Chapter 8
Major Compatible Solutes and Structural Adaptation of Proteins in Extremophiles

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ABSTRACT

Extremophiles are the most ancient microbes on the Earth and also a center of attraction for the scientific community for research because of their ability to adapt to extreme habitats. Compatible solutes are among those factors which enable these microorganisms to thrive in such extreme habitats. Under osmotic stress, the majority of extremophiles accumulate specific organic solutes such as amino acids, sugars, polyols, and their derivatives. In addition, proteins in extremophiles are found to be evolved by changing their amino acid composition to alter the hydrophobicity of its core and surface charge to maintain activity. This chapter encompasses a comprehensive study about the role of various compatible solutes in the endurance of microorganisms under extremophilic conditions, synthesis of compatible solutes, nature of extremophilic proteins, and their applications. Furthermore, an attempt has been made to cover various strategies adopted by the scientific community while pursuing research on compatible solutes.

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INTRODUCTION

Over the previous decades, the scientific community had explored various extreme environments for the hunt of microorganisms that can thrive in them. Because of their ability to sustain life in extreme habitats, these microorganisms are entitled extremophiles. Extremophiles can be considered as an important key to the evolutionary history on earth since such habitats are existing on earth from the time of evolution. These organisms can survive in extreme hot niches, acidic, alkaline, salt solutions, and ice whereas some have the unique ability to grow in toxic waste (Alavi et al., 2020), organic solvents (Isken & de Bont, 1998), and heavy metals (Alavi et al., 2020). Extreme conditions mentioned above are intolerable for other earthly life-forms. The word 'extreme' in itself implies that they are capable of growing and surviving in uncommon conditions. These microorganisms utilize various strategies for adaptation to extreme habitats. Proteins and other molecules of extremophilic microorganisms can be great resources for mankind with unique biotechnological importance (Raddadi et al., 2015). The organisms are categorized as extremotolerant and extremophiles which indicates that former organisms can tolerate extreme environments while later love such harsh conditions respectively (Verma et al., 2020).

Most of these organisms fall under the domain of Bacteria and Archaea. This includes those that love the extremely high temperature and extremely low temperature known as Thermo/Hyperthermophiles and psychrophiles respectively, those that survive in high pH and low pH termed as Acidophiles and Alkalophiles respectively, organisms survive in high salt concentration known as Halophiles, those that thrive at high atmospheric pressure called barophiles and organisms which can withstand a high level of toxic agents are termed, toxitolerants (Rampelotto, 2013). As physicochemical parameters can be extremely high where these microorganisms are capable to live, they are also called polyextremophiles (Chela-Flores, 2013). A common example of polyextremophiles is thermoacidophiles which can survive in extremely high temperatures as well as they require acidic pH for survival. In addition to being extremely alkaline and acidic simultaneously, many hot springs are rich in metal content. Several hypersaline lakes are extremely alkaline, while the deep oceans are usually cold and oligotrophic (very low nutrient content) and exposed to high pressure (Strazzulli et al., 2020).

ADAPTATION TO THE EXTREME ENVIRONMENT

For any cell with smaller dimensions of micrometer-scale and a higher surface-to-volume ratio, surviving in an extreme environment could be a critical challenge. In the case of hyperthermophiles, to survive high temperatures for a lifetime, all the cell components must be either heat resistant or had adopted an alternative mechanism that aids in thermal stability. Therefore, they are evolved with the strategies to survive in extremely high temperatures (Berezovsky & Shakhnovich, 2005). Biomolecules required in the cell such as lipids, nucleic acid, and proteins must be heat resistant for survival in high temperatures. Structural and functional proteins available in the cells must be thermostable. Additionally, the process of protein folding must be synchronized in a manner to fold it appropriately immediately followed by protein synthesis to exert thermostability. Reverse gyrase is a type I DNA topoisomerase found in thermophiles, that stabilize DNA throughout the processes involving DNA such as replication, transcription, etc. (Garnier et al., 2021). Heat stability of the protein in hyper/thermophiles is due to the increased number of salt bridges and the highly hydrophobic interior of the protein. Membranes of these microbes are found to be rich in saturated fatty acids. In some thermophiles, special lipids are present such as hopanoids