

From Extremes to Industries: Exploring the Potential of Extremophiles

Shubham Pandey¹, Bhavna Parmar¹, Anjali Gupta¹, Kuo-Wei Huang^{2*}, Ram Karan^{1*}

¹Department of Microbiology, University of Delhi South Campus, New Delhi, India

²King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia

*Corresponding author

ABSTRACT

Enzymes are essential in industrial applications and are important in developing pharmaceuticals, food production, bioremediation, and biofuel production. However, their instability in extreme industrial conditions, including high salinity, extreme pH, and thermal variations, continues to be a major bottleneck, raising costs and decreasing efficiency. Extremophiles, organisms uniquely adapted to thrive in harsh environments, represent a promising source of robust enzymes and bioactive compounds. Our study identified 42 extremophilic bacteria and archaea from various salt pans and lakes. These microbes produce industrially relevant enzymes, including lipases, esterases, proteases, amylases, laccases, peroxidases, cellulases, and xylanases, all exhibiting exceptional stability and functionality under extreme conditions. Simultaneously, next-generation sequencing (Illumina NovaSeq X Plus) was used to explore unculturable microbial diversity. Functional annotation using COG, KEGG, GO, and Pfam identified enzymes and pathways with significant biotechnological potential. Our work highlights the critical role of extremophilic microbes and their enzymes in addressing industrial challenges from pharmaceuticals to biofuel production. These environmentally friendly enzymes serve as potent, low-cost natural catalysts, supporting the development of low-carbon, renewable technologies.

Keywords: Extremophiles, Extremozymes, Halophiles, Psychrophiles, Haloalkaliphiles, polyextremophiles, Industrial enzymes, Next-generation sequencing

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