

Cyanobacteria Metabolites Application in Agricultures, Medicine and Environment

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Abstract

Cyanobacteria are considered as one of the important group of organisms having significant ecological, industrial and biotechnological importance. Cyanobacteria have gained a lot of attention in recent years because of their potential applications in biotechnology. This review presents an overview of uses of cyanobacteria in industry agriculture, environment pharmaceutical and medicinal roles and to provide future prospects of the field of cyanobacteria biotechnology. Nowadays cyanobacteria have gained attention researchers because of their various potential applications such as food and feed pharmaceutical industries in medicine, in bioremediation, soil conditioning, as biopolymers, bio adhesives and bioenergy and bio fertilizers. Due to presence of wide spectrum of bioactive compounds cyanobacteria has possesses antiviral, antibacterial, antifungal and anticancer activities. Several strains of cyanobacteria are also rich in food supplements. Further nitrogen fixing and soil conditioning capacity of cyanobacteria attracted researchers. Recent studies have also shown that cyanobacteria have capability to degrade environmental pollutants and are also being used as a promising source of alternative energy. This review is an effort to forward the valuable information about the qualities of cyanobacteria and their potential role in solving the agricultural and environmental problems for the future welfare of the planet. Thus more efforts should be made in search of more potential strains of cyanobacteria to ensure maximum production of the desired products.

Keywords: Cyanobacteria bioremediations; Nitrogen fixation biological metabolites; Biopolymers; Bio adhesives; Bioenergy and bio fertilizers

Introduction

Cyanobacteria are a group of aquatic organisms officially classified as bacteria, but they display characteristics of algae and bacteria. Cyanobacteria produce their own nutrients *via* photosynthesis. The color of the chlorophyll required for this process produces the coloration that has led to their common name, 'blue green algae'. Others explained cyanobacteria as common and natural aquatic organisms present in many surface waters. They are single celled microscopic bacteria and can be found in fresh, salt or brackish waters. Like plants, they use sunlight to make food and energy [1-5].

In similar way Castenholz, explained cyanobacteria or blue green algae as prokaryotic microalgae classified as a phylum of eubacteria. The blue green appearance of these bacteria is originated by the two pigments, chlorophyll a (green) and phycocyanin (blue) and which can survive in wide variety of environments. They are photoautotrophic in that they can harvest energy from the light source with their chlorophyll a pigment. Also, they consume CO₂ to produce organic compounds plays a substantial task in the recycling of CO₂ *via* their photosynthesis, which is similar to photosynthetic plants in oxygen generation. However, some species of cyanobacteria survive under mix trophic and heterotrophic conditions and as consortia with other microorganisms. Using water as an electron donor during photosynthesis resulting in the release of oxygen is another important characteristic of the setiny organisms. Furthermore, Number of findings reported that cyanobacteria have the ability to fix nitrogen. Cyanobacteria have been recognized as an opulent source of various bioactive compounds possessing antibacterial, antiviral, antifungal and anticancer activities. They are also contributing positively in bioremediation and sustainable development of ecosystem. In view of the above, the objectives of the current review are to point out overall contribution of cyanobacteria and their potential role in sustainable development of agriculture and ecosystem. This is also an effort to

give the valuable information about multifunctional roll of cyanobacteria and their potential role in solving the agricultural and environmental problems for the future welfare of the planet [6-10].

Literature Review

Cyanobacteria as food and feed supplement

The global population explosion has resulted in the need to look for alternative sustainable sources of food apart from conventional agricultural products. This has promoted interest in the use of functional foods to meet the nutritional demands of the growing human population [11].

Microorganisms, especially cyanobacteria, are an untapped resource as their secondary metabolites have nutritional or therapeutic values. Commercial exploitation of cyanobacteria since the establishment of human civilization is owing to its different properties which make it a suitable source of functional foods.

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According to Dixit and Suseela many characteristics which make cyanobacteria a promising alternative for sustainable food production due to high nutrient content of cyanobacteria, especially *Spirulina*, which is the most commercialized and cultivated cyanobacteria species. Its worldwide distribution, requirement of small amounts of water for growth including waste water, need for small land (unfertilized and unsuitable for other crops), easily digestible and product stability over a wide pH and temperature range [12-15].

According to some statistics findings of Singh 1 kg of *Spirulina* may replace 1000 kg of assorted fruits and vegetables in terms of nutritional value.

The use of algae as an additive feed in aquaculture has also received a lot of attention due to the positive effect it has on weight gain. Quality of aqua feed is one of the most important criteria for the success of aquaculture. The popularity of microalgae particularly cyanobacteria as fish feed is increasing rapidly as suitable alternative source in modern aquaculture industry [16-20].

Research findings from Sirakov reported that cyanobacteria have been assessed for their nutritional value into fish feed formulation which provides balanced nutrition and improved fish growth. According to Tartiel the green algal species like *Chlorella* and *Scenedesmus* contains crude protein (40-50%), carbohydrate content (25-60%) and a considerable amount of β carotene beneficial for the growth of fishes and also use of *Spirulina* possessing protein as high as 40-70% is well documented as fish feed.

There are numerous records of historical usage of cyanobacteria and microalgae in the human diet as it was reported by Tomaselli. *Spirulina* has been consumed by the local population in Chad after drying the biomass used for preparing dishes, such as meat and vegetable broth and also sold in the local markets.

As photosynthetic microorganisms, cyanobacteria harvest light as their energy source through a wide variety of photosynthetic capability that are rich in pigments have been reported to have beneficial health effects, e.g. providing micronutrients and macronutrients, aiding in digestion, etc. Among the most widely used species is the halo tolerant *Spirulina* spp due to high nutritional value and high digestibility and their richness in various nutrients and high protein content with additional health benefits as a source of antioxidants, coenzymes and vitamins.

As it was reported by Devillers, some cyanobacteria like *Nostoc* strains can be eaten directly without performing purification since it contain 60% protein, rich in beta carotene, thiamine, riboflavin vitamin B₁₂ and fibers thus plays an important role in nutritional composition of human diets.

Similar findings reported by Abed that *Spirulina*, *Anabaena* and *Nostoc* are commonly used as a food source in different countries such as Mexico, Chile and the Philippines due to its popularity as a health and food supplement in the form of powder, tablets or capsules. Consumption of cyanobacteria results in several health benefits and considered traditionally as a "food for fitness". Another type of cyanobacteria, *Arthrospira platensis* with a rich source of β carotene and various biomolecules of nutraceutical value thus regarded as "food for the future." Cyanobacteria produce carotenoids such as canthaxanthin, beta carotene, nostoxanthin and zeaxanthin as food supplements, animal feed, food additives and colorant.

In addition to the above important factors *Spirulina* produce carotenoid such as the keto carotenoid, astaxanthin as powerful

antioxidant which play a vital role in preventing damage in human cells through photo oxidation. He also reported that Astaxanthin obtained from *Haematococcus pluvialis* contains protease inhibitors that may be used to treat diseases, such as HIV (Human Immunodeficiency Virus). Compounds and extracts with anti HIV activity have been reported but the amount of antiviral activity varies with the compound and extract.

Medicinal effects of cyanobacteria

The bioactive compounds available in cyanobacteria possess several medicinal benefits as it was suggested by Romay and have some specific applications such as their use in the formation of medicinal drugs.

Other findings by Dew indicated that cyanobacteria have biochemical pathways that produce unique bioactive molecules with potential commercial and medical applications based on their anti-fungal, antibiotic, antimicrobial, immunosuppressant, anti-inflammatory, anticancer, antiviral, anti-bacterial, anti-coagulant, anti-malarial, anti-protozoan, anti-tuberculosis, anti-tumor and anti HIV (Human Immunodeficiency Virus) and activities due to cyanovirin N, a carbohydrate binding protein from *Nostoc ellipsosporum*.

In human clinical trials, supplementation with several species of *Spirulina* exhibited lipid lowering effects. In patients with diabetic type 2 diabetes its consumption showed significant reduction in ratios of total cholesterol and plasma lipids.

Cyanobacteria compounds are found to target tubulin or actin filaments in eukaryotic cells, making them an attractive source of natural products as anti-cancer agents due to molecules different types of anti-microtubule agents have been in preclinical and/or clinical trials as potential anti-cancer drugs.

Findings by Bernardo and Morais, reported that *Arthrospira* sp produces metabolites such as sulphate polysaccharides, which have anti-viral and anti-cancer properties. They also form Gamma Linolenic Acid (GLA) that is useful in the control of cholesterol levels, lowering blood pressure and protecting the cardiovascular system. These properties resulted from the availability of carotenoids, chlorophylls, phycocyanin, various amino acids and minerals.

Human skin is one of the most complex body organs that functions as a physical barrier against water loss and environmental stressors including, pathogens, chemicals and physical agents. According to studies conducted by Ariede, cyanobacteria are rich sources of metabolites, which can be used to fight against skin related problem such as skin aging, fragility, laxity, enlarged pores, dryness and wrinkles happen to skin texture as a result of chronic exposure to intrinsic and extrinsic destructive factors.

Derikvand also reported that *Spirulina*, *Nostoc*, *Anabena* and *Oscillatoria* strains are most commonly used in skin care products for various skin conditions by acting as sunscreens, anti-wrinkling agents, moisturizer or texture enhancing agents.

Agricultural applications of cyanobacteria

Nowadays agricultural practices heavily dependent on the application of synthetic fertilizers and pesticides, intensive tillage and over irrigation, to meet the food requirement; nevertheless the effect on environmental, health, soil fertility and increased cost of agricultural production. Similar reports suggested by Singh and

Strong, that sustainable agriculture practices as well as environmental quality besides ecofriendly, low cost farming systems with the help of native microorganisms such as cyanobacteria (blue green algae) make the agro-ecosystem more resilient, self-regulating and also maintain the productivity and profitability.

Some cyanobacteria have a capability have to solubilize soil phosphate since Phosphorus (P) is the second important nutrient after nitrogen for plants and microorganisms, thus algae are particularly adapted to scavenge their environments for resources through structural changes, storage or increased resource utilization efficiency.

Similarly Healy also pointed out that different adaptation methods of algae such as biochemical and physiological adjustments mechanisms enabled them to excrete substances to enhance nutrient availability, excrete extracellular phosphatases upon the onset of P limited conditions, store resources like P in excess of their immediate needs and change the pH of their surroundings.

N fixers cyanobacteria increase the N content through nitrogen fixation in natural desert soils and released to the surrounding environment which make it available to plants or either released to the atmosphere in the form of N₂O or NO and HONO, which influence ozone and OH reactivity at the atmosphere.

Cyanobacteria also influence the availability of P which is the second important nutrient to plants as they have the ability to transform non usable forms of inorganic P to a usable form through biological processes. Soil surface inoculated with different heterocystous and non heterocystous cyanobacteria has been reported to enhance total N, available N and available P. In the field of agriculture, cyanobacteria have been mainly used as bio fertilizers due to their role as nutrient supplements. Also Thajuddin and Subramanian reported that inoculation of soil with cyanobacteria species such as *Nostoc*, *Calothrix*, *Tolypothrix* and *Scytonema* have diverse N fixing potential in non-water logged soils shown beneficial effects in terms of improvement of quality of soil properties, enhancement in different plant growth such as wheat, maize and lettuce as natural fertilizers.

Cyanobacteria also provide a number of ecological roles that open the range for their application in agricultural systems from dry lands by providing promising extreme resistance to the abiotic stresses such as low rainfall, high radiation levels and long periods of drought.

Discussion

Cyanobacteria as biocontrolling agents

Many research papers demonstrate the mechanisms of fungal and Oomycete growth inhibition by the activity of cyanobacteria extracts. Several extracts from, *Anabaena* spp., *Fischerella* sp., *Nostoc* spp. and *Oscillatoria* spp inhibited *Aspergillus* and mycelial growth due to methanol, acetone, diethyl ether, ethyl acetate, ethanol and methyl chloride extract depending on cyanobacteria.

Other results of last investigations also give evidences about the defensive role of cyanobacteria and micro algal secondary metabolites. Cyanobacteria are known to produce metabolites with diverse biological activities such as anti-bacterial, anti-fungal and anti-viral activities. Several reports have shown that the extracts of *Nostoc* species significantly inhibited the growth of phytopathogenic fungi because cyanobacteria produce biologically active compounds that have antibiotic and toxic activity against plant pathogens. Other findings by Mohamed investigated the suppression effect of

cyanobacteria species *Nostoc endophytum* and *Nostoc muscurum* against the causal agent of soya bean root rot *Rhizoctonia solani* which confirms effect of cyanobacteria in biological control of wilt disease which may help to obtain a higher yield and good health in agriculture.

Cyanobacteria as a bioenergy

The rapid growing population of the world continuously increases the global demand for fuel energy. The intensive use of fossil fuels worldwide leads to its depletion and will bring them close to the point of exhaustion due to unsustainable and non-renewable nature. Thus, bio fuels are now a growing opportunity throughout the world as alternative to fossil fuels. Thus advantageous features of biofuels produced from microalgae biomass are renewability and a significantly smaller contribution to environmental pollution and global warming. The emission of greenhouse gases mainly CO₂ from burning of fossil fuels are the main cause of global warming by releasing 29 giga tons/year release of CO₂. But bio fuels from algal have oxygen levels of 10-45% and very low levels of Sulphur emission while petroleum based fuels have no oxygen levels with high Sulphur emission. According to Paul cyanobacteria bio fuels are non-polluting,

Locally available, accessible, sustainable and reliable fuel obtained from renewable sources. In addition to the above points microalgae algae based fuels are ecofriendly, nontoxic and with strong potential of fixing global CO₂.

Cyanobacteria as bioremediating agents

Large quantities of synthetic pesticides, inorganic fertilizers and manure and/or bio solids amendments (usually containing pharmaceuticals and antibiotics residues) are regularly applied in agricultural land. The translocation and losses of these contaminants usually happen through field runoff and drainage after irrigation or strong storm events leading to potential negative impacts against aquatic ecosystems (including aquifers) and eventually human health.

Microalgae based systems have recently demonstrated to be very efficient in treating different types of wastewater, including domestic and agricultural runoff, removing not only nutrients such as nitrate, phosphate or ammonium, but also contaminants of emerging concern such as pharmaceuticals, pesticides or UV filters.

The following cyanobacterial genera such as *Anabaena*, *Arthrospira*, *Aphanothece*, *Chroococcus*, *Fischerella*, *Lyngbya*, *Limnothrix*, *Nostoc*, *Oscillatoria* and *Phormidium* were involved to remove various nutrients such as NO₃⁻, NH₃, PO₄ and metals Cd, Co, Cr, Cu, Ni, Pb and Zn from different wastewaters (ground water, domestic and industrial sewage, synthetic, plating industry, urban, swine, agro industrial and animal wastewater).

Cyanobacteria also play an important role in the biological treatment of wastewater, called "phyco remediation" by accumulating organic and inorganic toxic substances, as well as radioactive materials, in their cells and self-purification of municipal, industrial and agro industrial wastewater by developing several detoxifying mechanisms, including bio sorption, bioaccumulation, biotransformation, bio mineralization and *in situ* and/or *ex situ* biodegradation.

The same findings was reported by Hall that cyanobacteria can also be used as bioremediation agents to eliminate toxic wastes from

contaminated sites including soil, water, wastewater and sediments. In addition to the above points they degrade or detoxify many gaseous, solid and liquid recalcitrant pollutants such as assimilate atmospheric nitrogen, remove heavy metals from aquatic ecosystems and reduce the extra phosphate and nitrate in farmlands. Above all its usage as bioremediation agent was low cost, ecofriendly nature; high efficacy and public acceptance are the major advantages of using cyanobacteria for bioremediation.

Cyanobacteria for bio-plastics production

Cyanobacteria, have the potential to produce renewable biopolymers from natural resources such as, solar energy, water and CO₂, reducing the need for fertile soils, fertilizers, herbicides and potable water for crop production. Among the cyanobacteria species *Arthrospira* (*Spirulina*), *Synechococcus* and *Synechocystis* are widely employed in biodegradable polymers such as PHAs production.

Conclusion

Cyanobacteria, known as “blue green algae”, are one of the oldest photosynthetic prokaryotes on planet earth, with the ability to live and flourish in a diverse range of environments from hot springs to underneath of ice pack in frozen lakes and under the surfaces of rocks in deserts.

Cyanobacteria, like higher plants, are capable of converting light energy into chemical energy and generate O₂. Due to interaction with other of microorganisms and their environment, cyanobacteria also produce a wide variety of secondary metabolites applied in feedstock for biofuel production, bioremediation agents to eliminate toxic wastes from contaminated sites including soil, water, wastewater and sediments, bio fertilizers to improve soil fertility in agriculture, supplement for animal and aqua cultural feed, as well as human nutrition and also in the pharmaceutical, food and cosmetic industries. In recent year cyanobacteria have gained importance in various areas of research such as drug discovery, treatment of deadly disease such as HIV and cancer.

Cyanobacteria also get attention due to their ability to fix atmospheric nitrogen and degrading pollutants and removing heavy metals by agriculturalist and environmentalist respectively.

Cyanobacteria like *Spirulina*, *Anabaena* and *Nostoc* also are used to solve problem of food crisis and malnutrition in different contents. Thus the possibility of producing novel biopolymer blends biofuel components and pharmaceutical compounds that are capable of meeting the demands of a biotechnologically based society. To achieve these target great strides in the cyanobacteria production sector a synergistic approach should be adopted by cyanobacteria related companies so that more fruitful results will come out.

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