



Research Progress of *Lysinibacillus*: Classification, Function and Application

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Abstract

Among commonly used probiotics, *Bacillus* has become a research hotspot due to its strong stress resistance, good stability, and tolerance to oxidation and acid/alkali. Additionally, *Bacillus* exhibits growth-promoting and disease-preventive effects, making it a potential alternative to antibiotics, a feed additive, and a water quality regulator. Currently, *Bacillus* species primarily studied in domestic aquaculture research include *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus cereus*, and *Bacillus coagulans*. In contrast, research on *Bacillus lysine* has mainly focused on isolation, screening, and identification. This article reviews the research progress of *Bacillus lysine*, covering its classification, functions, applications, and future prospects.

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1. Introduction

1.1. Origin and Characteristics of *Lysinibacillus*

The genus *Lysinibacillus* was reclassified from the genus *Bacillus* in 2007. Traditional classification primarily relied on phenotypic characteristics, with insufficient genomic evidence. In 2025, a comparative whole-genome study published by SpringerLink filled this gap. Through genomic analysis of 4 spherical *Lysinibacillus* (*L. sphaericus*) strains and 24 representative strains, it was confirmed that the genus forms an independent branch in the core gene composition and phylogenetic tree. Key differences from *Bacillus* were concentrated in metabolic pathways and cell wall/membrane biosynthesis gene clusters.

Bacillus lysinefermentans is a Gram-positive bacterium, typically rod-shaped and facultatively anaerobic, capable of forming endospores. It thrives under conditions of 25-40° C (optimal 30° C), pH 7.0-9.0, and tolerates NaCl concentrations of 0-7% (w/v). The bacterium can utilize glucose, sucrose, cellulose, and mannitol as carbon or energy sources. *B. lysinefermentans* is widely distributed, primarily in the atmosphere, soil, and water sources, and is also found in industrial wastewater, leachate from landfills, plant rhizosphere, animal intestines, and livestock manure.

Studies have demonstrated that *Bacillus lysine* isolate from soil can not only remediate cadmium-contaminated soil but also produce biosurfactants. *Bacillus lysine* isolate from water sources is capable of degrading 3-chloroacetic acid and exhibits superior performance compared to most bacteria in generating surfactants and biocatalytic emulsifiers. A *Bacillus lysine* strain isolated from wastewater treatment plant sludge, which utilizes m-cresol as its sole carbon source, serves as an ideal microbial agent for phenolic compound removal and pollution mitigation. *Bacillus lysine* isolate obtained from landfill leachate can utilize diester of phthalic acid as its exclusive carbon source. *Bacillus lysine* isolate isolated from banana tree roots demonstrates significant dissolution index when decomposing phosphate. Two *Bacillus lysine* strains isolated from termite intestines both exhibit strong cellulose-degrading capabilities. A *Bacillus lysine* strain isolated from livestock manure, which can degrade oxytetracycline, provides a green pathway for treating poultry manure and wastewater.

The core phenotypic characteristics of this genus have been clearly defined: the cell wall peptidoglycan contains lysine-D-aspartate residues, the respiratory chain primarily uses MK-7 as the main quinone, and the polar lipids of the cell membrane are predominantly composed of diphosphatidylglycerol and phosphatidylglycerol. Notably, its spores exhibit remarkable stress resistance and have been discovered in amber dating back 25-40 million years, providing a unique model for the study of extreme environment microorganisms.

2. Functions of Bacillus Lysine

2.1. Synergistic Disease Resistance Mechanism

The 2025-2026 study by Microbiome and Shandong Agricultural University revealed a novel role model of *Bacillus lycii* in plant disease control. In the prevention and control of apple root rot disease (ARD), when the disease-resistant rootstock (CG935) was infected by the pathogen *Fusarium proliferatum* MR5, it specifically activated the lysine synthesis pathway. The expression levels of key rate-limiting enzymes (aspartate kinase and dihydropyridine dicarboxylic acid synthase) were 2.79-6.81 times higher than those in susceptible rootstocks, leading to a significant increase in rhizosphere lysine secretion. This metabolic signal directed the recruitment of *Bacillus lycii*, resulting in a 40.73% increase in its relative abundance, forming a "plant-metabolite-microbe" synergistic defense system. The recruited strains produced antifungal compounds such as 2,4-di-tert-butylphenol and bacitracin, which directly inhibited the germination of pathogen spores and mycelial growth. Pot experiments confirmed that the synergistic treatment of lysine and this fungus significantly reduced the number of rhizosphere pathogens, enhanced soil enzyme activity, and strengthened microbial network modularization, resulting in a 31.18% increase in the fresh weight of apple seedlings. This provides a novel pathway for green control of soil-borne diseases.

The misuse of chemical pesticides has led to increased insect resistance, resulting in more frequent pest outbreaks. From an ecological perspective, biological pesticides are superior to chemical pesticides. The primary reason for this is that biological pesticides are more targeted, toxic only to the intended organisms, and non-toxic to non-target organisms. For example, *Bacillus lysinicus* can be used for mosquito control. Additionally, *Bacillus lysinicus sphaericus* exhibits toxicity to earthworms, German cockroaches, and nematodes, which is closely related to the toxins it produces (including Mtx1, Mtx2, Bin, etc.). These toxins can act independently or synergistically. *Bacillus lysinicus sphaericus* has been proven to possess strong antibacterial activity, inhibiting the growth of *Bacillus subtilis*, *Staphylococcus aureus*, and *Escherichia coli*. *Bacillus lysinicus odysseyi* can produce gold nanoparticles (AuNPs) extracellularly, and these AuNPs exhibit antibacterial properties.

2.2. Growth Regulatory

Effects A 2026 study published in SciSpace first elucidated the core function of *Bacillus licheniformis* as a plant growth-promoting rhizobacterium (PGPR). All 12 tested strains could synthesize indole-3-acetic acid (IAA) at concentrations ranging from 20 to 70 $\mu\text{g/mL}$, with IAA synthesis genes via the indole pyruvate pathway present in all strains. Some strains also possessed genes for tryptophan pathway

synthesis. Greenhouse experiments demonstrated that six strains significantly enhanced maize biomass and root architecture at an inoculation concentration of 10^8 CFU/mL. Five of these strains simultaneously promoted *Arabidopsis thaliana* growth and partially reversed root defect phenotypes in *aux1-7/axr4-2* mutants, confirming IAA synthesis as the key mechanism of their growth-promoting effects. This discovery expands the application potential of the genus in biofertilizer fields. In mice, soil-derived *Bacillus licheniformis* inhibited the abundance of pathogenic and opportunistic bacteria in the gut while increasing beneficial bacterial populations, and also exhibited potential for reducing hypertension.

2.3. Environmental Remediation Potential

In recent years, fuels, aromatic hydrocarbons, heavy metals, synthetic substances, and industrial waste have caused severe water, soil, and air pollution. Microbial remediation methods are not only highly efficient but also cost-effective. The genome sequence of *Bacillus lysiniformis* contains coding sequences for S-layer proteins and heavy metal efflux pumps, enabling it to exhibit resistance to heavy metals such as As, Sb, Ni, Zn, Cu, Cd, Te, Cr, Mn, and Co in contaminated environments. *Bacillus fusiformis* can regulate jasmonate signaling by synthesizing acetic acid, which helps inhibit cadmium uptake in tomato plants.

3. Research Progress on Bacillus Lysine

Currently, *Bacillus lysine* has been widely applied in ecological restoration, disease control, and growth promotion. In environmental remediation research, *Bacillus lysine* has been found to decompose plastics. Polyethylene and polypropylene, which are extensively used in plastic production, are difficult to degrade in natural environments. Studies have demonstrated that *Bacillus lysine* can decompose 4% of polyethylene and 9% of polypropylene within 26 days, respectively. In disease control, a strain of *Bacillus lysine* isolated from the rhizosphere of *Cynanchum officinale* produces a mixture of rhamnolipids, a biosurfactant that inhibits the biofilm formation of pathogenic bacteria (*Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Serratia marcescens*), thereby suppressing their growth.

In promoting plant growth, a spherical *Bacillus lysine* isolate from the root zone of maize enhances plant growth by producing phytohormones and iron carriers, while also solubilizing minerals, generating hydrolytic enzymes and antifungal metabolites, and demonstrating positive effects in biological disease control.

In aquaculture, *Bacillus lysine* can also play a positive role. For instance, in the cultivation of *Macrobrachium vannamei*, the addition of *Bacillus lysine* not only regulates ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen in the water but also promotes shrimp growth and improves survival rates. Wang *et al.* also found that the application of *Bacillus lysine* enhances the antioxidant and immune capabilities of zebrafish and increases gut microbiota diversity.

To address the demand for safe L-lysine-producing strains in the feed industry, the research team employed CRISPR-Cas9 technology to perform metabolic engineering on *Bacillus subtilis* (a feed-grade safe strain), constructing a dual-functional strain capable of "probiotic function + L-lysine synthesis." This study resolved the endotoxin issue associated with traditional *Escherichia coli* and *Corynebacterium glutamicum* production strains, meeting the safety standards

for feed additives and laying the foundation for industrial application.

Currently, *Bacillus* has been widely applied as a probiotic across various industries, yet research on *Bacillus licheniformis* remains underdeveloped, particularly regarding its probiotic effects and mechanisms of action on postbiotics.

4. Application Scenario Expansion and Future Directions

Currently, the applications of *Bacillus lysine* have covered three major fields: Biological control: *Bacillus lysine globosus* produces mosquito-killing toxins (Bin protein, Mtx toxin, Cry48/Cry49 complex), demonstrating higher larval mortality efficiency than *Isolium cerasi* Israel subspecies and stronger field persistence, making it a crucial biological agent for mosquito-borne disease control; Agricultural cultivation: As a PGPR formulation and soil-borne disease biocontrol agent, it reduces the use of chemical fertilizers and fungicides; Feed industry: The dual-functional recombinant strain achieves integrated supply of "probiotics + amino acids," simplifying production processes.

Future research priorities include: elucidating the molecular mechanisms of signal interactions between *Bacillus lycosus* and plant roots; optimizing fermentation processes of metabolic engineering strains to reduce L-lysine production costs; exploring resources of extreme environment strains to expand their applications in bioremediation, pharmaceuticals, and other fields; improving mosquito-killing strains based on genome editing technology to enhance toxin yield and environmental adaptability.

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