

Spirulina: Pharmacological Activities and Health Benefits

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ABSTRACT

Spirulina, a tiny blue-green algae, is a great dietary supplement for both people and animals since it is among the planet's finest sources of organic nutrients. In addition to being a rich source of high-quality proteins, vitamins, and minerals, spirulina also contains a wide range of naturally occurring carotene and xanthophyll phytopigments. Due to its extraordinary and astounding nutrient content, which not only enhances their nutritional properties but also serves medical reasons, spirulina is used as a dietary inclusion in a wide range of food products. Spirulina has a variety of pharmacological properties, including antimicrobial (including antiviral and antibacterial), anticancer, antimicrobial, anti-inflammatory, hypocholesterolemic, radio protective, and metalloprotective (prevention of heavy-metal poisoning against Cd, Pb, Fe, and Hg). This is because of its high protein, polysaccharide, lipid, essential amino and fatty acid, dietary mineral, and vitamin content. Phycocyanin, carotene, tocopherols, linolenic acid, and phenolic compounds are some of the natural components of spirulina that have been shown to have potent antioxidant properties and strong scavenging activities against Reactive Oxygen Species (ROS), such as superoxide and hydrogen peroxide radicals. These substances are responsible for spirulina's therapeutic and pharmaceutical properties. An overview of the therapeutic uses for Spirulina spp. is provided in this article.

Keywords: Spirulina, Micro-algae, Pharmacological activities, Reactive Oxygen Species (ROS).

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Received: 12-01-2023;

Revised: 03-07-2023;

Accepted: 02-08-2023.

INTRODUCTION

Spirulina is the collective term for the 15 species of filamentous, multicellular, blue-green microalgae that fall under the two genera *Spirulina* and *Arthrospira*. The most widely utilized and generally accessible genus of spirulina has undergone substantial research in a variety of disciplines, particularly the food industry and medicine.¹ The most researched cyanobacterium species in medicinal applications and the food industry are *Arthrospira platensis* and *Arthrospira maxima*, which are more widely known as spirulina due to their spiral or helical structure. Cyanobacteria, which are Gram-negative bacteria, have had a profound impact on the evolution of ancient Earth and the biosphere since the Great Oxidation Event (GOE) about 3 billion years ago. Cyanobacteria have been identified in a variety of biological niches, including soils, rocks, and habitats with severe physico-chemical properties, from freshwater to the seas. Spirulina's body surface is smooth and bare, making it simple for enzymatic systems to digest. Some have a red or pink color due to the presence of the pigment phycocyanin. Spirulina are autotrophic because they are photosynthetic.^{2,3} According to a chemical analysis of microalgae

spirulina, it is an excellent provider of several macro and micronutrients. Due to its high protein, vitamin, essential amino acid, dietary mineral, and essential fatty acid content, spirulina provides a lot of health advantages. Just a few of the possible health impacts include immunomodulation, anticancer, antioxidant, anti-viral, and anti-bacterial properties. Other advantages include defense against anaemia, hyperlipidemia, obesity, diabetes, heavy metal and chemical toxicity, allergic inflammation, and radiation damage.⁴ The benefits of various types of algae and microalgae for health have previously been extensively documented.

STRUCTURE OF SPIRULINA

Depending on the growth circumstances and the analytical methods, spirulina composition can differ. Spirulina is one of the more promising microalgae because to its abundance in proteins, essential amino acids, PUFAs, vitamins, minerals, and a number of phytonutrients (Figure 1). Spirulina has a high protein content of 60–70% of its dry weight, depending on the source.⁵ It is a complete protein since leucine, isoleucine, and valine are all necessary amino acids. It has less methionine, cystine, and lysine than typical proteins such those found in meat, eggs, and milk. Spirulina has a significant PUFA content, with PUFAs making up 1.5–2.0% of its total lipid content. For instance, spirulina has large amounts of g-linolenic acid, which accounts for 36% of all PUFAs.



DOI: 10.5530/jyp.2023.15.59

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Stearidonic acid, eicosapentaenoic acid, docosahexaenoic acid, and arachidonic acid are also found in it.⁶

Vitamin B1 (thiamine), Vitamin B2 (riboflavin), Vitamin B3 (nicotinamide), Vitamin B6 (pyridoxine), Vitamin B9 (folic acid), Vitamin B12 (cyanocobalamin), Vitamin C, Vitamin D, and Vitamin E are all present in this diet in rather significant amounts. Notably, Spirulina contains every essential mineral (about 7% of the total mineral composition), including potassium, calcium, chromium, copper, iron, magnesium, manganese, phosphorus, selenium, sodium, and zinc. Beta-carotene, echinenone, zeaxanthin, canthaxanthin, diatoxanthin, 3-hydroxyechinenone, oscillaxanthin, beta-cryptoxanthin, and allophycocyanin are only a few of the pigments found in spirulina. Along with having 13.5% of its weight in carbs, spirulina also contains rhamnose, mannose, xylose, galactose, and two unusual sugars named 2-O-methyl-L-rhamnose and 3-O-methyl-L-rhamnose. These carbohydrates are predominantly in the form of glucose.⁷

SPIRULINA NUTRITIONAL VALUES

Various human foods and animal feeds have included spirulina as an ingredient. Traditional, scientific, and technological breakthroughs as well as the so-called "green movement" are three examples of previous uses of this resource. It has been consumed in Mexico for a very long period; it first emerged during the Aztec culture about 400 years ago.⁸ *Spirulina maxima* were allegedly retrieved from Lake Texcoco, dried, and sold for human consumption in a market in Tenochtitlan. Spirulina was named a "great future food source" by the International Association of Applied Microbiology in 1967; it is now widely grown around the globe. For the past 30 years, it has been produced commercially for use in food and speciality feeds.⁹

Commercial spirulina is typically grown in controlled environments in big outdoor ponds or directly from lakes. Around 3000 metric tonnes of spirulina are thought to be produced globally at this time. More than 70% of the spirulina market is currently for human consumption because to its high protein, essential amino acid, mineral, vitamin, and essential fatty acid content. *Arthrospira platensis* and *Arthrospira maxima* are frequently used as food, dietary supplements, and feed additives.¹⁰ Spirulina is currently promoted and used as a meal for people, and it has been recognised as such by numerous governments, health organisations, and associations of nearly all countries.

In addition to their nutritional value, some cyanobacteria also contain toxins that have become a significant public health concern as a result of the increase in toxic cyanobacterial blooms. Algae that produce microcystin are the cause of these toxic blooms.¹¹ Even little doses of that toxin exposure can have long-term effects on people. Therefore, these poisons should be strictly and effectively controlled in order to avoid significant public health issues. Despite the fact that spirulina often does not contain toxins, other cyanobacteria may contaminate outdoor

cultures. Therefore, it is extremely unlikely that there will be an issue with effective administration and control of Spirulina monoculture.¹²

HEALTH BENEFITS OF SPIRULINA

- Spirulina thrives in warm weather and is found in many bodies of water around the world. It is known to have anti-inflammatory, antioxidant, and immune system boosting qualities.
- Spirulina contains beta carotene, iron, lutein, Vitamin B12, vitamin C, vitamin D, and Zinc. Beta carotene is a precursor to Vitamin A. Lutein is a protective agent against cataracts and supports vision. Iron helps with red blood cells production, and Vitamin C boosts immunity. Vitamin B12 aids in proper brain function and nerve regeneration. Zinc supports testosterone levels, muscle repair, and bone formation.¹³
- Spirulina is high in protein content. It is considered a complete food due to its high nutritional value.
- Spirulina is rich in antioxidants, especially lycopene. Strong antioxidant lycopene fights free radicals. Eating foods rich in lycopene reduces the risk of heart disease, stroke, and some types of cancer, diabetes, and premature aging.¹²
- Spirulina is often recommended for people who suffer from depression. Depressed individuals often exhibit fatigue, lack of appetite, and low self-esteem. Spirulina alleviates these symptoms by promoting mental clarity and relieving feelings of sadness and hopelessness.¹⁰
- Spirulina is effective at treating hyperactivity disorders in children. Children suffering from ADHD (Attention Deficit Hyperactive Disorder) are prone to hyperactivity and impulsiveness. Spirulina has been shown to reduce impulsive behavior when consumed daily over a three months period.¹²
- People who consume Spirulina regularly tend to experience less pain than those who do not. Studies show that consuming Spirulina decreases inflammation caused by arthritis and gout.¹¹
- Spirulina has a positive effect on skin conditions. It promotes elasticity and softness in the skin. It also prevents wrinkles and sagging skin.
- Spirulina is known to improve athletic performance. Athletes who consume Spirulina before exercise report feeling more energized and focused. Athletes who consume it after exercise feel more relaxed and recover faster.¹³
- Spirulina is helpful in weight loss. Research shows that Spirulina increases fat burning and lowers cholesterol levels (Figure 2).^{12,13}

PHARMACOLOGICAL ACTIVITIES OF SPIRULINA

Spirulina is blue-green algae that grow abundantly in warm fresh water bodies around the world. Spirulina contains high levels of protein, iron, vitamins B12 and C, riboflavin, niacin, Vitamin E, beta carotene, and phycocyanin. It is considered a superfood due to its nutritional value. Omega-3 fatty acids are abundant in spirulina, which is also known to have anti-inflammatory, antioxidant, antibacterial, and antiviral properties. In addition, it helps to lower cholesterol and blood pressure and boost immunity. Spirulina is among the few organisms that have been known to show remarkable therapeutic effects. Spirulina has been used traditionally throughout history to treat ailments, including diabetes, cancer, heart disease, arthritis, and even depression.¹⁴ Numerous businesses produce spirulina, which is sold as a nutritional supplement in a variety of health food stores throughout the globe. The investigation of Spirulina's therapeutic properties has received increased focus recently. Numerous toxicological studies on the liver, kidneys, reproductive system, and human physiology have established the safety of spirulina administration, whether it be chronic or transient. The FDA of the United States has presently classed it as "Generally Regarded as Safe" (GRAS). Spirulina is the first superfood in the world, boasting a complete nutritional profile and being the ideal "food of the future" due to its eco-sustainability. Spirulina is now industrially produced under strict controls. In reality, a variety of factors, including nutrient concentration, temperature, the spectrum of the light, intensity, and pH, affect the growth and production of this microbe and also have an effect on its biochemical composition. Spirulina's bioactive components, including phenolics, phycobiliproteins, and chlorophyll, operate as antioxidants, immunostimulants, anti-inflammatory, anti-bacterial, anti-viral, anti-cancer, anti-allergic, and anti-diabetic agents as well as treat a variety of medical disorders. Many different medical disorders are thought to be prevented or treated by these and other Spirulina-derived chemicals (Figure 3).²

Antioxidant Activity

Pre-treatment with 700 mg/kg/day of spirulina reduced several toxicity markers in rats given a single injection of 6-hydroxydopamine, 6-OHDA (16 mg/2 mL), including nitric oxide levels, ROS generation, lipoperoxidation, and mitochondrial activity. Rats exposed to gamma radiation experience oxidative stress and tissue damage that can be prevented by taking a spirulina supplement.¹⁵ By scavenging free radicals, the aqueous extract of spirulina prevents apoptotic cells from dying.¹⁶ Particularly the c-phycocyanin in spirulina has been found to be an effective free radical scavenger¹⁷ via triggering the antioxidant enzyme systems catalase, SOD, and glutathione peroxidase.¹⁸

Anti-inflammatory Activity

Phycocyanin injection (50-200 mg/kg) reduced edema as well as PGE2 and LTB4 levels in the arachidonic acid-treated mouse ear in a dose-dependent manner.¹⁹ Phycocyanin displays anti-inflammatory effects in four separate experimental types of inflammation. Carrageenan-induced rat paw edema was significantly and dose-dependently reduced in intact and adrenalectomized animals, as was the arachidonic acid- and tetradecanoyl phorbol acetate-induced mouse ear edema. Moreover, phycocyanin also demonstrated an inhibitory effect in the cotton pellet granuloma test.²⁰

Anti-allergic Activity

In a clinical trial, consumption of spirulina dramatically decreased nasal discharge, sneezing, nasal congestion, and itching in allergic rhinitis patients as compared to placebo.²¹ In addition, enhanced IgA antibody production was seen in lymphoid cell culture supernatants, particularly in the spleen and mesenteric lymph node of mice fed Spirulina extract for four weeks prior to antigen stimulation.²² Spirulina's capacity to lower IL-4 production, which may aid in preventing Th2 cell development, was also demonstrated to have a therapeutic effect on allergic rhinitis.²³ Phycocyanin was reported to increase biological defense activity against infectious diseases by reducing antigen-specific IgE antibody and reducing allergic inflammation in mice.²⁴

Anticancer Activity

In experimental studies utilising animal models, spirulina algae have been found to have an inhibitory effect on oral carcinogenesis. 250 mg of phycotene (extract of Spirulina and Dunaliella algae) enhances tumour regression in DMBA (7, 12 dimethylbenz(a)anthracene)-induced hamster squamous cell carcinomas. In contrast to the remaining 70% of rats, 30% of the animals experienced full tumour regression.²⁴ Spirulina has been demonstrated to prevent cancer when dibutyl nitrosamine damages the liver and causes carcinogenesis in rats.²⁵ Spirulina supplementation reduced liver tumour incidence from 80% to 20%. A considerable drop in p53, a decrease in cell proliferation, an increase in p21, and a decrease in Rb expression levels were all seen 48 hr after treatment. By increasing Bax expression and decreasing Bcl-2, spirulina also caused apoptosis.²⁶ In example, Selenium-containing Phycocyanin (Se-PC) has demonstrated powerful antiproliferative effects by triggering apoptosis, accumulating sub-G1 cell populations, DNA breakage, and nuclear condensation in human melanoma A375 cells and human breast cancer MCF-7 cells.²⁷

Anti-viral and Anti-bacterial Activity

The bioactive elements of *S. platensis* were studied because of its anti-HSV effectiveness. It was discovered that a polysaccharide having rhamnose as its main sugar component and a glycolipid known as sulphoquinovosyl diacylglycerol were both effective

against HSV-1 with IC_{50} values of 21.32 and 6.8 $\mu\text{g/mL}$, respectively.²⁸ While *S. maxima* displayed HSV-2 inhibitory action, *S. platensis* successfully inhibited HSV-1. A hot water extract from *S. maxima* considerably decreased HSV-2 infection at the initial stages of adsorption and penetration (ED_{50} , 0.069 mg/mL). Six *Vibrio* strains, including *Vibrio parahaemolyticus*, *Vibrio anguillarum*, *Vibrio splendidus*, *Vibrio scophthalmi*, *Vibrio alginolyticus*, and *Vibrio lentus*, have been successfully fought off by Spirulina micro-algal cells.^{29,30} Pure C-phycoerythrin from *S. platensis* effectively inhibited the growth of some antibiotic-resistant bacteria, including *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*.³¹

Antidiabetic and Antiobesity Activity

Moreover, spirulina reduces blood sugar, lowers cholesterol and triglycerides, improves insulin resistance, and possesses anti-lipidemic and anti-hyperglycemic properties.³² Hamsters fed spirulina and fish oil showed hypocholesterolemic and anti-inflammatory benefits.³³ Spirulina may be useful in treating cognitive dysfunction linked to obesity and ageing in rats because oral administration of both Spirulina and glycyrrhizin decreased serum glucose, cholesterol, and leptin levels as well as the activity of the enzyme Acetylcholinesterase (AChE) in the hippocampal tissue homogenates of obese rats.³⁴ β -carotene from *Spirulina platensis* demonstrated hypoglycemic activity in streptozotocin-induced diabetic mice, lowering blood glucose levels and regulating the mice's increased food and water intake.³⁵ Feeding hamsters Silicon-Enriched Spirulina (SES) could reduce the atherogenic effect of a High-Fat (HF) diet by decreasing the activity of nicotinamide adenine dinucleotide phosphate-oxidase and regulating the activities of superoxide dismutase and glutathione peroxidase in the heart and liver to protect them from oxidative damage.³⁶

Hepatoprotective Activity

Aqueous Spirulina extract reduced the lipid peroxidation brought on by cyclophosphamide in goat liver homogenates through its ability to scavenge free radicals.³⁷ Spirulina treatment significantly reduced lipid peroxidation in mice fed a diet contaminated with aflatoxins and restored reduced glutathione, which in turn lowered oxidative stress and liver apoptosis.³⁸ *Spirulina platensis* has also been demonstrated to have hepatoprotective properties in rats given deltamethrin poisoning, where it was able to lower oxidative stress and lipid peroxidation while also restoring the rats' increased levels of ALT, AST, APL, urea, creatinine, and uric acid.³⁹ *Spirulina fusiformis* had a stronger hepatoprotective impact than silymarin by restoring liver marker enzymes, the antioxidant status, and lipid peroxidation levels to normal levels in rats treated with Isoniazid (INH) and Rifampicin (RIF).⁴⁰

Nephroprotective Activity

Spirulina platensis demonstrated therapeutic potential in rats with renal dysfunction brought on by gentamycin sulphate by reducing lipid peroxidation (MDA), increasing levels of SOD, GSH, GPX, and Nitric Oxide (NO), bringing levels of creatinine and urea into normal range, and enhancing the kidney's histological picture.⁴¹ *Spirulina maxima* could reduce the oxidative stress in mice's kidneys caused by mercuric chloride exposure (HgCl_2)⁴² By acting as antioxidants, phycocyanobilin from spirulina prevents diabetic nephropathy.⁴³ Male Sprague-Dawley rats' drinking water with *Spirulina platensis* added had a significant protective effect against chromium-induced nephrotoxicity by bringing back to normal levels renal function biomarkers like urea and creatinine levels, catalase activity, and MDA contents while lowering chromium-induced histological alterations.⁴⁴

Neuroprotective Activity

Spirulina also exhibits neuroprotective effects; in rats, it boosted post-stroke locomotor activity and markedly decreased the extent of cerebral cortical infarction. Spirulina supplementation over an



Figure 1: Spirulina Microalgae under Microscope.

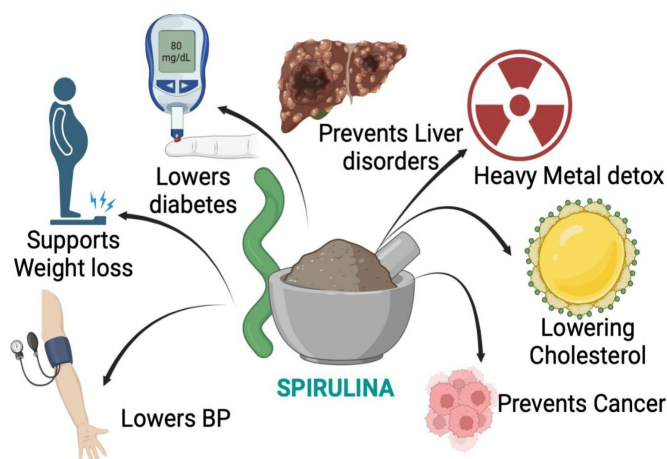


Figure 2: Health benefits of spirulina.

extended length of time may also lessen the risk of ischemic brain injury.⁴⁵ In the offspring of pregnant rats exposed to fluoride revealed a protective role in the neurological system against oxidative stress generated by exposure to fluoride.⁴⁶ *Spirulina maxima* had a neuroprotective impact in the rat striatum against 6-OHDA-induced toxicity, and they discovered that it reduced levels of ROS, nitric oxide, and lipoperoxidation in the striatum while restoring locomotion and maintaining dopamine mitochondrial activities.¹⁸ *Spirulina platensis* treatment for rats improved their ability to move their hind limbs and lessened the morphological damage to their spinal cord.⁴⁷

Anti-genotoxic Activity

Spirulina's polysaccharide shields DNA against radiation damage, especially during the excision, repair, and synthesis processes.² Spirulina has been shown to lower the frequency of micronuclei in mice's gamma-radiated bone marrow's polychromatic erythrocytes.⁴⁸ *Spirulina polysaccharides* stimulate cell nucleus enzymes and speed up DNA repair.⁴⁹

Immunomodulatory Activity

In broilers, an immunomodulatory and protective effect of a polyherbal remedy called Immon that contained spirulina was seen.⁵ Spirulina has also been discovered to have immunomodulatory properties in a variety of fish species, including tilapia (*Oreochromis niloticus*), where dietary Spirulina enhances immune system functions by increasing bactericidal responses against *Aeromonas hydrophila*, phagocytic activity, and lysozyme activity.⁵⁰ The addition of *Spirulina maximus* to the diets of common carp improved haematological parameters such as RBC, WBC, Hb, PCV, MCV, MCH, and MCHC in addition to parameters for immune function such as lymphocyte, lysosome activity, monocytes, Alternate Complement Pathway (ACP), IgM, phagocytic Index, and Phagocytic Activity (PA).⁵¹

Metallo-protective Activity

S. platensis may have a direct protective impact against cadmium-induced oxidative stress by decreasing lipid peroxidation and free radical scavenging, or it may have an

indirect protective effect by increasing the activity of GSH peroxidase and superoxide dismutase (free radical scavengers). These traits result from *S. platensis's* high concentration of antioxidant components.⁵² In rats that have been exposed to Pb, Cd, Zn, and Hg poisoning, spirulina may help with iron and haemoglobin metabolism.⁵³ Superoxide Dismutase (SOD), Catalase (CAT), and Glutathione S-Transferase (GST) activity as antioxidant potential are all greatly increased in the liver by spirulina. This lowers the degree of lipid peroxidation, which in turn lowers the transaminases (SGOT AND SGPT) activity in serum.⁵⁴

Nutraceutical in Covid-19 Pandemic

As a form of preventive medicine, people attempted to boost their immunity during the pandemic. Nutraceuticals are foods or parts of foods that have health benefits, such as the ability to prevent or treat disease. In addition to offering their basic nutritional value, nutraceuticals also have a number of health advantages. Given that both are meant to enhance health, nutraceuticals and dietary supplements are frequently misunderstood. Nutraceuticals, as opposed to supplements, help with the prevention and/or treatment of illnesses and diseases whereas supplements primarily increase nutrient intake from food. Natural foods rich in nutrients like garlic, spirulina, etc. are included in the range of nutraceuticals, as is a specific ingredient like Omega-3 oil from salmon.⁵⁵

Iron Supplements

As an alternative to the iron tablets that are now consumed around the world, a functional food that contains a lower amount of inorganic iron together with a variety of antioxidants would be a viable choice. In this aspect, the blue-green algae *Spirulina platensis* has an extremely accessible form of iron. This contains 20–25 g, which is enough to meet the ICMR RDA for iron. Spirulina is offered for sale in commercial quantities as food for people because of its high iron content. The body may utilise the antioxidant molecules in spirulina to counteract the negative effects of oxidative stress. Spirulina appears to be a promising source of iron, perhaps without the corresponding rise in oxidative stress levels.⁵⁶

DISCUSSION

The 15 species of filamentous, multicellular, blue-green microalgae that belong to the two genera *Spirulina* and *Arthrospira* collectively go by the name *Spirulina*. Significant study has been conducted on the most popular and widely available genus of spirulina, particularly in the fields of food and medical. According to a chemical analysis of microalgae spirulina, it is an excellent provider of several macro and micronutrients. Due to its high protein, vitamin, essential amino acid, dietary mineral, and essential fatty acid content, spirulina provides a lot of health advantages. Just a few of the potential health impacts

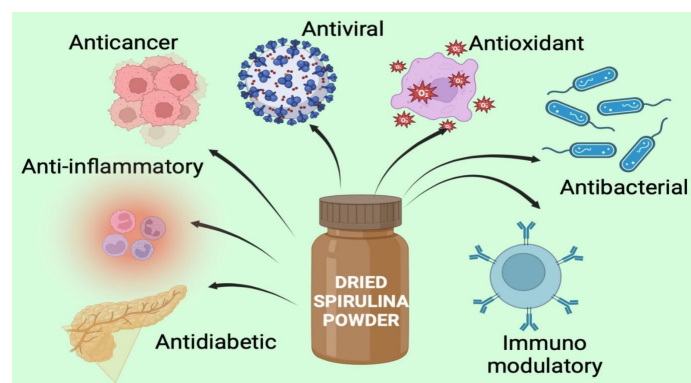


Figure 3: Pharmacological activities of spirulina.

include immunomodulation, anticancer, antioxidant, antiviral, and antibacterial properties. Other advantages include defence against anaemia, hyperlipidemia, obesity, diabetes, heavy metal and chemical toxicity, allergic inflammation, and radiation damage.

Great polynutrient value and phytopigments of spirulina have given it the high importance and global demand due to their significance in multiple purposes, including the manufacture of safe and healthy food products, animal feed, and many other diagnostic and therapeutic activities. Spirulina is preferable to other synthetic sources of nutrition for ingestion as a whole food supplement because it contains naturally occurring, highly concentrated nutritious components. Spirulina has also been approved as safe and is suitable for usage in a range of food items and applications, such as nutraceuticals, cosmetics, and functional foods. Spirulina is renowned for its high protein content (60-70% by dry weight), which contributes to its well-known nutritional benefits. It is one of the richest sources of proteins, including all nine necessary amino acids. Its protein content is similar to that of legumes and may be comparable to that of meat, eggs, and milk while having lower quantities of cysteine, methionine, and lysine.

Spirulina offers a wide spectrum of biological capabilities, advantages, and modes of action. The potential for spirulina to enhance reproductive and productive performance, overall health, and the signs of many animal diseases such as arthritic, diabetic, anaemic, hypertensive, and cardiovascular problems have been the subject of extensive research. Spirulina possesses a variety of biological features that are worth investigating, including anticancer, antibacterial, antiviral, anti-inflammatory, hypocholesterolemic, radioprotective, and metalloprotective activities, which have been discovered through more research. Phycocyanin, carotene, tocopherols, linolenic acid, and phenolic compounds are some of the natural components of spirulina that have been shown to have potent antioxidant properties and strong scavenging activities against Reactive Oxygen Species (ROS), such as superoxide and hydrogen peroxide radicals. These components give spirulina its medicinal and pharmacological capabilities.

CONCLUSION

Along with population growth, the need for wholesome food and the use of nutritional supplements has both risen. People are more aware of the link between a healthy diet and personal happiness. The prevention and treatment of the most serious diseases in the world have demonstrated to benefit greatly from a healthy diet. The importance of spirulina and other cyanobacteria in this competition stems from the fact that it is widely acknowledged that their sustainable production for the food and nutraceutical industries benefits not only Planet Earth but also provides a workable solution to the problem of hunger. The nutritious, non-toxic food spirulina is well known for a variety of health

advantages. It is believed that spirulina has the potential to be a miraculous nutritional supplement and supplemental treatment. However, spirulina harvest has the potential to contain harmful substances and dangerous substances that could have serious negative impacts on human health. Spirulina may also include microcystins, which accumulate in the liver and cause cancer and other liver diseases. As a result of the extensive research on spirulina, safe health foods will be produced. It has antioxidant characteristics due to its high protein content, which is characterized by a complete amino acid profile that includes all of the important amino acids, and its excellent vitamin supply, which includes the B vitamin complex, Vitamin C, and Vitamin E. There are many consequences that have been observed thus far. Spirulina has been the focus of various studies that have shown how using it might improve health because of its high-value mix of micro and macro nutrients. Additionally, it contains anti-inflammatory and anticancer effects that can help boost the immune system when used as a supplement to improve the health of the gut microbiota.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Cite this article: Saraswathi K, Kavitha CHN. *Spirulina: Pharmacological Activities and Health Benefits*. *J Young Pharm*. 2023;15(3):441-7.