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Research review paper

Thermophiles in the genomic era: Biodiversity, science, and applications

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ABSTRACT

Thermophiles and hyperthermophiles are present in various regions of the Earth, including volcanic environments, hot springs, mud pots, fumaroles, geysers, coastal thermal springs, and even deep-sea hydrothermal vents. They are also found in man-made environments, such as heated compost facilities, reactors, and spray dryers. Thermophiles, hyperthermophiles, and their bioproducts facilitate various industrial, agricultural, and medicinal applications and offer potential solutions to environmental damages and the demand for biofuels. Intensified efforts to sequence the entire genome of hyperthermophiles and thermophiles are increasing rapidly, as evidenced by the fact that over 120 complete genome sequences of the hyperthermophiles Aquificae, Thermotogae, Crenarchaeota, and Euryarchaeota are now available. In this review, we summarise the major current applications of thermophiles and thermozymes. In addition, emphasis is placed on recent progress in understanding the biodiversity, genomes, transcriptomes, metagenomes, and single-cell sequencing of thermophiles in the genomic era.

Contents

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1. Introduction

Thermophiles and hyperthermophiles dominate heated environments. The optimum growth temperature (OGT) for thermophilies is generally >55 °C, whereas that for hyperthermophiles is >80 °C. Hot springs are one of the main sites where hyperthermophiles and thermophiles are isolated, although they can also thrive in man-made environments, such as the compost facilities (Rastogi et al., 2010). Fig. 1 shows images of several types of hot springs and biomats taken from around the world. Hot springs adjacent to volcanic environments are usually acidic (Urbieta et al., 2014b), but the pH is neutral or slightly alkaline in regions near limestone. Thermophiles may also live under harsh conditions involving extreme pH or high salt concentrations (Futterer et al., 2004; Giaveno et al., 2013; Ruepp et al., 2000; Urbieta et al., 2014a). Most early biodiversity studies adopted culture-dependent approaches. Findings from these studies demonstrated that typically only 1–10% of the total population from any biosphere is cultivable. Because of this limitation, microbiologists later chose culture-independent approaches

Fig. 1. Photographs of hot springs in the form of a pool or basin (A–C), a stream (D), heated mud (E–F), and a pot (G). Various colours of biomats and sediments that can form in hot springs (H–L).

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