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LIPASES FROM THERMOPHILIC BACTERIA: PROPERTIES AND PROSPECTS FOR FOOD AND INDUSTRIAL BIOTECHNOLOGY

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Abstract: Lipases from thermophilic bacteria combine catalytic versatility with high stability to temperature, alkaline pH and organic solvents. Based on an analysis of recent literature, this paper summarizes their sources, structural and biochemical features and the main areas of application, with emphasis on the food industry. Thermophilic bacterial lipases from the genera *Geobacillus*, *Anoxybacillus* and *Aeribacillus* are active at 50–75 °C and pH 8–11, tolerate organic solvents and detergents, and can be further stabilized by protein engineering. Their use is promising in dairy flavour development, fat processing, detergents and biodiesel production.

Keywords: thermophilic bacteria, lipase, *Geobacillus*, *Anoxybacillus*, *Aeribacillus*, thermostability, food biotechnology.

Annotatsiya: Zamonaviy adabiyotlar tahlili asosida termofil bakteriyalar lipazalarining manbalari, tuzilishi, biokimyoviy xususiyatlari va qo‘llanilish sohalari umumlashtirilgan. *Geobacillus*, *Anoxybacillus* va *Aeribacillus* turkumlari lipazalari 50–75 °C va pH 8–11 da faol, organik erituvchilar va detergentlarga chidamli bo‘lib, sut sanoati, yog‘larni qayta ishlash, yuvish vositalari va biodizel ishlab chiqarishda istiqbolli hisoblanadi.

Kalit so‘zlar: termofil bakteriyalar, lipaza, *Geobacillus*, *Anoxybacillus*, *Aeribacillus*, termobarqarorlik.

Аннотация: На основе анализа современной литературы обобщены источники, структурно-биохимические свойства и области применения липаз термофильных бактерий. Липазы бактерий родов *Geobacillus*, *Anoxybacillus* и *Aeribacillus* активны при 50–75 °C и pH 8–11, устойчивы к органическим растворителям и детергентам и перспективны для молочной промышленности, переработки жиров, производства моющих средств и биодизеля.

Ключевые слова: термофильные бактерии, липаза, *Geobacillus*, *Anoxybacillus*, *Aeribacillus*, термостабильность.

Introduction

Lipases (triacylglycerol hydrolases, EC 3.1.1.3) catalyse the hydrolysis of long-chain triacylglycerols at the oil–water interface and, under low-water conditions, the reverse reactions of esterification and transesterification. Most of them possess a mobile lid domain over the active site, whose opening at the interface is responsible for interfacial activation [1, 4]. Microbial lipases dominate industrial use, and bacterial enzymes are especially valued for their activity at neutral and alkaline pH [1]. Many technological processes, however, run at elevated temperatures, which inactivate mesophilic enzymes. Thermophilic microorganisms are therefore regarded as a key source of robust biocatalysts for industry [2]. The aim of this work was to systematize current data on lipases from thermophilic bacteria and to assess their application potential, especially in the food industry.

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Methods

The study is based on an analysis of recent (2023–2026) peer-reviewed publications on the production, characterization, engineering and application of microbial and thermophilic bacterial lipases. Data on enzyme sources, temperature and pH optima, stability and application areas were compared and generalized.

Results

Among the reported thermophilic producers of lipases are *Geobacillus*, *Bacillus*, *Anoxybacillus*, *Aeribacillus* and *Thermus* species, and thermophilic enzymes generally work best in the range of 50–80 °C [2]. Subfamily I.5, represented mainly by *Geobacillus* lipases, has been studied most thoroughly. Its members are proteins of roughly 43–45 kDa that bind calcium and zinc ions, a feature linked to their heat tolerance, and they retain their structure in the presence of organic solvents [3]. For example, the recombinant lipase Lip7 from the Antarctic thermophile *Geobacillus* sp. ID17 showed maximum activity at 50 °C and pH 11.0, and its activity increased up to 250% in 50% (v/v) ethanol [3]. The lipase of *G. zalihae* T1 has an optimum of 70 °C and pH 9; a single substitution (F180C) raised its optimum to 75 °C and its melting temperature from 73.5 to 78.2 °C, while also improving its stability in organic solvents [4]. Representatives of the less studied genera show similar properties. A lipase of about 73 kDa purified from *Anoxybacillus gonensis* UF7 was most active and stable at pH 8.0 and 60 °C, kept its activity when methanol, ethanol or non-ionic and anionic surfactants were added, and converted waste frying oil into biodiesel with a yield of 87.7% [6]. A lipase of about 34 kDa from *Aeribacillus pallidus* IO3, isolated from a geothermal spring in Erzurum (Türkiye), had its optimum at pH 8.0 and 50 °C, retained 45–69% of its activity after 2 h at 70–80 °C, preferred the long-chain substrate p-nitrophenyl palmitate and was activated by chloroform and surfactants [5]. In addition, a *Bacillus* sp. lipase with a pH optimum of 9.5 and a temperature optimum of 60 °C hydrolyses natural fats and oils, which is relevant for food processing [2].

Discussion

The combination of thermostability, alkaline tolerance and solvent resistance determines the practical value of these enzymes. In the food industry, microbial lipases are used for the controlled hydrolysis of milk fat to develop cheese flavour [1]. Thermostable variants are also of interest for the modification of fats and oils, where higher process temperatures keep substrates liquid, lower viscosity and reduce the risk of microbial contamination. Outside the food sector, these enzymes are used in laundry and cleaning formulations and for the enzymatic conversion of oils, including waste frying oil, into biodiesel [1, 5, 6]. Remaining challenges include relatively low yields in native strains, the cost of purification and immobilization, and the need to confirm the safety of producer strains for food use. Recombinant expression and rational protein engineering, as shown for *G. zalihae* T1, offer effective ways to overcome these limitations [3, 4].

Conclusion

Lipases from thermophilic bacteria of the genera *Geobacillus*, *Anoxybacillus* and *Aeribacillus* are promising biocatalysts for processes requiring high temperature, alkaline pH or organic solvents. Screening of thermophiles from local extreme habitats, such as the hot springs of Central Asia and the Caucasus, combined with protein engineering, may provide new enzymes for food, chemical and environmental biotechnology.

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