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The Role of *Lacticaseibacillus paracasei* as a Probiotic in Health

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Abstract

Probiotics are gaining popularity due to their beneficial role in various health issues. A growing body of studies has demonstrated the benefits of *Lacticaseibacillus paracasei* in supporting gut health, modulating the immune system, lowering cholesterol, and acting as an antimicrobial and antibiofilm agent. This review summarizes several specific strains of *L. paracasei*, their benefits, and sources of isolates. *L. paracasei* is widely found in various traditional fermented foods from different countries. *L. paracasei* is not only used as a starter culture in the dairy and fermented food industry, but it has the potential to treat a variety of health issues at the cellular and molecular levels. It is fascinating to highlight the most recent findings on the features and role of *L. paracasei* in health issues.

Keywords: Fermented Food, Gut Health, *L. paracasei*, Probiotics

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INTRODUCTION

The International Scientific Association of Probiotics and Prebiotics, the World Health Organization (WHO), and the Food and Agriculture Organization (FAO) define probiotics as live bacteria that, when supplied in suitable proportions, promote the host's health.[1] These microorganisms, predominantly bacteria but also yeasts, can be found in fermented foods, added to other goods, and used as nutritional supplements.[2] Probiotics often exert their effects in the gastrointestinal system, where they might affect the gut microbiome. Probiotics can colonize the human intestinal mucosa in highly particular patterns, depending on the baseline microbiota, the probiotic strain, and the region of the gastrointestinal tract.[3] Probiotics have general health benefits, species-specific, and strain-specific.[4]

Promising probiotics include bacteria from the genera *Enterococcus, Pediococcus*, *Streptococcus*, *Propionibacterium*, *Lactococcus*, and *Bacillus*. *Lacticaseibacillus paracasei* is a species identified in various fermented beverages and foods. *Lactobacillus* has been widely explored for its distinct health benefits, making it a popular genus among gut commensal bacterium. *L. paracasei* is also one of the most commonly employed probiotic species in human applications.[5] It comprises diverse strains with a long history of safe use in food and agricultural uses that have been studied for their health-promoting characteristics.[6] This review article discusses the role of probiotics in health, with a focus on the latest research updates regarding the use of *L. paracasei* in the health field.

Properties of *Lacticaseibacillus paracasei*

Lacticaseibacillus paracasei, previously known as *Lactobacillus paracasei*, is a facultative anaerobic, Gram-positive, rod-shaped, nonspore-forming and non-motile bacteria.[7] This bacterium is found in fermented foods and host-associated environments and is capable of producing lactic acid as the primary fermentation product.[8] It can produce lactic acid from hexoses and lactate and acetate from pentoses and its optimal growth temperature range (10-37 °C).[9]

L. paracasei can withstand various stresses, including low water activity, heating (60 °C for 30 minutes), and low pH.[9,10] Certain strains, such as *L. paracasei* L2, exhibit high adhesion to HCT-116 cells, survive in acidic conditions (pH 3), and exhibit resistance to bile salts. *L. paracasei* L2 is deemed safe. This strain also exhibited antioxidant activity[8,11] and can be used as a probiotic for fermented food production (proteolytic properties, autolytic, acidification activity, and EPS synthesis).[8]

Lacticaseibacillus paracasei is widely employed in both dairy and non-dairy products. *L. paracasei* has probiotic qualities in the gastrointestinal tract, including tolerance to pepsin, acid, bile salts, and pancreatin, adhesion ability, antipathogenic activity, and antibiotic sensitivity.[11] *Lacticaseibacillus paracasei* can adhere to human intestinal epithelial cells, which is required for colonization and potential health benefits. This bacterium can form biofilms, which are bacterial communities enclosed in a self-produced matrix, and this ability may contribute to its persistence in the intestine.[12] Some *L. paracasei* strains exhibit varying susceptibility to various antibiotics.[11-14] *Lacticaseibacillus paracasei* can also help keep the gut microbiota balanced and stable.[8]

Food and Beverage Matrices Containing *L. paracasei*

Several isolates of *L. paracasei* from Argentina, Brazil, Iran, Tibet, Russia, and Greece, as well as water kefir from Belgium and Mexico, have been studied for their health benefits to consumers. The majority of strains were derived from kefir, with a few from water kefir.[15,16] Similar studies have employed omics based evaluation of *L. paracasei* as a starter in Brazilian-style sour beers.[17] This microorganism's positive qualities include pathogen protection, immunomodulation, as well as antioxidant, anti-inflammatory, and antiproliferative activity. Sornsenee et al. identified *L. paracasei* strain T0901 which had previously been isolated from fermented palm sap, using MALDI-TOF and 16S rRNA sequencing.[18] This resilience is consistent with reports of *L. paracasei* F19 maintaining viability in high-hopped beer environments.[19]

Ren et al. isolated *L. paracasei* from koumiss made by local herders in Aluke'erqin Qi; Inner Mongolia, China.[20] Another investigation found *Lacticaseibacillus paracasei* TRA061676 in coalho cheese and grown in extruded sorghum flour in Brazil.[21] Milk has been widely reported to contain probiotics, one of which is Chinese Yak Milk, which is known to contain *Lacticaseibacillus paracasei* SB27.[22] *L. paracasei* strain 62L (NCBI GenBank accession number KU886178) was isolated from fermented cassava using cassava fermentation water collected in Dschang city, Western Cameroon.[23] Sornsenee et al. discovered seven *L. paracasei* isolates from fermented palm sap, in Southern Thailand.[24]

The Role of *L. paracasei* in Health

Probiotics can improve human and animal health in a variety of ways, including suppressing intestinal pathogenic microbes, modifying immunological responses, lowering serum cholesterol levels, and exerting antioxidant activity, among others. These impacts may be attributable to the presence of the organisms themselves or the metabolites they make and, in some cases, release into the environment (e.g., exopolysaccharides, bacteriocins and organic acids).[8] The literature describes several benefits for *L. paracasei* strains. According to studies, *L. paracasei* can help break down food, improve nutritional absorption, and potentially relieve diarrhea symptoms. *L. paracasei* can also improve gut barrier function and reduce intestinal permeability, which is critical for preventing dangerous bacteria translocation.[20,25,26]

According to studies, *L. paracasei* can assist in controlling the immune system, perhaps lowering inflammation and boosting the body's ability to fight infection. Some strains have been shown to increase antibody (IgA) production and promote the development of regulatory T cells, which help to modulate the immunological response.[27-29] *Lactobacillus paracasei* subsp. *paracasei* NTU 101 is known to reduce skin inflammation and symptoms of allergic reactions by maturing regulatory T cells (Tregs) and raising the expression of Forkhead box protein P3 (FOXP3), which helps regulate the immune response.[27]

Some strains are known to decrease cholesterol. *L. paracasei* TISTR 2593, for example, reduces obesity via altering adipogenesis (the development of fat cells).[30] Other strains, including *L. paracasei* 8700:2, have been shown to lower triglycerides, reduce the severity of metabolic syndrome, and delay weight gain.[31] *L. paracasei* supplements have the potential to improve endothelial function by lowering cholesterol levels.[31] Another study demonstrated that the *L. paracasei* NL41 strain might reduce insulin resistance and oxidative stress while also maintaining beta cell function.[32]

The gut microbiota and gut-brain axis modulate signaling, which influences emotional behavior and the stress response system. Probiotics have been shown to benefit gut, brain, and mental health by altering gut microbiota and modulating the gut-brain axis. Randomized controlled trials of *L. paracasei* Lpc-37® and *L. paracasei* K56 were found to reduce stress-related biomarkers.[33,34] Another role of *L. paracasei* in oral health is that it can help prevent dental caries (cavities) by reducing the presence of harmful bacteria. *Lactobacillus paracasei* SD1 was found to inhibit mutans *streptococci* (MS), thereby reducing caries in a randomized controlled trial.[35]

Lactobacillus paracasei is also known for its ability to suppress the growth of certain harmful bacteria, thus exhibiting antibacterial activity. This is accomplished through a variety of methods, including the synthesis of antimicrobial compounds and competition with pathogens for nutrients and attachment sites in the intestine.[24,36] Several investigations have indicated that *L. paracasei* has antibacterial efficacy against *E. coli*.[20,24,36,37] In addition, *L. paracasei* has effects against *Bacillus cereus*, *Acinetobacter baumannii,*[24] *S. aureus,*[36,37] *P. aeruginosa*[38] and *mutans streptococci.*[35]

L. paracasei generates bacteriocin-like compounds that have antibacterial properties. These chemicals can increase bacterial membrane permeability, disrupt cell membranes, and cause intracellular leakage. These chemicals can also inhibit protein synthesis and bind to genomic DNA.[38] Furthermore, *L. paracasei* has demonstrated substantial antibiofilm efficacy against several pathogens, particularly those linked to oral and gastrointestinal illnesses. Its various mechanisms of biofilm disruption include inhibition of biofilm formation, eradication of mature biofilms, production of antibacterial substances, and competition for resources.

L. paracasei can create numerous chemicals, including biosurfactants and postbiotics, that can directly inhibit or kill harmful bacteria within biofilms.[39-42] Studies have demonstrated the ability of *L. paracasei* to inhibit biofilms of *Vibrio parahaemolyticus* and *Salmonella typhimurium*, both known to cause gastrointestinal problems.[41,42] *L. paracasei* has also been shown to be effective in combating biofilms formed by other pathogens, including *Listeria monocytogenes.*[12] Furthermore, Ghane et al. demonstrated that neutralized cell-free supernatants from *L. paracasei* strains LAB2 and LAB4 reduced the growth and biofilm formation of uropathogenic *E. coli.*[43]

Current Research and Future Research Potential of *L. paracasei*

Current research on *L. paracasei* focuses on its potential health benefits, particularly in areas such as cardiometabolic health,[30,34] gut health,[14] and immune function.[29] Studies highlight its ability to influence gut microbiota composition,[44,45] increase gut barrier function,[44] and modulate the immune system.[29] Specifically, *L. paracasei* strains have shown promising results in reducing inflammation, improving lipid metabolism,[46] and even potentially impacting life expectancy and anti-aging effects.[47]

Current research also examined the role of *L. paracasei* as an antibiofilm. The results revealed that *L. paracasei* was effective inhibiting biofilm formation against *Streptococcus mutans*[48] and *Pseudomonas aeruginosa.*[12] More research is needed to completely understand the particular pathways through which *L. paracasei* exerts its antibiofilm actions. The antibiofilm activity of *L. paracasei* can vary between strains, further study should be conducted to determine which strains are most useful for various applications. Clinical trials are required to determine the efficacy and safety of *L. paracasei*-based therapies for biofilm-related diseases in humans.

The potential of specific *L. paracasei* strains to treat various diseases as therapeutic targets is an exciting prospect for future research. Individual responses to *L. paracasei* differ depending on genetics and gut microbiota composition, paving the way for tailored probiotic therapies. Research into the use of postbiotics generated from *L. paracasei* could provide new pathways for therapeutic therapies. Studies have shown that *L. paracasei* can enhance the antitumor effects of chemotherapy drugs such as 5-FU in colorectal cancer models.[49] Further research could explore its potential as a complementary therapy for other cancers. Research on the anti-aging effects of *L. paracasei* HII01 in *C. elegans* suggests potential benefits for healthy aging and longevity.[47] Further human studies are needed to examine its potential for aging prevention. Recent studies have explored the use of *L. paracasei* in novel fermented beverages. This includes sour beer trials with *Spondias mombin* juice supplementation that demonstrated both feasibility and enhancement of functional properties.[50] Future study on *L. paracasei* could include optimizing its application in food production and investigating its impact on flavor and nutritional profile.

CONCLUSION

L. paracasei is one of the probiotics isolated from various fermented foods around the world. It possesses many benefits for human health. Studies have revealed that this microorganism can stimulate the immune response and reduce cholesterol levels. Furthermore, it exhibits antioxidant, antimicrobial, anti-aging, and antibiofilm properties. In addition, some strains of *L. paracasei* may help reduce stress-related biomarkers. Current research on *L. paracasei* primarily focuses on gut, cardiometabolic health, and the immune system. Further studies should explore its potential benefit in disease treatment.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest

AUTHORS' CONTRIBUTION

All authors listed have made a substantial, direct and intellectual contribution to the work, and have approved it for publication.

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DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors.

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