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Review

Microbial mats in French Polynesia and their biotechnological applications

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ABSTRACT

It is well known that microorganisms well-adapted to survival in extreme ecosystems could be considered as new sources of biomolecules that have biotechnological importance. On French Polynesian atolls, microbial mats are developing in water ponds exposed to fluctuations in physical and chemical parameters. In these microbial mats, which are called "kopara" by the inhabitants, bacteria coexist with cyanobacteria, and a synergistic relationship may exist between these two types of living microorganisms. A large number of cyanobacteria and bacteria have been isolated from different mats. Under laboratory conditions, these microorganisms were shown to produce various exopolymers, including exopolysaccharides and poly-β-hydroxyalkanoates, along with pigments for further commercial developments. This manuscript gives an overview of substances isolated and characterized from these bacteria and cyanobacteria and discusses their potential applications in biotechnology.

Contents

1. Introduction

In the past few years, a remarkable number of structurally unique and highly bioactive metabolites have been isolated from marine bacteria. Though there is a long, successful history of antibiotics of terrestrial origin, the search for marine microbial metabolites remains a relatively untouched subject, even today. Biotechnology has been recognized as one of the most promising technologies for the 21st century [1]. Life originated in the sea, and the incredible diversity of ocean life is linked to the relatively prolonged evolutions and adaptations of marine organisms over their land counterparts. Developing novel drugs for treating diseases, such as cancer and neurodegenerative diseases, producing diagnostic devices (biosensors) for monitoring health, discovering new types of composite materials, biopolymers and enzymes, finding new ways of harnessing bioenergy, ensuring sustainable and safe aquaculture and fisheries and providing new approaches to protect and manage marine environments make up just a small subset of the possibilities of marine biotechnology.

Microbial mats are laminated communities primarily composed of phototrophic and chemotrophic prokaryotes. The vertical stratification of such communities is a response to the organisms' physiological requirements to the gradients of light, oxygen, redox

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Fig. 1. Microbial mats from Polynesian atolls.

Table 1
Abundance of the exopolysaccharide fractions of Tetiaroa and Rangiroa mats.

Section	Depth (cm)	Abundance mg/g dry
IT1	0–1	26.8
IT1' + IT2	1–6	11.2
IT3 + IT4	6–13	4.3
IT5	13–19	4.5
R2-1	0–2.7	46.8
R2-2	2.7–4.5	9.4
R2-3	4.5–8	1
R2-4	8–13.7	0
R2-5	13.7–18.5	0
R9	0–2.5	25.1
R9 P	0–2.9	48.2
R9 G	0–3.1	37.1

potential, sulfide and pH. These microbial mat ecosystems require nitrogen fixation from nitrogen fixing cyanobacteria to develop [2]. Such microbial mats are found in many lagoons in Baja California [3], lakes in the Sinaï, Egypt [4] and still waters in Spain [5]. Benthic microbial communities, growing as gelatinous deposits several tens of centimeters thick, are also present in some shallow lakes on the rims of some French Polynesian atolls (Fig. 1). The inhabitants call these benthic microbial communities "kopara" [6]. "Kopara" mats are characterized by varied physical and chemical parameters, with pH values ranging from 6 to 10.5, salinity levels ranging from 5 g/l to 42 g/l, temperatures ranging from 20 °C during the night up to 42 °C around mid-day [7] and light intensities varying from one site to another. In such unusual environments, bacteria co-exist with cyanobacteria and may form a synergistic relationship.

From the discoveries of novel biopolymers and biomolecules of biotechnological significance, it is now widely accepted that microorganisms from unusual environments not only provide valuable resources for exploiting novel biotechnological processes but also serve as models for investigating how biomolecules are stabilized when subjected to changing conditions [8]. In this regard, microbial mats offer new sources of fascinating microorganisms well-adapted to these changing environments. Over the past 10 years, an increasing number of new mesophilic bacteria and cyanobacteria species have been isolated from these Polynesian ecosystems. This new microbial diversity includes strains able to produce novel molecules, such as biopolymers, pigments and other bioactive molecules.

This paper examines the discovery and applications of innovative biopolymers produced under laboratory conditions by microorganisms isolated from different microbial mats present on Polynesian atolls.

2. Microbial community structure

The microbial community structure in "kopara" mats is dominated by only a few functional groups of microorganisms, which include cyanobacteria, with the predominating genera *Phormidium* and *Scytonema*, sulfurous and non-sulfurous photosynthetic bacteria, sulfate-reducing bacteria in the deeper layers and *Desulfovibrio* and *Desulfobacter* species [9,10]. Other microorganisms isolated include the following: *Chromatium* sp., *Thiocapsa*, *Thiocystis* spp., *Blastochloris* spp., *Rhodobacter* spp. and *Rhodospirillum* spp., along with heterotrophic bacteria belonging to the *Pseudomonas*, *Alteromonas*, *Paracoccus* and *Vibrio* genera [11–14].

3. Vertical distribution of exopolysaccharides in different mats

Various macromolecules, including polysaccharides, proteins, lipids and nucleic acids, form the architectural matrix in the intercellular space of microbial biofilms and unattached aggregates and have been characterized from the environment of the mats (Fig. 2) [10]. Extracellular polymers help microorganisms to compete and survive in changing environmental conditions by altering the physical and geochemical microenvironment around the cell [15]. In most mats analyzed to date, the highest levels of exopolysaccharides, up to 50 mg EPS/g of dry weight, were found in the uppermost layers (Table 1, Fig. 3). The exopolymer proportion decreased markedly with increasing depth and was negligible beyond 8 cm.

Fig. 2. Scanning electron micrograph of the occurrence of exopolymeric substances within microbial mats. Bar represents 10 μm.

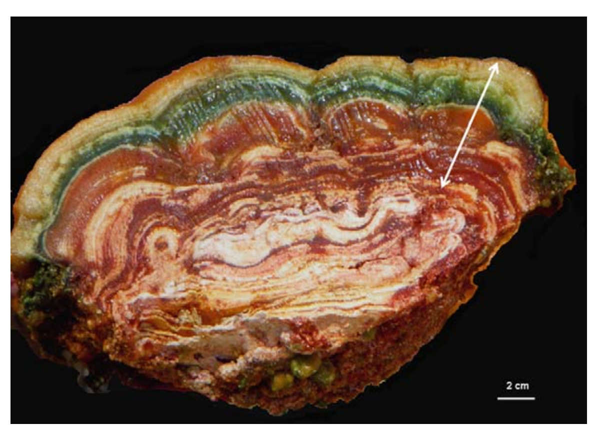

Fig. 3. Microbial stratification within "kopara" mats showing different microbial metabolistic developments. White arrow corresponds to high EPS concentration area.