



Research review paper

Consortia of cyanobacteria/microalgae and bacteria: Biotechnological potential

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ABSTRACT

Microbial metabolites are of huge biotechnological potential and their production can be coupled with detoxification of environmental pollutants and wastewater treatment mediated by the versatile microorganisms. The consortia of cyanobacteria/microalgae and bacteria can be efficient in detoxification of organic and inorganic pollutants, and removal of nutrients from wastewaters, compared to the individual microorganisms. Cyanobacterial/algal photosynthesis provides oxygen, a key electron acceptor to the pollutant-degrading heterotrophic bacteria. In turn, bacteria support photoautotrophic growth of the partners by providing carbon dioxide and other stimulatory means. Competition for resources and cooperation for pollutant abatement between these two guilds of microorganisms will determine the success of consortium engineering while harnessing the biotechnological potential of the partners. Relative to the introduction of gene(s) in a single organism wherein the genes depend on the regulatory- and metabolic network for proper expression, microbial consortium engineering is easier and achievable. The currently available biotechnological tools such as metabolic profiling and functional genomics can aid in the consortium engineering. The present review examines the current status of research on the consortia, and emphasizes the construction of consortia with desired partners to serve a dual mission of pollutant removal and commercial production of microbial metabolites.

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1. Introduction

Cyanobacterial and microalgal metabolites such as proteins, fatty acids (eicosapentaenoic acid), steroids, carotenoids, phycocolloids (agar, carrageenan, and alginate), lectins, mycosporine-like amino acids, halogenated compounds, and polyketides are of huge biotechnological potential (Cardozo et al., 2007). Species of *Nostoc*, *Arthrospira* (*Spirulina*) and *Aphanizomenon* have been used as food and a source of proteins since 2000 years ago (Jensen et al., 2001). Use of algae has been extended to the treatment of wastewaters, energy generation, and even as the photosynthetic gas exchangers for space travel (Spolaore et al., 2006). The systematics of cyanobacteria is generally on the classification schemes based on cell or colony shape (Rippka et al., 1979; Oren, 2011), but the evolutionary basis includes these organisms under one of the ten groups termed 'Eubacterial Phyla' (Woese et al., 1985). Included in the definition of plants are microalgae which are eukaryotic unicellular and microscopic with size ranging from 1/1000 of a mm to 2 mm and include species of diatoms, dinoflagellates and green flagellates (Hallegraeff, 1991). Based on the Tamura-Nei model (Tamura and Nei, 1993), the 16S rRNA sequences of cyanobacteria (oxygenic photosynthetic bacteria), heterotrophic bacteria and eukaryotic microalgal plastids suggest the sharing of a common ancestor (Fig. 1). These organisms have been isolated, selected, mutated, and genetically engineered for effective bioremediation of organic or recalcitrant pollutants, achieving enhanced rates of degradation, and ensuring better survival and colonization in the polluted areas (Koksharova and Wolk, 2002; Ramakrishnan et al., 2010; Venkateswarlu, 1993). 'Industrial sustainability' now aims at achieving sustainable production and requires the need of incorporating 'designs for environment' into many production processes. Many ancient as well as modern biotechnological techniques are used in treating wastewaters and pollution in the environment. Further research and advances are

necessary to improve the benefits from these biotechnologies. To abate industrial pollution, to enhance profitability and sustainability, and to uncouple economic growth from adverse environmental impact, bioremediation technologies are required (Gavrilescu and Chisti, 2005).

In nature, most microalgae and cyanobacteria are found in association with other aerobic or anaerobic microorganisms. The bacterial assemblages are known to influence the development or decline of algal blooms (Fukami et al., 1997). Even the long-term laboratory algal cultures have maintained symbiotic relationship with bacteria (Park et al., 2008). The molecular oxygen from algal photosynthesis is used as an electron acceptor by bacteria to degrade organic matter. Carbon dioxide (CO₂) from the bacterial mineralization completes the photosynthetic cycle. The symbiotic interactions of microalgae and bacteria form the basis of the biological oxygen demand (BOD) removal in the wastewater treatment ponds, first reported by Oswald et al. (1953). Depletion of ammonium, nitrate and phosphate by the algal growth is advantageous for nutrient removal from wastewaters. The principle of self-oxygenation by natural systems can be effectively employed for remediation of many pollutants (Muñoz and Guieysse, 2006) since the conventional engineering technologies suffer from high costs for oxygen supply, incomplete utilization of natural resources, creation of secondary pollutants, and technical impracticability in some situations. The biodegradation processes involving the consortium of cyanobacteria/microalgae and bacteria will be an ideal self-sustaining system that is cheaper and technically superior. In nature, there are many evidences of microbial communities of cyanobacteria or microalgae and bacteria, either fossilized or living together. What is pertinent now is to gain insights on the interactions and organization from the ancient stromatolites and modern cyanobacterial mats, and to apply molecular techniques to select the desired microbial members for engineering

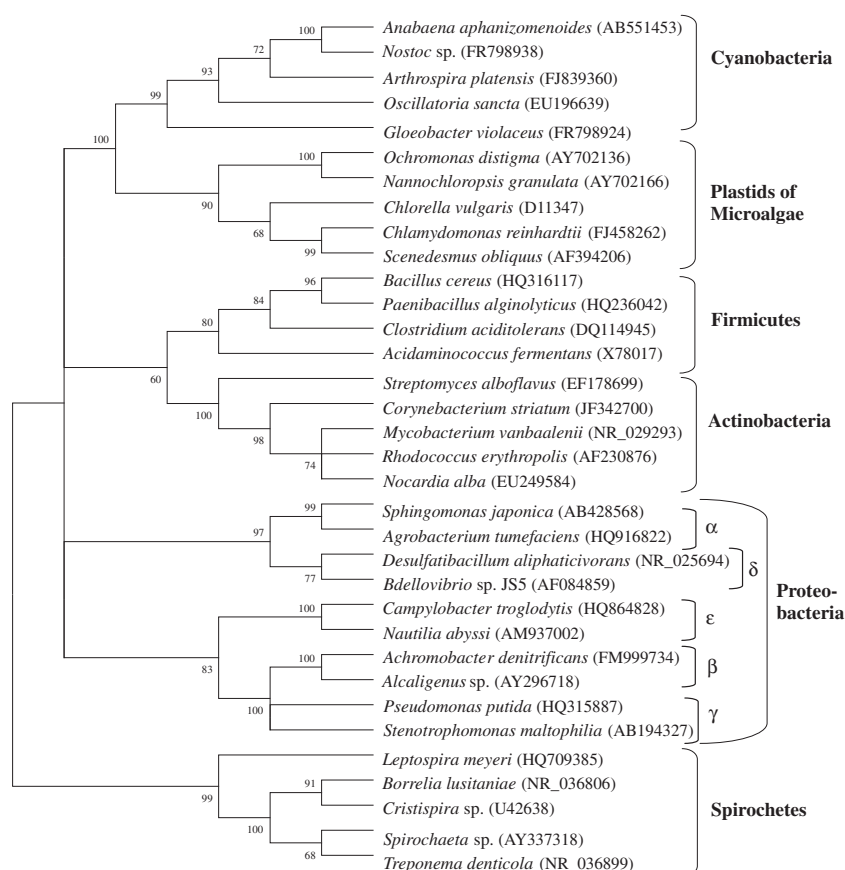


Fig. 1. Phylogenetic tree showing evolutionary relationships among cyanobacteria (oxygenic photosynthetic bacteria), other eubacteria and eukaryotic microalgal plastids (constructed by using MEGA4 (Tamura et al., 2007) based on maximum likelihood method with 34 representative 16S rRNA gene sequences).

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