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Biocatalytic transformation of Ganoderma lucidum by porcine pancreatic lipase in hydrophobic deep eutectic solvents

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Abstract

Enzyme applications in industry are often limited by low stability, poor reusability and challenging recovery. This study presents a sustainable strategy for enhancing enzyme performance by immobilizing porcine pancreatic lipase (PPL) onto Ganoderma lucidum using a hydrophobic deep eutectic solvent (HDES) as a reaction medium to facilitate enzyme immobilization. Among several HDESs tested, menthol:decanoic acid (HDES 1) showed the highest lipase activity (198.38%) and was selected for immobilization. Under optimized conditions (3 h, 40 °C, pH 7.0), the immobilized PPL achieved 212.41% catalytic efficiency, a 13 day half-life and retained activity over two reuse cycles. FTIR analysis revealed a shift in the secondary amide band from 3312 to 3306 cm^{-1}, indicating modifications in protein hydrogen bonding. BET and EDX analyses confirmed enzyme adsorption and successful loading, while GC−MS identified fatty acid derivatives, demonstrating effective catalysis. Notably, HDES 1 enabled the immobilized enzyme to replace hexane in esterification reactions, achieving ~90% fatty acid conversion surpassing the free enzyme. Molecular docking further highlighted strong interactions between HDES 1 and PPL's catalytic residues, validating its stabilizing role. Overall, the G. lucidum-HDES 1 platform provides a green, efficient and versatile biocatalytic system with significant potential for bioenergy production and sustainable applications in the oil industry. © 2026 Elsevier B.V.

Author keywords

Enzyme immobilization; Green solvent; Menthol-decanoic acid

Indexed keywords

MeSH
Animals; Biocatalysis; Deep Eutectic Solvents; Enzyme Stability; Enzymes, Immobilized; Esterification; Hydrophobic and Hydrophilic Interactions; Lipase; Molecular Docking Simulation; Pancreas; Reishi; Swine

Engineering controlled terms
Amides; Catalyst activity; Esterification; Eutectics; Green manufacturing; Hydrogen bonds; Hydrophobicity; Petroleum industry; Radioactive waste vitrification; Reusability; Solvents

EMTREE drug terms
decanoic acid; deep eutectic solvent; menthol; triacylglycerol lipase; deep eutectic solvent; immobilized enzyme; triacylglycerol lipase

Engineering uncontrolled terms
Decanoic acid; Deep eutectic solvents; Enzyme performance; Ganoderma Lucidum; Greener solvents; Hydrophobics; Immobilisation; Menthol-decanoic acid; Porcine pancreatic lipase; Sustainable strategies

EMTREE medical terms

animal experiment; Article; biocatalysis; bioenergy; Brunauer Emmett Teller method; crystallization; energy dispersive X ray spectroscopy; enzyme activity; enzyme immobilization; esterification; Fourier transform infrared spectroscopy; Ganoderma lucidum; hydrogen bond; hydrolysis; hydrophobicity; mass fragmentography; molecular docking; nonhuman; pH; pig; scanning electron microscopy; temperature; thermostability; animal; chemical phenomena; chemistry; enzyme stability; enzymology; metabolism; pancreas

Engineering main heading

Enzyme immobilization

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decanoic acid	334-48-5, 3398-75-2
menthol	1490-04-6, 89-78-1, 15356-70-4, 2216-51-5, 98167-53-4
triacylglycerol lipase	9001-62-1

Deep Eutectic Solvents

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