IJASRM
International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019
www.ijasrm.com
ISSN 2455-6378

The Potential Applications of Cyanobacteria (Blue Green Algae): A Brief Review

Aithal Sadanand V.

[1] Dept. of Botany, Vai. Dhunda Maharaj Degloorkar College,Degloor, Nanded, Maharastra, India

Abstract

Cyanobacteria (Blue green algae) are among the earliest of inhabitants of Earth and are highly diverse members of the current global biodiversity and are making significant contributions to the Carbon and Nitrogen bio-geochemical cycles, particularly in the deep oceans. In recent year it has gained importance because of their potential use in various areas of research. This diverse group has application in various fields like biotechnology, pharmacology, agriculture etc. Due to presence of wide spectrum of bioactive compounds Cyanobacteria has possesses antiviral, antibacterial, antifungal and anticancer activities. Several strains of cyanobacteria are rich in food supplements. Further nitrogen fixing capacity of Cyanobacteria has attracted agriculturists and researchers and they used blue green algae as a component of biofertiliser to improve both the fertility of soil as well as growth of plants. Recent studies have also shown that Cyanobacteria have capability to degrade environmental pollutants. In spite of all these investigation and research more efforts should be made in search of more strains of cyanobacteria and genetically modifying known strains to ensure maximum production of the desired products.

Keywords: *Cyanobacteria, secondary metabolites, biofertiliser, nitrogen fixation, bioremediation*.

1. Introduction:

The Cyanobacteria are a group of gram-negative, photosynthetic prokaryotes which found in all kinds of habitats and originated on Earth about 2.5 to 3.5 billion year ago in Pre-Cambrian Era (2.7 billion years ago) (**Thajuddin, N. and Subramanian, N. 2005)**. Cyanobacteria were the first organisms to utilize two photosystems (photosystems I and II) and split H_2O instead of H_2S as other bacteria do. Cyanobacteria capture sunlight using chlorophyll a and various accessory pigments especially c-phycocyanin and perform photosynthesis as algae and plants. Although Cyanobacteria perform oxygenic photosynthesis just like eukaryotic green algae and higher plants, they do not store food in the form of starch.

They are found as photoautotrophs, photoheterotrophs, chemoheterotrophs and bacteria like anoxygenic photosynthesis at different condition (**Rippka, 1972**). The Cyanobacteria contain their own photosynthetic machinery for the synthesis of organic food and during the process of photosynthesis they derive electrons form water for the fixation of carbon dioxide and evolve oxygen as by product (**Nubel, *et. al.*, 2000**). Cyanobacteria have ability to survive in different types of environments with capacity to change their mode of nutrition (**Stal, 1995**). Beside the oxygenic photosynthesis, Cyanobacteria are also capable in the anoxygenic photosynthesis (**Cohen, *et. al.*, 1986**).

Some Cyanobacteria have ability to survive in abnormal habitats like low and high pH; high temperature; metal polluted soils and waters and in such environment where other algae could not be survive (**Broady, *et. al.*, 1996**). They also show the symbiotic relationships with bryophytes, fungi, lichens, pteridophytes, gymnosperms and angiosperms (**Adams, 2000**) and heterocystous forms have the ability to fix atmospheric nitrogen (**Capone, *et. al.*, 2005**). The Cyanobacteria have long been known for their impacts on ecology and agriculture, because they are primary producers of an ecosystem and fixer of atmospheric nitrogen. In recent years significant researches have been made to elaborate the biotechnological potential of Cyanobacteria (**Meyer and Hamann, 2005).** Cyanobacteria have been identified as one of the most promising group of micro-organisms from which several novel and biochemically active natural products have been isolated. Cyanobacteria such as *Microcystis, Anabaena, Nostoc and Oscillatoria* produce a vast variety of secondary metabolites (**Skulberg, 2000**). Cyanobacteria today are not only explored in agriculture as biofertiliser but also in pharmacology, in cancer treatment, bioremediation, as and also as a food supplements .Potential applications of Cyanobacteria in various fields are briefly describe here.

2. Applications of Cyanobacteria

Cyanobacteria as a Natural Biopharmaceuticals:

.Cyanobacteria are Gram-negative eubacteria and are known for their morphological diversity leading to the development of natural biopharmaceuticals due to presence of structurally diverse groups of compound (**Wrasidlo, *et.al* 2008**). The secondary metabolites of cyanobacteria are belonging to phenolic compounds (**Papendorf, *et. al.*, 1998**); polychlorinated aromatic compound (**Falch, *et., al.*, 1993**); alkaloids (**Carmeli, *et. al.*, 1990**); cyclic(**Tidgewell, *et., al.*, 2010)** and depsipeptides (**Taniguchi,*et.al.*, 2010**); lipopeptides; glycolipids and sulfolipids (**Reshef, *et. al.*, 1997)**; fatty acids (**Mundt, *et. al.*, 2003**); amides (**Gerwick, *et. al.*, 1987**); ichthyopeptins A and B,(**Zainuddin, *et. al.*, 2007**) isonitriles (**Carmeli, *et. al.*, 1990**); lactones (**Singh, *et. al.*, 1999**) and nucleosides. The cyanobacterial secondary metabolites include several biological activities like antibacterial, antifungal, antialgal, antiprotozoan, and antiviral activities (**Volk, *et. al.*, 2006).**

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Antibacterial compounds: A large number of bioactive compounds have been isolated and identified from various species of Cyanobacteria those have remarkable potential against different gram-positive and gram-negative bacteria such as *Pseudomonas aeruginosa, Staphylococcus aureus, S. epidermidis, Enterococcus aerogenes, Salmonella typhi, Mycobacterium tuberculosis, M. laprae, Vibrio cholarae, Bacillus subtilis, B. cereus, Escherichia coli, Klebsiela pneumoniae* etc. Hormothamnions are cyclic undecapeptides, produced from marine Cyanobacteria *Hormothamnion enteromorphoides*, shows activity against bacteria (**Gerwick, *et. al.*, 1989**) and cyclic undecapeptides schizotrin form *Schizothrix sp.* (**Pinzon-Gamez, *et. al.*, 2005**). Malyngolides are a group of antibacterial compounds produced by marine Cyanobacteria *L. majuscula* (**Burja, *et. al.*, 2001**). The freshwater Cyanobacteria *Oscillatoria redeki* produced an unsaturated hydroxyl fatty acid α –dimorphenolic acid and coriolic acid which reduces the bacterial infections (**Mundt, *et. al.*, 2003**). Noscomin, obtained from *Nostoc commune*, shows activity against *Bacillus cereus, Staphylococcus epidermididis* and *Escherichia coli* (**Zaki, *et. al.*, 1999)**; Carbomidocyclophanes are a group of compounds have potential against *Staphylococcus aureus* (**Bui, *et. al.*, 2007**); ambiguine-1-isonitrile from *Fishcerella sp*. active against *E. coli, Staphylococcus albus* and *Bacillus subtilis* (**Raveh and Carmeli, 2007**).

Antifungal compounds: Cyanobacteria are shows remarkable activity against various fungi and inhibit their growth and development. Antifungal potential was observed in a large number of cyanobacterial extracts.The cryptophycins comprises the largest class of cyanobacterial depsipeptides (**Trimurtulu, *et. al.*, 1994**). Cryptophycin-1, an important member of cryptophycin class, was first isolated from *Nostoc ATCC53787* which exhibited antifungal properties (**Hirsch, *et.al.*, 1990;**). Another compound, scytophycin, having antifungal potential was also reported from various species of cyanobacteria (**Patterson and Carmeli, 1992**). Scytophycins are highly cytotoxic metabolites. Ambigols are polychlorinated aromatic compound, isolated from terrestrial cyanobacterium *Fischerella ambigua*, having potent activity against several fungi and other compound named parsiguine (**Ghasemi, *et. al.*, 2004**). Cyanobacterium *Hapalosiphon fontinalis* produce a group of indole alkaloids, hapalolindoles, act as antifungal agent (**Moore, *et. al.*, 1987**).

Antialgal compounds: Various metabolites from cyanobacteria have been isolated and identified as antialgal agent *i.e.* they inhibit the growth and development of different algal species. These metabolites are Galactosyldiacylglycerols from *Phormidium tenue* (**Murakami, *et. al.*, 1991**), Nostocin-A from *Nostoc spongiaeforme* (**Hirata, *et. al.*,1996**), Cyanobacterin LU-1 from *Nostoc inckia* (**Gromov, *et. al.*, 1991**), Cyanobactericin from *Scytonema hoffmanii* (**Abarzua, *et. al.*, 1999**), Fischerellin from *Fischerella muscicola* (**Dahms, *et. al.*, 2006**) and Aponin form *Gomphosphaeria aponia* (**Bhadury and Wright, 2004**).

Antiprotozoal compounds: An estimate of World Health Organization (WHO) said that more than one billion people among the world are suffering from tropical diseases caused by *Plasmodium, Trypanosoma* and *Leishmania* (**Simmons, *et. al.*, 2008**). Currently available medicines for the treatment of malaria and leishmaniasis are unable to cure the disease symptoms due to development of resistance by these parasites (**Lanzer and Rohrbach, 2007; Prioto, *et. al.*, 2007**). Almiramide B and C are liner lipopeptides, isolated from *Lyngbya majuscula*, have potential to inhibit the growth of *Leishmania donovani* (**Sanchez, *et. al.*, 2010**).

Antiviral compounds: Several cyanobacterial species have been identified for the production of novel compounds which shows potent activity against a variety of viral pathogens including HIV. It is well known that cyanobacteria have potential against a vast variety of viruses (**Damonte, *et. al.*, 2004; Meyer and Hamann, 2005; Meyer, *et. al*, 2009**). Many observations made for the approval of antiviral metabolites and extracellular polymeric substances from various cyanobacteria (**Guang**

Zhou, *et. al.*, 2004; Rechter, *et. al.*, 2006; Santoyo, *et. al.*, 2006; Rodriguez-Meizso, *et. al.*, 2008). Indolocarbazoles shows activity against herpes virus which produced by *Nostoc sphaericum* (**Xiong, *et. al.*, 2006**). A polysaccharide, Ca Spirulan, exhibit the potent activity against HIV which produced by *Spirulina platensis* (**Santoyo, *et. al.*, 2006**). Ca-spirulan shows activity against HIV-1, HIV-2, Influenza virus and other enveloped viruses. Ca-spirulan inhibits the activity of reverse transcriptase of HIV-1 and also inhibits the attachment of virus to the host. Caspirulan prevent the fusion of HIV infected and uninfected CD4 lymphocytes (**Feldmann, *et. al.*, 1999**). Another acidic polysaccharide, Nostoflan, have been isolated from *Nostoc flagelliforme* with virucidal potential against Herpes Simplex Virus (**Kenji, *et. al.*, 2005**).

Cyanobacteria as Healthy Food: Several species of Cyanobacteria such as *Aphanizomenon, Chroococcus, Arthrospira, Phormidium, Nostoc, Spirulina* etc were used as food in the past and still used in many countries like China, Chile, Mexico, Peru, Mongolia, Philippines, Japan etc. and rich in protein content (**Becker, 2007**). *Spirulina* has received tremendous attention due to its higher protein content than cereals, vegetables and soyabean (**Venkataraman, 1983; 1993**). *Spirulina platensis* contains more than 60% proteins and rich in β-carotene, thiamine, riboflavin and richest source of vitamin B12. *Nostoc commune* is rich in fibers and proteins. Some of the marine cyanobacteria constitute potential sources for large-scale production of vitamins, such as vitamins B and E.

Cyanobacteria in Bioremediation: Water pollution is the major problem of world and Cyanobacteria have ability to assimilate various kinds of pollutants from soils and waters. BGA are phototrophs but several of them are diazotrophs having the potential for biodegradation (**Kuritz and Wolk, 1995**). Cyanobacteria have the ability to degrade oil components and other substances like surfactants and herbicides (**Radwan and Al-Hasan, 2000; Raghukumar, *et. al.*, 2001**). Heavy metals can be accumulated by cyanobacteria either by bioaccumulation or biosorption (**Fehrmann and Pohl, 1993**). *Phormidium valderianum* able to adsorbing Cd++, Co++, Cu++, Zn++ and N++ respectively (**Karna, *et. al.*, 1999**). Cyanobacteria based biosensor has also been generated that could be used to detect herbicides and other environmental pollutants. freshwater cyanobacterium, *Synechocystis* sp. strain PCC6803, was chromosomally marked with the luciferase gene *luc* (from the firefly *Photinus pyralis*) to create a novel bioluminescent cyanobacterial strain and expression of the *luc* gene during growth of *Synechocystis* sp. strain PCC6803 cultures was characterized by measuring optical density and bioluminescence (**S.Shashirekha, *et.al* 1997**).

Cyanobacteria as Biofertiliser: The exponential growth in population is now becomes a major problem because agricultural fields are limited on earth. So it is a challenge how to produce the sufficient food and fodder for human and other domestic animals. For this problem many solutions have been adopted like development of high yielding varieties with improved agricultural technologies. These high yielding varieties require more chemical fertilizers for maximum production. But excess use of these chemical fertilizers may results the deficiencies and infertility in soils. The accumulated insoluble forms of fertilizers through the food and fodder may be harmful to human and other domestic animals. Cyanobacteria play an important role to retain soil fertility by consequently increasing the yield by converting atmospheric nitrogen into an available form of ammonium. Dominant nitrogen-fixer blue-green algae are *Anabaena, Nostoc, Aulosira, Calothrix, Plectonema* etc. In addition to augmenting, the cyanobacteria increase the availability of fertilizer nitrogen to the crop. Substantial quantities of amino acids like aspartic, alanine and glutamic acid, vitamins like B12 and auxin like substances are liberated by nitrogen fixing cyanobacteria (**Gupta and Shukla, 1969**).

3. Conclusion:

Cyanobacteria are the most primitive organism and are known for creating oxygenic atmosphere through their photosynthetic activities. Cyanobacteria perform photosynthesis as plant and algae does by capturing sunlight by using chlorophyll a and various other accessory pigments. They are ubiquitous in nature and play a major role in the nitrogen, carbon, and oxygen dynamics of many aquatic environments. Cyanobacteria are found not only as free living organism but are also found in symbiotic association with plant and other organisms.

In recent year Cyanobacteria have gained importance in various areas of research viz agriculture, drug discovery, treatment of deadly disease such as HIV and cancer, bioremediation Various pharmacological effect of Cyanobacteria are due to the presence of bioactive compounds found in cyanobacteria and are being used in agricultural field due to its ability to fix atmospheric nitrogen into ammonium which promote growth of plants. Cyanobacteria has also attracted attention of environmentalist in bioremediation due to its ability to degrade pollutants including pesticides, crude oil, naphthalene ,phenanthrene, phenol and catechol, could also serve as effective biosorbant for removing heavy metals from contaminated water bodies.

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