, tone, pigmentation, wrinkles, and UV sensitivity. Similarly, *L. plantarum* CJLP55 supplementation improved acne severity and overall skin condition in patients with mild to moderate acne. These findings suggest that probiotics, particularly *L. plantarum*, may serve as effective interventions for maintaining and restoring skin health (Hao et al., 2024)

Modulation of Chronic Metabolic Diseases by *L. plantarum*

Lactiplantibacillus plantarum has demonstrated significant potential in modulating chronic metabolic diseases such as diabetes and obesity through multiple biochemical and microbiological mechanisms. In diabetes, *L. plantarum* regulates glucose metabolism by inhibiting α-glucosidase and α-amylase enzymes, improving fasting glucose, glycated hemoglobin, and hepatic glycogen levels. It also reduces inflammation and oxidative stress, two major contributors to diabetic complications. Moreover, *L. plantarum* can restore gut microbiota balance and increase short-chain fatty acid (SCFA) production, which enhances pancreatic function and glycemic control. Although animal studies consistently report these benefits, human clinical results remain variable due to strain-specific and dosage differences, with effective concentrations typically ranging from 10^9 to 10^{10} CFU/mL (Tian et al., 2023).
In obesity, *L. plantarum* exhibits anti-lipogenic and lipid metabolism–modulating effects by activating peroxisome proliferator-activated receptor (PPAR) pathways, enhancing fatty acid oxidation, and suppressing adipocyte differentiation. It also promotes a healthier gut microbiota composition by increasing beneficial species such as *Akkermansia* and *Bifidobacterium*. Beyond obesity, *L. plantarum* supplementation has been associated with improved cardiovascular parameters, including reduced blood pressure in hypertensive subjects and decreased triglyceride, total cholesterol, and LDL-C levels in hyperlipidemic conditions. These effects are mediated through enhanced bile acid excretion, AMPK pathway regulation, and the upregulation of hepatic transporters involved in cholesterol metabolism, highlighting *L. plantarum*'s promise as a multifunctional probiotic for chronic metabolic health management (Tian et al., 2023).

Conclusion and Suggestion

Lactiplantibacillus plantarum is a versatile and well-studied probiotic with remarkable health-promoting properties. It plays a vital role in maintaining gut microbiota balance, improving immune function, and regulating metabolic processes such as glucose and lipid metabolism. Its therapeutic potential extends to managing chronic metabolic disorders like diabetes, obesity, hypertension, and hyperlipidemia through anti-inflammatory, antioxidant, and enzyme-regulatory mechanisms. Beyond metabolic health, L. plantarum also supports oral, skin, and gastrointestinal health by promoting microbial homeostasis and reducing pathogenic activity. Advances in food biotechnology have enhanced its application in functional foods and nutraceuticals, emphasizing its value in disease prevention and overall well-being.

Future research should focus on conducting large-scale, long-term human clinical trials to confirm the strain-specific benefits and safety of L. plantarum. Standardization of probiotic dosage, formulation, and delivery methods is also needed to optimize its therapeutic efficacy. Moreover, integrating L. plantarum into daily diets through fermented foods or functional supplements could be an effective strategy for promoting public health. Collaboration between food technologists, microbiologists, and clinicians is essential to fully harness the potential of L. plantarum in preventive and personalized nutrition.

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