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NUTRITIONAL AND THERAPEUTIC POTENTIAL OF SPIRULINA: MINI REVIEW

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Abstract
Spirulina, blue green algae has high protein content (50-60%), antioxidant content, fatty acid content , and is currently utilized as nutritional supplement around the world. Composition of amino acid in Spirulina ranks among the best in the plant world. Spirulina, a blue green microalga found in alkaline water bodies, has antioxidant, anti-tumor, antiobesity, and anti-diabetic properties. Its high nutritional value and diverse applications make it a "wonder medicine." Spirulina contains high-quality protein, vitamins, amino acids, carbohydrates, fatty acids, and pigments, including beta-carotene. It is used as a nutraceutical food supplement and has a long history of use as a food source. Studies show Spirulina has promising biological activities like antitumor, antimicrobial, antiviral, anti-inflammatory, hypocholesterolemic, effects due to its natural constituents, including antioxidants and scavenging activities. Spirulina is used as a nutraceutical food supplement and has a long history of use as food service.

Keywords: *Spirulina, Microalgae, Antioxidant, Nutraceutical, Food*

Introduction

1.1 General characteristics of Spirulina

Spirulina is multicellular, filamentous, symbiotic bacteria that fixes nitrogen from the air. It is recognized by open left handed multicellular trichomes which are left handed and have a length of 50-500 mm and width of 3-4 mm. Simple enzymatic systems can readily break down the trichomes due to their smooth surface. (Capelli and Cysewski, 2010; Habib *et al*., 2008; Ali and Saleh, 2002). Under light microscope Spirulina shows heterocystous filament which are made up of vegetative cells that undergo binary fission in the single plane. Filaments are solitary ,posses gliding motion. The trichomes are covered in a thin sheath and exhibit somewhat shortened ends as well as more or less noticeable constrictions at the cross-walls. Apical cells can be capitate and calyptrate, and they can be broadly spherical or pointed. (Ali and Saleh, 2012). Environmental factors mainly, chemical composition, temperature, and physical state can impact the helix geometry. A drastic alteration in the shape from helix to spiral that occurs when filaments are transferred from liquid to solid medium. Despite the helical form of the trichome being a stable and consistent feature in culture, significant differences in helicity degree may exist within and across species. (Eykelenburg, 1979)

Spirulina is photosynthetic and autotrophic, with its main pigment being phycocyanin, chlorophyll a, carotenoids, and some phycocyanin (Vo *et al* .,2015)

Source: Algae Base, last accessed: 17th April, 2019(Nege *et al.,*2020)

Kingdom	Eubacterla
Subkingdom	Negibacteria
Phylum	Cyanobacteria
Class	Cyanophyceae
Subclass	Oscillatoriophycidae
Order	Oscillatorlales
Family :	Osellatorlaceae
Genus	*Arthrospira*
Species	A. *platensis*

Table:1 Brief Biological Classification of Spirulina

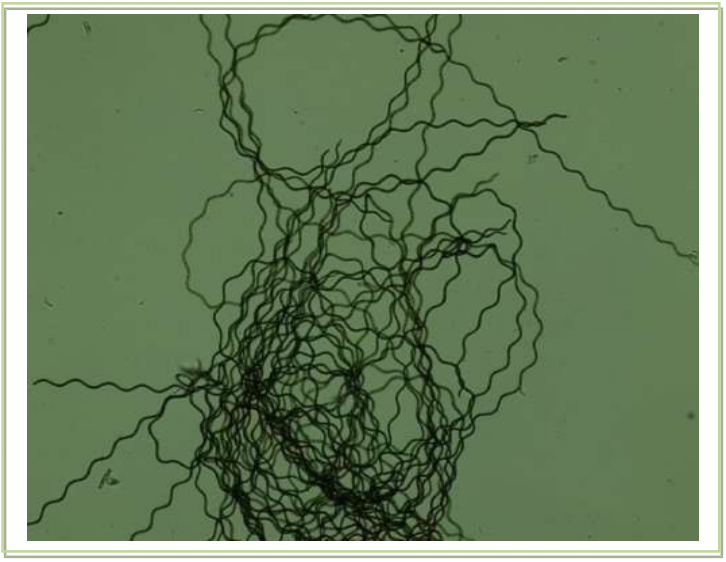

Figure I: Microscopic view of Spirulina

1.2 Natural habitat and source

Central Africa, surrounding Lakes Chad and Niger, Lake Texcoco, and East Africa, along the Great Rift Valley, are home to the largest Spirulina lakes. Lakes Bodou and Rombou in Chad have a stable monoculture of Spirulina dating back centuries. In Ethiopia's Lakes Aranguadi and Kilotes, as well as Kenya's Lakes Nakuru and Elementeita, it is one of the most significant species. Spirulina (Kebede and Ahlgren 1996) grows best in alkaline lakes, where as other microorganisms have a hard time surviving.

Spirulina, found in soil, marshes, and water, thrives in alkaline, saline water with high pH (8.5e11.0). As an obligate photoautotroph, it cannot grow in the dark media containing organic carbon compounds. Glycogen is the primary assimilation product of photosynthesis in Spirulina. The ideal growth temperature range for Spirulina is 35 to 39 °C. (Richmond, 1986)

1.3 Nutritional values of Spirulina

Microalgae is found to be abundant in protein contents comparable to those in milk eggs and meat. Spirulina also contains various bioactive components with high therapeutic potential such as dietary fiber, polyphenols, carotenoids, phycobiliproteins, polysaccharides, vitamins, sterols, and polyunsaturated fatty acids (PUFAs) like the ω-3 PUFAs eicosapentaenoic acid and docosahexaenoic acid. Different species have different proportions of bioactive chemicals, which are also dependent on different growing conditions. Currently Tetraselmis, Chlorella, and Arthrospira species of Spirulina are used for human nutrition due to their rich minerals, vitamins, antioxidants, (beta carotene, and phycocyanin) PUFAs, and phenolic compounds (Romero *et al* .,2021). Spirulina containing 13.5% carbohydrates, is primarily composed of glucose, rhamnose, mannose, xylose, galactose, and two unusual sugars, 2-O-methyl-L-rhamnose and 3-O-methyl-Lrhamnose. (Habib *et al.,* 2008; Koru, 2009)

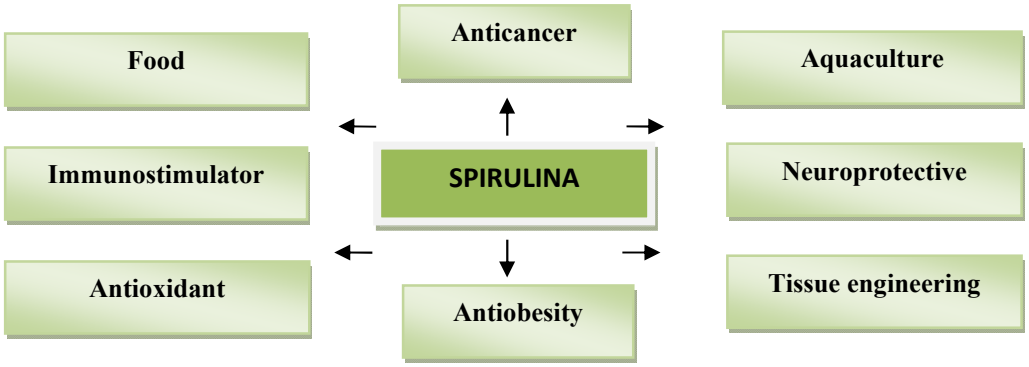

Figure II: Radial illustration of diverse properties of Spirulina

Vitamin Composition	Mineral Composition
Biotin	Potassium (K)
Folic acid	Calcium(Ca)
Pantothenic acid	Phosphorus(P)
Vitamin B12	Manganese(Mn)
Pyridoxin	Zinc(Zn)
Thiamine	Magnesium(Mg)
Riboflavin	Sodium(Na)
Niacin	Iron (Fe)
Tocopherol	Pigments
Inositol	Phycocyanin
Beta carotene	Chlorophyll
Bioflavonoids	Total Carotenoids

Table II: Vitamins, Minerals and Pigments composition of Spirulina (per 1 g sample)

1.4 Spirulina used as a food source for humans

Spirulina has been used as food additive for both humans and animals. The present uses of Spirulina include : traditional, scientific, and technological development, and the so called green tendency. Spirulina was reportedly taken from Lake Texcoco, dried, and sold in a Tenochtitlan market for human consumption. In the Republic of Chad's Lake Chad region, the Kanembu tribe continues to eat it. It is marketed there as "dihe," a type of dried bread. In 1967 The International Association of Applied Microbiology recognized Spirulina as a "wonderful future food source" (Sasson, 1997), and it is now widely cultivated all over the world (Dangeard, 1940).

Spirulina is currently hailed as “Food of future”. Specifically, compared to beef, which has a protein content of about 22%, Spirulina has a high protein content of over 60% of its dry weight. Spirulina, a plant with a high protein content of over 60%, has an 8–10% quicker photosynthetic conversion rate than soybeans and readily supplies a wide range of nutrients. (Ohmori, Ehira 2014)

Nutrient profile of Spirulinavs other foods

- More calcium (180% compared to whole milk),
- More protein (670% compared to tofu),
- More beta carotene (3100% compared to carrots),
- More iron (5100% compared to spinach), more antioxidant and anti-inflammatory action (3 g of Spirulina) than in five servings of fruits and vegetables (Capelli and Cysewski, 2010)

1.5 Ecology of Spirulina

Spirulina has valuable ecological properties. It form mats on the edges of alkaline lakes. It can withstand salt concentrations 1.5 times greater than sea water, demonstrating its salt tolerance. Furthermore, Spirulina can withstand temperatures as high as 60°C and flourishes in warm waters (32–45°C). Furthermore Spirulina thrives in warm seas (32–45°C) and can tolerate temperatures as high as 60°C. Moreover, Spirulina is resistant to temperatures up to 60°C

and flourishes in warm waters (32–45°C). Some species of Spirulina, suited to desert environments, can endure even when their ponds evaporate due to the harsh sun, resulting in a dormant state on rocks reaching temperatures of up to 70°C. (Ohmori and Ehira, 2014)

1.6Medicinal properties of Spirulina

- **Antioxidant properties of Spirulina**

The antioxidants properties of Spirulina extensively studied thathave drawn the interest of numerous researchers. Manoj and colleagues (1992) demonstrated that the alcoholic extract of Spirulina significantly (65%) inhibited lipid peroxidation more significantly (65%) than some chemical antioxidants like α-tocopherol (35%) and β-carotene (48%). Furthermore, they found that a Spirulina hot-water extract had a higher antioxidant effect (76%) than gallic acid (54%), and chlorogenic acid (56%)(Saho *et al* .,2019).

Tobon-Velasco *et al* (2013) evaluated neuroprotective effect of Spirulina on free radicals, finding that pretreatment of Spirulina results in reduction in mitochondrial activity, lipoperoxidation, nitric oxide levels, and the generation of ROS in rats injected with 6-OHDA.In another study, the phenolic compounds—salicylic, chlorogenic, trans-cinnamic, quimic, and synaptic—found in the methanolic alga extract were shown to have antioxidant activity, either alone or in a synergistic. The antioxidant impact was mostly linked to the combined or individual effects of phenolic compounds, β-carotene, and tocopherol (Miranda *et al*., 1998)

- **Anti-allergic Activities**

Eating edible microalgae can alter immune system components, potentially preventing allergic reactions. (Price *et al*., 2002) Spirulina increases IgG1 and IgA antibody production and decreases IgE antibody quantity in mice immunized with crude prawn extract. (Hayashi *et al* ., 1998)

Moreover Spirulina inhibits the synthesis of IL-4, it may also reduce TH2 cell development, which is why its therapeutic effect on allergic rhinitis has been established (Mao *et al*., 2005). Furthermore, It has been demonstrated that Spirulina is a highly effective allergen inhibitor by reducing blood histamine levels, anaphylactic shock, and passive cutaneous anaphylaxis in rats stimulated by compound 48/80 or anti-DNP IgE. (Yang *et al*., 1997; Kim *et al*., 1998). Recent research indicates that phycocyanin can prevent allergic reactions such as histamine production from rat mast cells, OVA-induced ear swelling in mice, and histamine-induced skin reactions in rats (Remirez *et al* ., 2002)

- **Antitumor Function**

There is strong evidence that Spirulina possesses antitumor and anticancer properties as well.Glioma cell development has recently been suppressed by complex polysaccharides from Spirulina by partially controlling interleukin-17 production and downregulating angiogenesis (Kawanishi *et al* ., 2013). In macrophages exposed to acidic polysaccharides derived from A. platensis, there was a significant increase in the production of tumor necrosis factor-α (TNF-α) (Parages *et al* ., 2012)

Radachlorin, a chlorine photosensitizer derived from S. platensis, significantly reduced tumors in rats through intravenous injection, and its hot water extract enhanced natural killer cell antitumor activity (Privalov *et al* .,2002)

- **Anti-diabetes and Anti-obesity Activities**

After giving 62 obese individuals 1 gram of Spirulina, Einalian and co workers found that there was a substantial decrease in appetite of 4.16% and a decrease in total cholesterol of 4.67%.

In the meanwhile(Becker *et al*., 1986) discovered that obese outpatients who received an additional meal containing 2.8 g of Spirulina three times per day for four weeks saw a statistically significant decrease in body weight. It has also been discovered that Spirulina lowers elevated blood pressure in rats.. While the water-insoluble fraction of Spirulina decreased the glucose level after glucose loading, the water-soluble fraction was found to be efficient in decreasing the serum glucose level while fasting.

- **Role of Spirulina in Immunity**

Spirulina enhances immunity and strengthens defenses against viral illnesses. Due to its ability to activate innate immune system cells, Spirulina can improve both mucosal and systemic immune system components. (Schwartz *et al.,*1987) Spirulina enhances systemic and mucosal immune systems by stimulating innate immune cells, improving resistance to infections, altering hematopoiesis, and inducing antibody and cytokine synthesis in various species, including humans, animals, and fish. (Mohan *et al*.,2014)

Moreover it has been found to protect against hay fever and reduce pro-inflammatory IL-4 secretion in allergic rhinitis patients, according to a double-blind, placebo-controlled study.The study found that stimulation of IL-2 secretion, which regulates the inflammatory response, was found to reduce inflammation in arthritis patients**. (** Hayashi *et al*., 1996)

- **Spirulina in Anemia**

It has been discovered that Spirulina may enhance red blood cell synthesis and function. During the course of a 12-week study period, ingestion of Spirulina was linked to constant increase in mean corpuscular hemoglobin average

levels. For older women, the benefits of Spirulina seen more quickly. Children anemia levels decreased when they included Spirulina in their diet. (Mohan *et al*.,2014)

1.7 Molecular studies of Spirulina

A comprehensive book highlights the particular physiological characteristics. The study emphasizes the significance of the cAMP signaling. A. platensis's gene expression spikes as it adapts to high salinity levels. Moreover, molecular investigation of adenylate cyclase genes has shown that A. platensis generates a range of unique cAMP-dependent signal cascades that enable adaptation to diverse severe environmental conditions.

It should be mentioned that A. *platensis* is now a significant industrial organic material used as a natural colouring agent, beta-carotene source, and health supplement. Furthermore, this cyanobacterium is valuable organism for the production of clean energy due to the presence of hydrogenase.In 1996, the whole genome of unicellular cyanobacterium Synechocystis sp. PCC 6803 was sequenced, leading to the sequencing of over 40 strains of cyanobacteria, including filamentous non-nitrogen-fixing species. (Sharma *et al* .,2014)

1.8 Future aspects of Spirulina

As we get closer to a greener and more sustainable world, algae—a diverse and complex species—deserve greater attention in the field of sport and exercise nutrition. They are also being used more and more in the biopharmaceutical, nutraceutical, and renewable energy sectors to reduce elevated CO2 levels.By replacing chemical goods derived from fossil fuels with biopolymers and bioplastics, the multipurpose Spirulina algae can reduce production costs for a variety of products and pave the way for a more sustainable future.

Conclusion

Spirulina, a wonder food supplement, is being used by leading organizations for its numerous health benefits. Its diverse nutritive nature and antioxidant properties have been used in treating various health issues, and its effectiveness is rapidly recognized, making it a valuable tool for managing life-threatening diseases.Spirulina, a non-toxic and nutritious food with numerous health benefits, is considered a potential source of wonder food supplements and alternative medicine.Spirulina, rich in proteins, PUFAs, and bioactive pigments, has health-promoting properties and potential for use in functional foods. Its derived pigments have health-promoting properties and are excellent sources of bioactive peptides, including antihypertensive, antidiabetic, antiobesity, and antioxidant ingredients.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

References:

1. Ahsan, M., Habib, B., Parvin, M., Huntington, T. C., & Hasan, M. R. (2008). A review on culture, production and use of Spirulina as food for humans and feeds for domestic animals. FAO Fisheries and Aquaculture Circular (FAO), (1034).
2. Ali, S. K., & Saleh, A. M. (2012). Spirulina-an overview. International journal of Pharmacy and Pharmaceutical sciences, 4(3), 9-15.
3. Anvar, A. A., &Nowruzi, B. (2021). Bioactive properties of Spirulina: A review. Microb. Bioact, 4, 134-142.
4. Becker, E. W. (2017). Nutritional properties of microalgae: potentials and constraints. In Handbook of Microalgal Mass Culture (1986) (pp. 339-420). CRC press.
5. Capelli, B., & Cysewski, G. R. (2010). Potential health benefits of Spirulina microalgae* A review of the existing literature. Nutrafoods, 9(2), 19-26.
6. Dangeard, A. (2007). Spirulina (Arthrospira): production and quality assurance. In Spirulina in human nutrition and health (pp. 15-40). CRC press.
7. Diraman, H., Koru, E., &Dibeklioglu, H. (2009). Fatty acid profile of Spirulina platensis used as a food supplement.
8. Hayashi, O., Ishii, K., Kawamura, C., Hei, S. Y., Bao, N. Y., Hirahashi, T., & Katoh, T. (2004). Enhancement of mucosal immune functions by dietary Spirulina platensis in human and animals. Nutritional Sciences, 7(1), 31-34.
9. Kawanishi, Y., Tominaga, A., Okuyama, H., Fukuoka, S., Taguchi, T., Kusumoto, Y., ... & Shimizu, K. (2013). Regulatory effects of Spirulina complex polysaccharides on growth of murine RSV-M glioma cells through Toll-like receptor 4. Microbiology and Immunology, 57(1), 63-73.
10. Kebede, E., & Ahlgren, G. (1996). Optimum growth conditions and light utilization efficiency of Spirulina platensis (= Arthrospira fusiformis)(Cyanophyta) from Lake Chitu, Ethiopia. Hydrobiologia, 332, 99-109.
11. Kim, H. M., Lee, E. H., Cho, H. H., & Moon, Y. H. (1998). Inhibitory effect of mast cell-mediated immediate-type allergic reactions in rats by Spirulina. Biochemical Pharmacology, 55(7), 1071-1076.
12. Mao, T. K., Water, J. V. D., & Gershwin, M. E. (2005). Effects of a Spirulina-based dietary supplement on cytokine production from allergic rhinitis patients. Journal of Medicinal Food, 8(1), 27-30.
13. Miranda, M. S., Cintra, R. G., Barros, S. B. D. M., & Mancini-Filho, J. (1998). Antioxidant activity of the microalga Spirulina maxima. Brazilian Journal of Medical and biological research, 31, 1075-1079.
14. Mohan, A., Misra, N., Srivastav, D., Umapathy, D., & Kumar, S. (2014). Spirulina, the nature's wonder: A review. Lipids, 5, 7-10.
15. Nege, A. S., Masithah, E. D., &Khotib, J. (2020). Trends in the uses of Spirulina microalga: a mini-review. SCIENTIFIC JOURNAL OF FISHERIES AND MARINE, 12(1).

16. Ohmori, M., &Ehira, S. (2014). Spirulina: an example of cyanobacteria as nutraceuticals. Cyanobacteria: an economic perspective, 103-118.
17. Parages, M. L., Rico, R. M., Abdala-Díaz, R. T., Chabrillón, M., Sotiroudis, T. G., & Jiménez, C. (2012). Acidic polysaccharides of Arthrospira (Spirulina) platensis induce the synthesis of TNF-α in RAW macrophages. Journal of applied phycology, 24, 1537-1546.
18. Remirez, D., González, R., Merino, N., Rodriguez, S., & Ancheta, O. (2002). Inhibitory effects of Spirulina in zymosan-induced arthritis in mice. Mediators of Inflammation, 11, 75-79.
19. Richmond, A., & Grobbelaar, J. U. (1986). Factors affecting the output rate of Spirulina platensis with reference to mass cultivation. Biomass, 10(4), 253-264.
20. Sahu, A., Pattanayak, A., Sahoo, R. K., Gaur, M., Sahoo, K., & Subudhi, E. (2019). Arsenite S-Adenosylmethionine-Producing Spirulina platensis: A New Trump Card on the Face of Global Arsenic Poisoning. The Role of Microalgae in Wastewater Treatment, 29-55.
21. Schwartz, J., &Shklar, G. (1987). Regression of experimental hamster cancer by beta carotene and algae extracts. Journal of Oral and Maxillofacial Surgery, 45(6), 510-515.
22. Sharma, G., Kumar, M., Ali, M. I., & Jasuja, N. D. (2014). Effect of carbon content, salinity and pH on Spirulina platensis for phycocyanin, allophycocyanin and phycoerythrin accumulation. Microbial and Biochemical Technology, 6(4), 202-206.
23. Tejero Pérez, A., Kapravelou, G., PorresFoulquie, J. M., López Jurado Romero de la Cruz, M., &MartínezMartínez, R. (2023). Potential benefits of microalgae intake against metabolic diseases: beyond Spirulina—a systematic review of animal studies. Nutrition Reviews, nuad098.
24. Tobón-Velasco, J. C., Palafox-Sánchez, V., Mendieta, L., García, E., Santamaría, A., Chamorro-Cevallos, G., & Limón, I. D. (2013). Antioxidant effect of Spirulina (Arthrospira) maxima in a neurotoxic model caused by 6-OHDA in the rat striatum. Journal of Neural Transmission, 120, 1179-1189.
25. Vo, T. S., Ngo, D. H., & Kim, S. K. (2015). Nutritional and pharmaceutical properties of microalgal Spirulina. In Handbook of marine microalgae (pp. 299-308). Academic Press.
26. Yang, H. N., Lee, E. H., & Kim, H. M. (1997). Spirulina platensis inhibits anaphylactic reaction. Life Sciences, 61(13), 1237-1244.