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Microorganisms under extreme environments and their applications

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ABSTRACT

Extremophiles are group of microorganisms that possess ability to tolerate and live under the extremes of physico-chemical, geological and nutritional conditions. Such microorganisms are evolutionary relics and have evolved adaptation strategies at cellular, biochemical and molecular levels. They produce enzymes that are capable to maintain stability and function under the multitudes of extremities. These organisms also produce variety of other molecules and metabolites, such as extremolytes and surface-active compounds to protect against extremes of salinity, pH, pressure, temperatures and solar radiation. Investigations on these microorganisms can further open new avenues and opportunity for research and biotechnological applications in the areas of waste water treatment, bio-plastics, biofuel, cosmetics, agriculture, food and pharmaceuticals. Further, extremophiles have potential roles to play in bioremediation, astrobiology and biorefinery.

Microbes are omnipresent on earth and can survive different environmental conditions including geochemical, physical, nutritional and water scarcity (Lu and Hunter, 2018; Raddadi et al., 2015; Najar el al., 2018; Singh et al., 2018). Based on the temperature extremity, the microorganisms have been categorised as mesophile, psychrophiles, thermophiles and hyperthermophiles (Pérez and Sommaruga, 2006). Similarly, depending on pH, the extremophiles are diversified as acidophilic and alkaliphiles. While on the basic of salinity, the organisms are categorised as halophiles, hyperhalophiles and halo-tolerant. Further, the organisms able to live under high pressure are known as barophiles (Borroni and Benussi, 2019).

The salt-in strategy is employed by the halophiles that keeps concentrations of potassium and chloride balanced in coordination with the external environment (Capece et al., 2013). The cytoplasmic proteins require high salt concentrations to be stable and active. To achieve this aim, these microorganisms have an acid proteome, a system requiring relatively low energy inputs (Roberts, 2005). Psychrophiles survives cold habitats by employing two most rugged protein known as Cold Shock Proteins (CSPs) and Cold Acclimation Proteins (CAPs). CSPs are usually expressed under mild conditions, while CAPs are overexpressed after extreme cold shocks (Yamada et al., 2020). Conformational changes in the structures of the enzymes reduces rigidity of the protein core leading to lower interactions between inter-domains(Lu and Hunter, 2018).

Extremophiles are having significant characteristics that highlight their importance in nature. These microbes or their metabolites are exceptional and can perform élite tasks in nature and at industrial level. Extremophiles play important roles in regulating plant growth and crop productivity in regions with adverse conditions (Yadav et al., 2018). They can be used as biofertilizers and bio-inoculants as they are perfect candidate for nutrient cycling, nutrient fixation, mineralization, and solubilization (Singh et al., 2018). More recently, investigations are being focused on the rhizosphere microbiome as it plays significant role in plant growth and protection against pathogens, particularly under stress. In this context, the concept of minimal and core rhizosphere microbiome is highly significant. In recent studies, the bacterial diversity, their ecological roles and biocatalytic potential in the saline desert of Rann of Kutch have been investigated (Bhatt and Singh, 2022). The synergistic approach to the dairy bio-refinery predicts a zero-waste generation in the dairy industry, providing strength at the academic and industrial level for bio-refinery process development (Thakrar and Singh, 2019).

Extremophilic microorganism's secrets a huge range of bioactive compounds, secondary metabolites, and many vitamins and are valuable in the food and food processing industries (Raddadi et al., 2015). There are medical applications of extremophile, such as production of halocins, diketotapiperazines, PHAs, DNA polymerase, lipases suitable as recombinant vesicles (Kumar et al., 2022). Carotenoids, namely β-carotene and astaxanthin, play a crucial role in the color of the retinal macula thus in-turn offers protection from the sun (Inoue et al., 2017). Carotenoids also contribute to the production of antibiotics (Herrera et al., 2006). Thus, extremophilic microorganisms possess unique abilities in increasing crop yield and production of biofuels and bio- surfactants. They are also significant in nutrient cycling, therapeutical and food processing. Extremophilic environments like hot springs are generally devoid of antibiotic resistance genes (Najar et al., 2020) whereas psychrohilic environment like glaciers have antibiotic resistance genes and it is generally coexist with heavy metal tolerance genes (Sherpa et al., 2020). It provides an opportunity to understand mechanisms governing the acceptance, occurrence, and expression of numerous genes associated with antibiotic resistance in extremophilic environments. As guest editors, we are confident that this Special Issue

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(through original research papers, reviews, genome announcements, or draft genomes) will provide an updated account on the extremophiles and their significance in research and varied application prospects.

Declaration of Competing Interest

None.

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