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Ubiquitousness of *Haloferax* and Carotenoid Producing Genes in Arabian Sea Coastal Biosystems of India

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Abstract: This study presents a comparative analysis of halophiles from the global open sea and coastal biosystems through shotgun metagenomes (n = 209) retrieved from public repositories. The open sea was significantly enriched with *Prochlorococcus* and *Candidatus pelagibacter*. Meanwhile, coastal biosystems were dominated by *Marinobacter* and *Alcanivorax*. Halophilic archaea *Haloarcula* and *Haloquandratum*, predominant in the coastal biosystem, were significantly ($p < 0.05$) enriched in coastal biosystems compared to the open sea. Analysis of whole genomes (n = 23,540), retrieved from EzBioCloud, detected *crtI* in 64.66% of genomes, while *cruF* was observed in 1.69% Bacteria and 40.75% Archaea. We further confirmed the viability and carotenoid pigment production by pure culture isolation (n = 1351) of extreme halophiles from sediments (n = 410 × 3) sampling at the Arabian coastline of India. All red-pigmented isolates were represented exclusively by *Haloferax*, resistant to saturated NaCl (6 M), and had >60% G + C content. Multidrug resistance to tetracycline, gentamicin, ampicillin, and chloramphenicol were also observed. Our study showed that coastal biosystems could be more suited for bioprospection of halophiles rather than the open sea.

Keywords: halophiles; haloarchaea; carotenoid; microbial pigments; *Haloferax*

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1. Introduction

Carotenoids are natural pigments produced by plants, microbes, some fungi and microalgae. More than 750 carotenoids of potential commercial importance have been isolated from microbial sources [1]. In particular, Haloarchaea is a reservoir of unique carotenoid bacterioruberin [2]. Carotenoids synthesized by extreme halophiles are of specific interest for their ease in the extraction process, for saline tolerance, and for their biological applications against infectious diseases, repression of tumors or cancer growth, and cancer growth [3–6]. These extreme halophiles are mainly predominant in marine biosystems such as the open sea and coastal regions (salty marshes, salted ponds or similar ecosystems) [7].

Marine biosystems are exposed to unique environmental stress based on geographical location. For instance, coastal biosystems are exposed to continuous abiotic fluctuations such as salinity, pH, temperature, nutrients, and light, which enrich stress-tolerant enzymatic systems [8–11]. In contrast to coastal biosystems with biogenic and abiogenic colonizable particles, the open sea is rich in biogenic particles [12]. For instance, the open ocean has a lower abundance of available iron, which has led to the significant reduction of iron stress genes in *Synechococcus* strains from the open sea compared to coastal regions [13]. The open sea is also a rich reservoir of bacteria representing over 90% of total