# Chapter 10
# Industrial Applications of Enzymes From Extremophiles

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## ABSTRACT

*Extremophilic microorganisms have developed a variety of molecular tactics to exist in extreme environments. Researchers are fascinated by extremophiles and unearth various enzymes from these fascinating microbes. Extremozymes are astonishing biocatalysts with distinctive properties of catalysis and stability under a multitude of daunting conditions of salt, pH, organic solvents, and temperature, which open up new possibilities for biocatalysis and biotransformation and outcompetes mesophilic counterparts. Biotechnological implications include simple, immobilized, as well as whole-cell applications. Stability in organic solvents adds to the asymmetric catalysis and thereby exemplifies the applicability of extremozymes and in fostering biobased economies. Marine, cold-adapted enzymes, and those that help in the removal of a toxic hazardous substance from the environment are obvious choices for food industries and bioremediation. The major area of application and research emphasis includes textile, detergents, food, dairy, agriculture, and environmental remediation.*

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## INTRODUCTION: EXTREMOPHILES AND BIOCATALYSTS ASSOCIATED INDUSTRIES

The current and future applications of extreme environment tolerating microorganisms and their enzymes in the field of biotechnology are discussed in this chapter. The microbial biotechnology has enormous advantages be it in the field of environment, product manufacturing or industrial processes for value added commercial products. The microbial approach to these processes has given it a new and improved eco-friendly dimension. This is now applied for management of different type of wastes generated by various industries. Microbial bioengineering contributes to the development of long-term technologies with a variety of process and market advantages. Microbial biotechnology has a number of advantages, including the ability to produce existing and novel products in a sustainable manner, as well as a reduce dependence on non - renewable fuels and many other resources, which improves industrial economics. Since 1970s, biotechnology and enzymology in particular has had a considerable influence on many sectors including healthcare, medicine, food, agriculture, environment and synthesis of fine chemicals. Until enzymes that could tolerate organic and biphasic conditions were discovered, "white biotechnology" was primarily based on aqueous enzymology (Vashist and Sharma, 2018).

The usage of enzymes extracted from microbes is beneficial to hundreds of industrial processes and products. However, the bulk of enzymes now on the market are made with mesophilic enzymes, which are frequently inhibited under extreme condition in industrial processes (Raddadi et al., 2015). Additionally, bio catalytic stability is important for cost reduction since enzymes that are stable enough to endure industrial conditions can be used for several cycles of the bio catalytic process, resulting in cost savings. The discovery of extremophilic bacteria opens the door to the synthesis of extremozymes that are stable in a variety of environment, which might be beneficial in industry applications. Enzymes which catalyze reactions in non-physiological environments and/or using non-natural molecules can also be found in extreme environments (Littlechild, 2015). As a result of their resilience to extreme physico-chemical conditions, extremozymes have grown at a rapid pace for their use in various industrial processes.

Extremophilic bacteria, on the other hand, have extremely flexible metabolisms and unique structural characteristics in their bio macromolecules that allow them to survive and grow in these hostile environments (Dalmaso et al., 2015). These extremophilic organisms have a wide range of functions and are taxonomically diverse too. The main categories of extremophiles and some examples are listed below in Table 1. These include the microbes that tolerate temperature extremities, specifically the psychrophiles, hyperthermophiles and thermophiles; alkaliphiles and acidophiles, which tolerate pH extremes; barophiles (piezophiles) which survive optimally under high pressure; halophiles, which thrive in high-salinity environments; xerophiles, which tolerate low water activity, and radioresistant organisms, which tolerate high levels of radioactivity that pose lethal effects on almost all organisms.

According to Dewan (2014), the market for industrial enzymes was expected to grow at an annual average growth rate of 8% in the next 5 years, reaching US$ 7,100 million by 2018. Microbes that produce novel hydrolytic enzymes, with biotechnological potential and remarkable activity at low temperatures are now being sought. Due to their biodegradability and exceptional stability, extremophilic microbes are a source of extremozymes with a wide range of commercial applications (Dumorne, et al., 2017). As biocatalysts, extremozymes are stable and active even within extreme environmental conditions traditionally thought to be incompatible with biology. Cold-tolerant, alkali-tolerant, acid-tolerant and salt-tolerant extremozymes are just a few of the resistant biomolecules that have been made possible by

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