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# Biotechnological application of Cyanobacteria in, Agriculture, 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 atten ion 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, bioenergy and biofertilizers. 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. Cyanobacteria has also its limitations through bloom production it influnces on the nutrient availability and usage of phytoplankton plants. 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.

## 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

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their common name, 'blue green algae [1]. 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.

In similar way [2] 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 $CO_2$ to produce organic compounds plays a substantial task in the recycling of $CO_2$ 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 [3].

Using water as an electron donor during photosynthesis resulting in the release of oxygen is another important characteristic of these tiny 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 anti bacterial, anti viral, anti fungal and anti cancer activities. They are also contributing positively in bioremediation and sustainable development of ecosystem. In view of the above, the objectives of the current review is to pointout 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.

*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.

Micro organisms, 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. According to [4] 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 (unfertile & unsuitable for other crops), easily digestible and product stability over a wide pH and temperature range.

According to some statistics findings of [5] 1kg 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 [6].

Research findings from [7] reported that cyanobacteria have been assessed for their nutritional value into fish feed formulation which provides balanced nutrition and improved fish growth. According to[8] the green algal species like Chlorella and Scenedesmus contains crude protein (40% to 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

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reported by [9]. 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 [10].

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 [11].

As it was reported by [12], 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 [13] 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, Arthospira platensis with a rich source of β carotene and various biomolecules of nutraceutical value thus regarded as “food for the future” [14]. 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 [15]. 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 [16] and have some specific applications such as their use in the formation of medicinal drugs.

Other findings by [17] 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 [18]

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 [19]. 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 [20].

Findings by [21] reported that Arthrospira sp produces metabolites such as sulphated 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, phycocyanins, various amino acids and minerals [22]. 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

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[23] 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.

[24] also reported that Spirulina, Nostoc, Anabena and Oscillatoria strains are most commonly used in skin care produts 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 [25] that sustainable agriculture practices as well as environmental quality besides eco friendly, 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 [26].

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 [27]. Similarly [28] also pointed out thatdifferent 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, [27]

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 [29].

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 [30]. In the field of agriculture, cyanobacteria have been mainly used as bio fertilizers due to their role as nutrient supplements. Also [31] reported that inoculation of soil with cyanobacteria specis such as Nostoc, Calothrix, Tolypothrix, and Scytonema have diverse N fixing potential in non water logged soils shown beneficial effects in terms of improvemen of quality of soil properties, enhancement in different plant growth such as wheat, maize, and lettuce as natural fertilizers [32]. 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.

*Cyanobacteria as Bio Controlling 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 [33] Other results of last investigations also give evidences about the defensive role of cyanobacteria and microalgeal secondary metabolites [34]

Cyanobacteria are known to produce metabolites with diverse biological activities such as anti bacterial, anti fungal and anti viral activities. Several reports [35, 36] have shown that the extracts of Nostoc species significantly inhibited the growth of phytopathogenic fungi because cyanobacteria produce biologically active

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compounds that have antibiotic and toxic activity against plant pathogens Other findings by [37] 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 Bio Energy*

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 nonrenewable 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 $CO_2$ from burning of fossil fuels are the main cause of global warming by releasing 29giga tons/year release of $CO_2$ [38] 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 [39] 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 eco friendly, nontoxic and with strong potential of fixing global $CO_2$.

*Cyanobacteria As Bio Remediating 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 [40, 41]. 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 [42].

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 $NO_3$-, $NH_3$, $PO_4$3 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 [43].

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 biosorption, bioaccumulation, biotransformation, bio mineralization, and in situ and/or ex situ biodegradation [44]

The same findings was reported by [45] 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 pointes 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, eco friendly nature, high efficacy, and public acceptance are the major advantages of using cyanobacteria for bioremediation [46]

*Cyanobacteria for Bio-Plastics Production*

Cyanobacteria, have the potential to produce renewable biopolymers from natural resources such as, solar energy, water and $CO_2$, reducing the need for fertile

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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 [47].

*Challenges of Cyanobacteria Cultures*

One of the challenges of cyanobacteria application is bioaccumulation process possibly affected by various factors, including the exposure route, duration, and concentration of Microcystin in their food resources, as well as bioaccumulation capacity and incomplete depuration after contact [48].

Studies conducted by [49:50] reported that the toxin accumulates on the seafloor in snail, in fish tissues, in various mammal organs, including muscle, liver, kidney, heart, lung, spleen, gastrointestinal tract and gonads, consequently leading to potential damage.

Similar research findings from [51:52] reported that Microcystin also affects vegetables and soils cereals, corn, peanuts, soybeans, and spices, among others during maturation, storage, and transportation. This toxin biomagnifies and persists in the medium of co occurrence, and poses a large potential ecological risk within the food chains which require urgent attention.

*Causes of Cyanobacteria Pollution*

Eutrophication is characterized by excessive algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis such as sunlight, carbondioxide, and nutrient fertilizers.

Eutrophication occurs naturally over centuries as lakes age and are filled in with sediments [53]. However, human activities have accelerated the rate and extent of eutrophication through both point source discharges and non point loadings of limiting nutrients, such as nitrogen and phosphorus, into aquatic ecosystems with dramatic consequences for drinking water sources, fisheries, and recreational water bodies. Similar findings by [54] reported that algal blooms to nutrient enrichment resulting from anthropogenic activities such as agriculture, industry, and sewage disposal and its consequences resulted in cultural eutrophication which include blooms of blue green algae (cyanobacteria), tainted drinking water supplies and degradation of recreational opportunities.

*Consequences of Cyanobacteria Blooms*

The most conspicuous effect of cultural eutrophication is the creation of dense blooms of noxious, foul smelling phytoplankton that reduce water clarity and harm water quality. Algal blooms limit light penetration, reducing growth and causing die-offs of plants in littoral zones while also lowering the success of predators that need light to pursue and catch prey [55]. Furthermore, high rates of photosynthesis associated with eutrophication can deplete dissolved inorganic carbon and raise pH to extreme levels during the day. According to [56] elevated pH can in turn 'blind' organisms that rely on perception of dissolved chemical cues for their survival by impairing their chemosensory abilities and eventually, algal blooms die, microbial decomposition severely depletes dissolved oxygen, creating a hypoxic or anoxic 'dead zone' lacking sufficient oxygen to support most organisms.

*Strategies to Control Its Limitations*

Algal pollution led to water quality degradation associated with nutrient enrichment, eutrophication which continues to pose a serious threat to potable drinking water sources, fisheries, and recreational water bodies. It is mandatory to employ a variety of strategies to minimize the effects of cultural eutrophication, including; diversion of excess nutrients altering nutrient ratios, physical mixing, shading water bodies with opaque liners or water based stains, and application of potent algaecides and herbicides [57]. Another alternative for improving water quality in nutrient rich lakes has been biomanipulation the alteration of a food web to restore ecosystem health as it was reported [58]

## Conclusions

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

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ice pack in frozen lacks, 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. A 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.

Though cyanobacteria has various applications, conversely it has some limitations because of its bloom which in one or another way affect the ecosystem. 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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