Economic Importance of Extremophilic Microorganisms

Sneha Mishra[1], Ghosh M [1,]

1Department of Bioengineering and Biosciences, Department of Molecular Biology, Lovely Professional University, Punjab-144411, India.

Abstract

Extremophile bacteria are known to be able to survive in extreme conditions such as high temperature in volcanic springs or low temperature in Polar Regions, in high atmospheric pressure in the deep sea, in extreme pH and high or low salt concentration. This is all possible because they produce unique enzymes that are responsible for these characteristics of extremophiles. So, some of these enzymes are being purified and then their genome is sequenced and further, they are cloned into a host, e.g.,- amylases, xylanases, chitinases, cellulases, etc. Some are DNA modifying enzymes with potential use in pharmaceuticals, food and chemical industries and are also used in environmental applications.

***Keywords*:** Extremophile, Enzymes, Pharmaceutical uses

Introduction

Extremophiles are said to be those living creatures that are present in extreme conditions and they can grow and flourish in extreme climatic conditions as they can grow in extremely hot conditions and extreme cold conditions. They can be also grown at extremely acidic and alkaline conditions. They are of utmost and immensely important to every industry from food to fabric to the pharmaceutical industry. They help in enhancing the production and quality of products. There are several extremophiles like psychrophiles, thermophiles, acidophilus, halophiles microorganisms.

They all have a different and crucial role to play in industries. These organisms use biocatalyst that makes them valuable. Biocatalyst enhances the rate of reaction that makes them useful for the industrial process. Thermophile organisms can grow at high temperatures. Enzymes like celluloses, xylanases, chitinases, pectinases can be obtained from thermophile organisms. Thermophile enzymes can undergo proteolysis under adverse conditions. Thermoenzymes have electric interactions and they can keep their configuration intact that help them to be active at high temperature. They are used as an additive to detergents and brewing and baking industries biodiesel industries and esterification.

Extremophiles are divided into 5 categories—thermophiles (high temperature), acidophiles (low pH), alkaliphiles (high pH), halophiles (high salinity), and psychrophiles (low temperature). The number of hyperthermophilic archaea has been isolated that can grow around the boiling point of water such as Pyrobaculum, Pyrodictium, Pyrococcus and Methanopyrus. So far more than 60 species of thermophilic archaea have been discovered. Metabolic processes and specific biological functions of these microorganisms are mediated by enzymes and proteins that function under extreme conditions. The enzymes that have been isolated recently from these exotic microorganisms show unique features, are extremely thermostable and usually resistant against chemical denaturants such as detergents, organic solvents, and extremes of pH.

Psychrophilic are organisms that thrive at very low temperature. Basically in Arctic and Antarctic regions. They harbor several enzymes like Amylases and proteases. They are used on a large scale in detergent feeds and textile biosensors. They are active at low temperatures due to vitrification and desiccation.

Halophiles are those organisms that can grow in high salt conditions and require one molar salt at least for growth and can grow in high salt conditions. Halophilic enzymes have high amino acid residues like serine and threonine. So halophiles are used in peptide synthesis.

Mesophyll can grow at a moderate temperature ranging from 20- 40 degrees Celsius. They can be used in the production of probiotics and sludge treatment. Acidophiles, as name suggests, are capable to thrive at low ph and in acidic conditions. They can grow in volcanic springs and they can be used in starch processing and single-cell protein from waste due to the presence of amylase and glucoamylase.

Habitats and the sources

The nature of the habitats favored by these microbes includes hot springs, shallow submarine hydrothermal systems, or hot-vent- vent systems, where microorganisms can be found at temperatures above 100℃. Extremophiles are also found in highly saline lakes or salters, sometimes at salt conditions near that of saturation, and in environments with extreme pH values, either acidic (acidic fields and acidic sulfur dominated areas) or alkaline (freshwater, alkaline hot springs, alkaline soils, and salt lakes). The sources of psychrophilic organisms include the cold polar seas and soils and Alpine glaciers, as well as deep-sea, sediments, which are cold and are also at high pressures. Some of the examples are mention in Table 1.

Condition	**Microorganism**	**Source**	**Growth Condition**	**Characteristics**
Low temperature	*Bacillus TA41, Polaromonas vacuolata*	Deep sea water	4℃	Aerobic heterotroph
High temperature	*Pyrococcus Furiosus, Thermotoga neapolitana*	Geothermal marine sediments	85-100℃	Anaerobic heterotroph
High-temperature High pH,	*Methanococcus Jannaschii, Clostridium paradoxum*	Deep-sea Hydrothermal vents Sewage sludge	85°C, 250 atm, pH 10.3	Methane/growth production, Anaerobic heterotroph

Low pH, High temperature	*Metallosphaera sedula*	Hot acid pools	pH 2.0, 75°C	Facultative chemo- lithotroph
High Salt	*Halobacterium halobium, Halobacterium salinarum*	Hypersaline waters	4–5 M NaCl	Aerobic heterotroph

Production and applications of biocatalysts from extremophiles

Amylases

The alpha-amylase family consists of a large number of starch hydrolases. Most stable alpha-amylase is extracted from *pyrococcus woesei,pyrococcus furiosus and thermococcus profundus*. The optimum temperature for the activity of these enzymes is 100℃, 100℃ and 80℃ respectively. Genes that encode for alpha-amylase in P.furiosus is recently cloned in *Bacillus subtilis* and *E.Coli*.

•Amylases are commonly used in starch liquefaction that converts starch into glucose and fructose syrups.

•Formulation of enzymatic detergents. 90% of all liquid detergents contain amylase.

•Bioconversion of starch into ethanol

Thermoactive Pullulanases

These are extracted from *P.furiosus* and *Thermococcus litoralis*. They are extremely thermostable and can attack both alpha 1-4 and alpha 1-6 glycosidic linkages. An only thermostable debranching enzyme is known to attack amylopectin. Purified recombinant enzyme is stable at 100℃. Pullulanase is known to improve the industrial starch Hydrolysis process.

Proteases

Proteases are used for the conversion of proteins to amino acids and peptides. A variety of heat-stable proteases has been identified in the thermophilic archaea of genera- *Desulfurococcus, Sulfolobus, Staphylothermus, Thermococcus.*

•Used in detergent industries as it digests stains due to food or other body secretions.

•Used for enzyme-mediated leather processing which improved quality of leather and causes low environmental pollution

•In food industries, they are used to improve nutritional values

•In the dairy industry proteases are used in cheese manufacturing to hydrolyze specific peptide bonds

Xynalases

Xylan is a heterogeneous molecule. Its main chain is composed of xylose residues linked by beta 1,4 glycosidic linkage. The endo beta 1,4 xylanase hydrolyzes these linkages. Few microorganisms can secrete this enzyme- *Dictyoglomus thermophilum, Thermotoga sp.* Xylanase from bacteria and eukarya comprises of 10-11 families with a wide range of biotechnological application

•Used as food additives in poultry for increasing feed efficiency

•In wheat flour for improving dough handling and quality of baked products

•Major interest is in enzyme aided bleaching of paper

Cellulases

A Thermostable cellulase from *T.maritima* has been isolated which is of molecular mass 27 kDa and is active at 95℃. The two thermostable endocellulases CelA and CelB are obtained from *Thermotoga neapolitama*

•These enzymes are used in commercial food processing of coffee

•Also used in the fermentation of biomass into biofuels

•Medically used for the treatment of phytobezoars

•Used in textile and laundry industry

Potential applications

Heavy metal removal and recovery

Microorganisms can interact with heavy metals in a variety of ways that result in decreased metal mobility and solubility. Two important groups of microbes, the metal, and sulfate-reducing bacteria, have suitable physiology for metal precipitation and immobilization. The activities of these microbes provide metabolic products such as iron and hydrogen sulfide which lead to the mineral formation. These minerals can react with heavy metals, forming precipitation and hence detoxification.

Two strains of thermophilic bacteria belonging to the Bacillus family were isolated from a hot water stream and used to remove strontium from aqueous stream systems. These bacteria were able to concentrate strontium on one side of a two-compartment bioreactor. Immobilization of heavy metals using sulfide-producing microorganisms has been reported as an effective means of treating some metals-contaminated sites

Energy Production

Extremozymes are also employed in the production of hydrogen gas. The process of converting glucose to hydrogen is more efficient at higher temperatures, and thus it makes sense to replace some standard enzymes with extremozymes (hydrogenase). This hydrogenase is produced by the extremophile *Pyrococcus furiosus*, a strain of bacteria from a deep-sea hydrothermal vent (Raven et al., 1992). It works most efficiently at a temperature of 85°C.

Biopolymers

Several biopolymers have been developed from halophilic microorganisms. These include biosurfactants, exopolysaccharides, and bioplastics. Biosurfactants enhance the remediation of oil-contaminated soil and water. By decreasing surface tension, they increase the solubility and thus the mobility of hydrophobic hydrocarbons, which may promote degradation. The desirable properties of EPS include high melting temperatures, pseudo-plasticity, and resistance to salt, color, and thermal degradation. EPS are often used as emulsifiers and mobility controllers. Polyhydroxyalkanoate (PHA) are intracellularly accumulated bacterial storage compounds. These biodegradable plastics have properties comparable to those of polyethylene and polypropylene.

Microbial Leaching

Microbial leaching is considered to be a simple and effective process for extracting precious metals from low-grade ores and mineral concentrates. Remediation using bioleaching has an economic advantage because it involves low capital and energy costs, high flexibility, and on-site application, and it does not cause environmental pollution.

Conclusion

Although several research findings have explored some of the unique features of extremophiles, some physiological and metabolic characteristics of these microbes about their growth environment still need further study. The steady increase in the number of newly isolated thermophilic and hyperthermophilic microorganisms and the related discovery of their enzymes has enormous potential within this field. Although major advances have been made in the last decade, our knowledge of physiology, metabolism, enzymology, and genetics of this fascinating group of organisms is still limited. In-depth information on the molecular properties of the enzymes and their genes, however, has to be obtained to analyze the structure and function of proteins that are catalytically active around the boiling point of water. There is little doubt that extremophiles will supply novel catalysts with unique properties.

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