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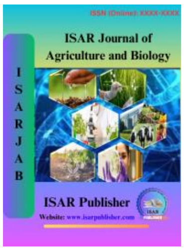

ISAR Journal of Agriculture and Biology
Vol-2, Iss-7 (July- 2024)
Abbriviate Title- ISAR J Agri Biol
ISSN *(Online)*- 2584-217X
https://isarpublisher.com/journal/isarjab
OPEN ACCESS

Health Benefits of Blue-Green Algae: Systematic Review

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Article History
Received: 04.07.2024
Accepted: 12.07.2024
Published: 26.07.2024

Abstract: Bacteria are the source of blue-green algae. Although they don't contain any more protein than milk or meat, they can be utilized as a source. Pigments rich in protein, iron, and other minerals are produced by blue-green algae. Blue-green algae is used as a protein supplement and a treatment for high blood pressure. It is also used to treat diabetes, obesity, high blood levels of cholesterol or other fats (lipids), and a host of other illnesses. However, these additional uses are not supported by solid scientific data. Certain goods made from blue-green algae are cultivated in regulated environments. Numerous bioactive substances are produced by cyanobacteria. Others are grown in their natural habitat, where contamination is more likely to occur. Use only items that have undergone testing and been shown to be free of pollutants such as dangerous microorganisms, heavy metals, and liver toxins called microcystins. An outline of blue-green algae's health-promoting properties against inflammatory and metabolic disorders is given in this review.

Keywords: Blue- Green algae, Diabetes, Cholesterol, Liver toxin, Microcystins, Cardiovascular disease.

Cite this article:
Singh, J., Bhardwaj, A., Bhardwaj, M., Mehwish, Z., Nigar, I., Kumar, S., Saurav., Nikhil., Rajput, S., Kumar, A., Kumar. V., Kumar, K., (2024). Health Benefits of Blue-Green Algae: Systematic Review. *ISAR Journal of Agriculture and Biology*, *2*(7), 13-18.

Introduction

Natural products provide a distinctive element of molecular diversity and biological functionality in the highly competitive world of contemporary pharmaceutical research and the development of new molecules, which is crucial for drug discovery 1-3. Drug development and discovery have traditionally benefited greatly from the study of secondary compounds that organisms, such as bacteria like BGA and plants, have evolved, mostly for their survival 4. They offer an abundant supply of structurally unique bioactive compounds, including fatty acids, amino acids, and lipopeptides, many of which have developed into medicines that can save lives 5. The earliest known organisms to produce oxygen were cyanobacteria. As a byproduct of photosynthesis, they produce and release oxygen. It is believed that cyanobacteria changed the early atmosphere from one that was low in oxygen to one that was oxidizing, which led to the great oxidation event and the "rusting of the Earth" 6. According to Parikh et al. (2001), Ciferri et al. (1983), Regunathan et al. (2006),7-9 and other scholars, BGA are nutrient-dense natural products that are high in fiber, B vitamins, calcium, phosphorus, iron, and pigments like β-carotene, xanthophylls, and chlorophyll. Research has demonstrated that BGA possesses lipid-lowering capabilities in addition to antiviral, anticancer, antioxidant, anti-inflammatory, anti-allergic, and antidiabetic qualities 10. According to Rasmussen et al. (2008)11, cyanobacteria are thought to have been the first oxygenic photosynthetic microorganisms on Earth and have had a role in the synthesis of oxygen in the Earth's atmosphere for the past three billion years. These principal photosynthetic microorganisms, commonly referred to as blue-green algae, can be found in a variety of settings, such as freshwater, the ocean, soil, and bare rock 12. These microbes can exist as filaments, colonies, or individual cells. Even though cyanobacteria are tiny, when they can exist as single cells or colonies, they can be seen. Despite their name, cyanobacteria are not algae; rather, they are members of the bacterial kingdom. They belong to the phylum Cyanobacteria of bacteria. The classification of blue-green algae is as follows:

Classification Level	Grouping
Kingdom	Bacteria
Phylum	Cyanobacteria
Class	Cyanophyceae
Order	Chroococcales, Nostocales, Oscillatoriales, Synechococcales
Family	Chroococcaceae, Nostocaceae, Oscillatoriaceae, Synechococcaceae
Genus	Microcystis, Nostoc, Oscillatoria, Synechococcus
Species	Many species of Cyanobacteria

Morphology:
The morphology of cyanobacteria varies; they might be filamentous, unicellular, or colonial. Functional cell differentiation is shown in filamentous forms, such as akinetes (cells in the resting stage), hormogonia (reproductive, motile filaments), and heterocysts (for nitrogen fixation). These and the intercellular connection they process are regarded as the initial indications of multicellularity 13.

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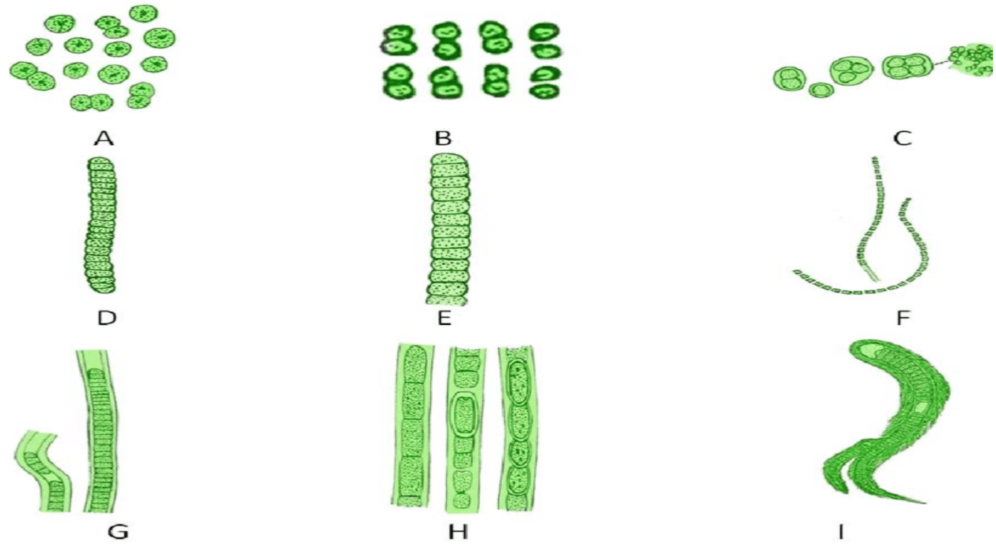

Fig1: (A) Synechocystis aqualis, (B) Merismopedia tenuissima, (C) Xenococcus acervatus, (D-E) Oscillatoria tennuis, (F) Phormidium fragile, (G) Lyngbya dendrobia, (H) Aulosira fertilissime var. tenuis, and (I) Calothrix parientia. 14

Cell Structure of Cyanobacteria:

Monocellular, colonial, or multicellular filamentous forms are known to exist in cyanobacteria. In the realm of bacteria, they are regarded as a subset. According to Righini et al. (2022)15, this group releases phytohormones, polypeptides, amino acids, polysaccharides, and siderophores, which in turn cause a considerable amount of N2 fixation, CO2 reduction, and phosphate solubilization. In addition, this subset produces plant growth regulators. The diverse duties and applications of cyanobacteria in sustainable agriculture can be attributed to their large number of organic inclusion units, each of which is capable of performing a wide range of specialized functions 16. 17(Fig 2) identified the following elements that constitute the structure of cyanobacteria: carboxysomes, lipid bodies, DNA-containing regions, ribosomes, phycobilisomes, polyphosphate bodies, cyanophycin granules, polyhydroxyalkanoate granules, and thylakoids. Chlorophyll-a, which allows for oxygenic photosynthesis, carotenoids, which shield chlorophyll-a from oxidative destruction, and phycobilins, which are specialized pigments attached to water-soluble proteins, are all present in cyanobacteria 18. According to Read N *et al*. (2007)19, cyanobacteria do not have flagella.

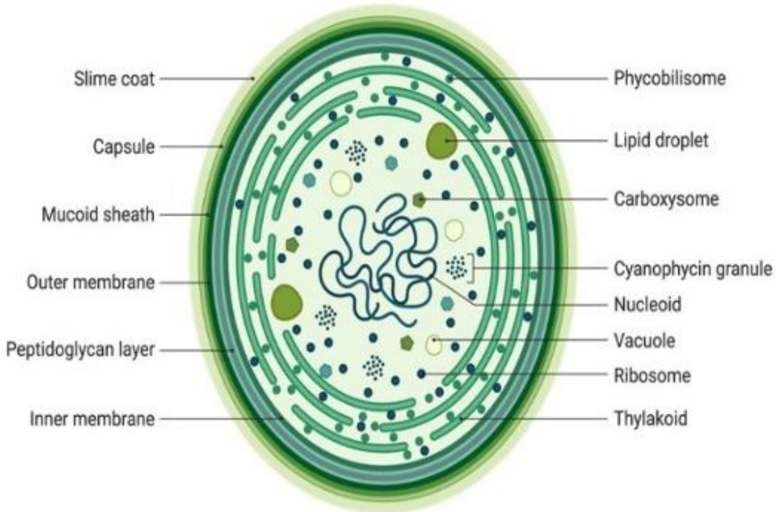

Fig 2: Cell Structure of Cyanobacteria 17

Application of Cyanobacteria in different areas:

In addition to their varied shape and environment, cyanobacteria, sometimes referred to as blue-green algae, also show variations in metabolism and structure. Furthermore, light, carbon dioxide, and other inorganic nutrients are all effectively used by cyanobacteria and microalgae, which have straightforward development requirements. Microorganisms' ability to produce H_2 through photobiological means has piqued public interest since it offers a renewable energy source made from two of nature's most abundant resources: sun energy and water. stocks for energy production, such as hydrogen (produced directly by cyanobacteria), lipids for the development of biodiesel and jet fuel, hydrocarbons and isoprenoids for the production of petrol, and carbohydrates for the production of ethanol 20.

Singh et al. (2005) 21 conducted studies that revealed that BGA possesses lipid-lowering capabilities in addition to antiviral, anticancer, antioxidant, anti-inflammatory, anti-allergic, and antidiabetic activities. The development of CVD and non-alcoholic fatty liver disease may be halted in part by BGA's inhibitory effects on hyperlipidemia, inflammation, and oxidative stress.

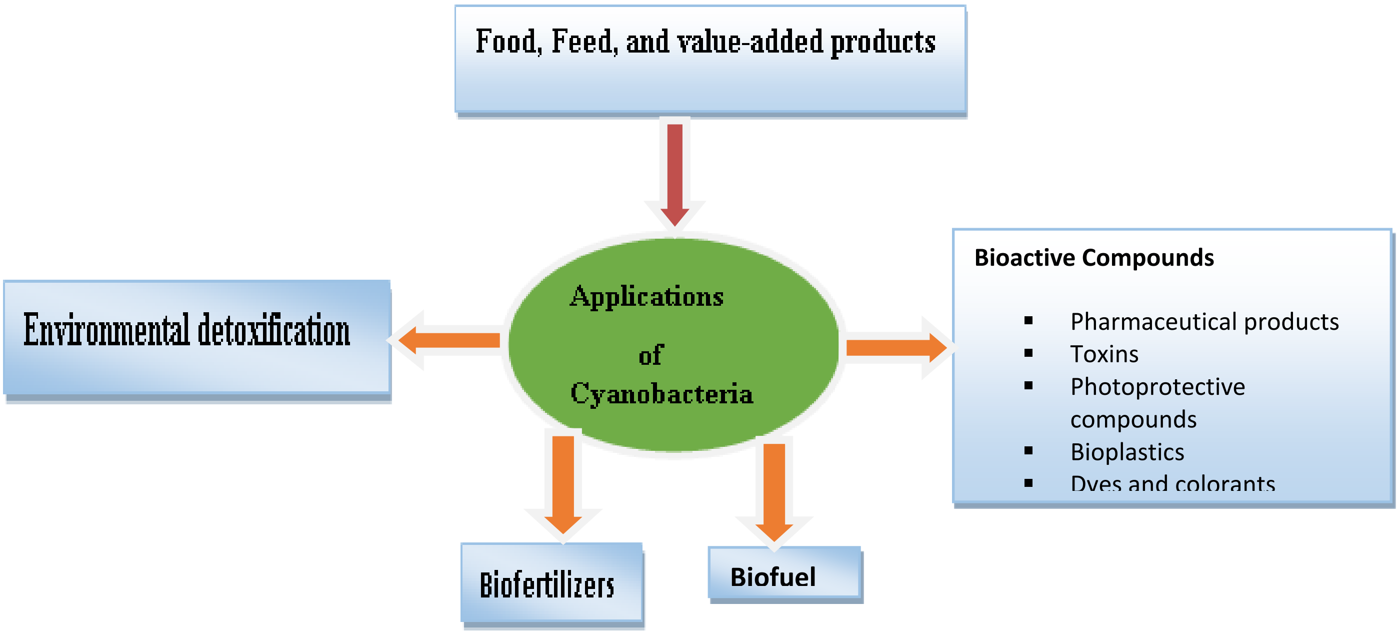

Fig 3: Different applications of Cyanobacteria

5.1: Cyanobacteria for Food and its Nutrition: Complex sugar, proteins, amino acids, active enzymes, phycocyanin, chlorophyll, beta-carotene, vital fatty acids, minerals, carbs, and vitamins are among the nutrients that are thought to be found in cyanobacteria. Iron and vitamin B12 are only two of the many essential elements and dietary minerals that are abundant in it. Vitamin B12 is well known for being an important ingredient that supports the health of the neurological system. According to Khan et al. (2005)22 and Campanella et al. (2002)23, it is crucial for DNA synthesis and contributes to the synthesis of hemoglobin. Worldwide interest has been shown in cyanobacterial protein, either as a food supplement or as a substitute for conventional food sources. Because they contain a significant amount of protein and fiber, certain species of Anabaena, Nostoc, and Spirulina are eaten as food 24. As a bioresource that may be utilized to produce both food and energy, algae have drawn special attention. The microalgae are thought to be beneficial for their nutritional qualities and curing properties because they contain 60–70 percent (wet basis) proteins, 12 amino acids, vitamins A, B1, B2, B6, B12, E, and K, and minerals iron, calcium, potassium, phosphorus, manganese, copper, zinc, and magnesium 25.

5.2: Medicinal use of Cyanobacteria: According to 26 (Romay *et al*., 2003), the bioactive chemicals found in cyanobacteria offer several medical advantages and certain uses, such as those used to make pharmaceuticals. Additional research by 27 revealed that cyanobacteria have biochemical pathways that produce distinct bioactive molecules with potential for use in industry and medicine. These molecules have anti-fungal, antibiotic, antimicrobial, immunosuppressive, anti-inflammatory, anticancer, antiviral, anti-bacterial, anti-coagulant, anti-malarial, anti-tuberculosis, anti-tumor, and anti-HIV (human immunodeficiency virus) properties. Additionally, these activities are attributed to Cyanovirin N, a carbohydrate-binding protein from Nostoc ellipsosporum 28.

5.3: Cyanobacteria as Biofertilizer: The organic materials that makeup biofertilizers are rich in microorganisms and biostimulants. Algae, PGPR (plant growth-promoting rhizobacteria), and other mineralizing organisms are examples of biofertilizers. These organisms can mobilize nutrients in the soil, potentially improving crop and soil productivity. The following are some advantages of using cyanobacteria biofertilizers: (a) the release of extracellular polymeric substances (polysaccharides) to improve soil aggregate stability; (b) the release of hormones that promote plant growth 29; (c) an increase in the amount of chlorophyll in leaves and the activity of antioxidant enzymes; and (d) the maintenance of symbiotic relationships with other microorganisms and the enhancement of microbial biomass in soil 30. Nitrogen (N) is typically the most challenging nutrient to regulate for the development of organic crops. The amount of plant-available N provided by the soil determines how much N is absorbed by the plants. Given that soil N frequently exists in organic forms that are unavailable to plants, the most significant limiting factor in organic systems seems to be N availability. Farmers confront the difficulty of projecting how much of the soil's organic N resource will be made available for plant uptake over time when controlling plant nutrients during ongoing crop cycles 31.

5.4: Cyanobacteria as Biofuel: According to 32 Velmurugan *et al*. (2022), 33 Peng *et al*. (2018), 34 Vandamme *et al*. (2013), 35 Quintana *et al*. (2011), and other studies, cyanobacteria generate a variety of metabolic products that are effective substrates for the synthesis of biofuels. Proteins, fats and/or lipids, and carbohydrates are stored macromolecules in cyanobacterial biomass, with the corresponding calorie values based on the final product. The global supply of liquid fuels today is nearly entirely reliant on petroleum due to the insatiable appetite for fuels in human civilization. Recently, there has been a lot of interest in the production of bioenergy due to growing concerns about the depletion of petroleum-based fuel supplies and the impact of fuel use on atmospheric CO_2 levels. One of humanity's most difficult problems is securing enough clean energy sources for the future. These resources are crucial to maintaining world peace, economic growth, and standard of living. This raises intriguing issues and discussions regarding the selection of alternative fuels to supplement or replace the current petroleum-based fuels, made from new basic materials 36 (Posten and Schaub, 2009). This raises intriguing issues and discussions regarding the selection of alternative fuels to supplement or replace the current petroleum-based fuels, made from new basic materials 36.

5.5: Cyanobacteria Use in Cosmetics: For many years, the cosmetics industry has utilized a variety of cyanobacteria species due to their anti-inflammatory, antioxidant, and detoxifying qualities 37, 38. The cosmetics industry has changed from focusing only on topical skin care products to taking a more intrusive approach to internal beauty. This rapidly growing sector aims to solve internal difficulties at the cellular level to treat skin-related diseases. Skin elasticity loss leads to aging, wrinkling, dryness, and other skin disorders.

5.6: Cyanobacterial biofuel: The global supply of liquid fuels today is nearly entirely reliant on petroleum due to the insatiable appetite for fuels in human society. Due to growing concerns about the depletion of petroleum-based fuel supplies and the fuels' role in contributing to atmospheric CO2 levels, bioenergy production has recently attracted much attention. One of the most difficult problems facing humanity today is securing enough clean energy sources, essential to maintaining world peace, economic growth, and standard of living. This raises thought-provoking issues and debates over whether to replace or supplement current petroleum-based fuels with alternative fuels made from new basic materials 36. Researchers and businesspeople worldwide are becoming interested in cyanobacterial biofuel production due to several factors. These include (1) their ability to perform oxygenic photosynthesis using water as an electron donor; (2) their ability to grow to high densities and high per-acre productivity in comparison to typical terrestrial oil-seed crops; (3) their non-food-based feedstock resource; (4) their use of otherwise unproductive, non-arable land; (5) their use of a wide range of water sources (fresh, brackish, seawater, and wastewater) 39; and (6) their production of biofuels and valuable co-products.

Conclusion:

Our review highlights the cyanobacteria's adaptability in biotechnological applications. They are now utilized in medication development, medical diagnostics, and bioremediation. They are rich sources of bioactive substances, biofertilizers, bioplastics, energy, and food. To enable their use, additional studies must concentrate on axenic cultivating these microorganisms to a suitable degree. The review's conclusions open the door to the creation of a useful platform for the use of cyanobacteria in a variety of applications, such as those related to the environment, sustainable agriculture, the production of pharmaceuticals, biofuels, and other worthwhile byproducts. Given their distinct traits and increasing distribution across many geographic locations, cyanobacteria have the potential to be a plentiful source of natural goods. Cyanobacteria have emerged as viable hosts for the effective conversion of solar energy to chemical energy and the subsequent product storage in the form of biomass or bioproducts, thanks in part to synthetic biology. The potential large-scale production of cyanobacterial biomass has been greatly enhanced by recent developments in isolating fast growers, discovering growth limitation factors, and optimising photosynthesis and carbon fixation. In the meantime, modifying cyanobacteria to manufacture particular nutrients has come to light as an intriguing side project worth investigating further.

Acknowledgments: For giving the resources required to finish this work, the writers would like to thank Krishna College of Science and Information Technology, Bijnor, which is connected to M.J.P. Rohilkhand University in Bareilly, U.P., India.

Conflict of Interests: No relevant conflicts of interest are reported by the authors.

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