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# A REVIEW ON THE NUTRITIONAL VALUE AND POTENTIAL HEALTH BENEFITS OF SPIRULINA

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## ABSTRACT

Spirulina is a biomass of microscopic and filamentous cyanobacterium growing in alkaline water bodies that have a long history of use as a safe functional food. Now it is widely used as nutraceutical food supplement all over the world. Recently, great attention and extensive studies have been carried out to evaluate its therapeutic benefits on an array of diseased conditions including hypercholesterolemia, cardiovascular diseases, inflammatory diseases, cancer, and viral infections. Potential health benefits of spirulina are mainly due to its chemical composition, which includes proteins, carbohydrates, essential amino acids, minerals (especially iron), essential fatty acids, vitamins, and pigments. Spirulina is generally considered safe for human consumption supported by its long history of use as food source and its favorable safety profile in animal studies. This review article is designed to cover the pharmacognostic aspects and some of the important health benefits of spirulina.

**KEYWORDS:** Biomass, Cyanobacterium, Nutraceutical, Pigments.

## INTRODUCTION

Spirulina is a biomass of cyanobacteria which grows well in alkaline waters. It is classified within the phylum of cyanobacteria. Popular food and nutritional supplements, this cyanobacterium exists as either blue-green bacteria or blue-green algae. Spirulina is a specific type of blue-green vegetable micro-algae, and is unique to only lakes which exhibit a high alkalinity. Certain African, Asian, and Mexican civilizations located within the vicinities of

such lakes began to unravel spirulina's beneficial therapeutic properties thousands of years ago. As of today, its worldwide popularity continues to grow as many health conscious consumers recurrently praise its extraordinary nutritional and therapeutic qualities. Spirulina's nutritional qualities are truly exceptional. With its structure consisting of nearly 71 percent total protein, spirulina represents the highest natural source of protein ever discovered. Its protein is five times that of meat, and nearly three times greater than the protein of the ever-popular soybean. In addition to this astounding amino acid profile, spirulina also contains a host of other beneficial nutrients including; carotenoids, essential fatty acids, B complex vitamins, vitamin E, copper, manganese, magnesium, iron, selenium, and zinc.[1]

Spirulina has become popularly known as a super food due to the great diversity and concentration of nutrients it contains. It is the most nutritious, concentrated whole food source found in nature. Spirulina is commercialized and marketed throughout the world as a food supplement or as an active ingredient in functional foods and beverages. It has attained considerable acceptance for the health benefits it bestows on consumers in Europe, North America, parts of Asia and Oceania. Besides, spirulina's concentrated nutrition makes it an ideal food supplement for people of all ages and lifestyles. Due to its wealth of nutrients and health benefits reported by consumers, spirulina has been subjected to research throughout the world. It has become a choice of natural health supplement throughout the world. In 1974, the United Nations named Spirulina one of the best foods for the future.[2] It is interesting to also note that scientists from the US Space Program at NASA have studied Spirulina as a potential food source for space travel and settlement of space stations due to its remarkable nutrient profile.[3]

**Nutritional information of spirulina**

Spirulina, the super food contains basic nutrients such as amino acids, essential fatty acids, vitamins and minerals. Apart from this spirulina also supplies many other phyto nutrients that are lacking in most of our daily diets. Moreover, spirulina supplies common nutrients at high levels.

**Nutrient profile of Spirulina vs. other foods**

- 180% more calcium than whole milk.
- 670% more protein than tofu.
- 3100% more beta carotene than carrots.

- 5100% more iron than spinach.
- More antioxidant and anti-inflammatory activity in 3 g of Spirulina than in five servings of fruits and vegetables.[4]

As it can be seen clearly by the above that spirulina succeeds at a great extent as compared with other regular nutritional foods.

**Potential health benefits of spirulina**

**Cholesterol-lowering effects and effects on diabetes**

Cardiovascular disease remains the number one cause of death in developed countries, despite increased awareness, and high cholesterol is one of the most important risk factors in atherosclerosis.[5] In the first human study, gave 4.2 g day−1 of Spirulina to 15 male volunteers and, although there was no significant increase in high-density lipoprotein (HDL) levels, they observed a significant reduction of Low-density lipoprotein (LDL) cholesterol after 8 weeks of treatment. The atherogenic effect also declined significantly in the above group.[5] Ramamurthy and Premakumari[6] in a more recent study administered Spirulina supplements in ischemic heart disease patients and found a significant reduction in blood cholesterol, triglycerides and LDL cholesterol and an increase in HDL cholesterol. More research is needed before Spirulina can be recommended to lower cholesterol levels but its role as a natural food supplement in combating hyper lipidaemia, in combination with other therapeutic options, should not be overlooked. Finally, Mani et al.[7] in a clinical study, found a significant reduction in LDL: HDL ratio in 15 diabetic patients who were given Spirulina. However, this study was small and better studies are needed before Spirulina can be recommended in diabetes.

**Anticancer effects**

It has been argued that the combined antioxidant and immune modulation characteristics of Spirulina may have a possible mechanism of tumor destruction and hence play a role in cancer prevention. Whilst there are many animal and in vitro studies, there has been only one trial with human subjects. This study looked specifically at the effects of Spirulina on oral carcinogenesis, in particular leukoplakia.[8] It is not surprising that few human studies exist to date as cancer prevention trials with lower cancer incidence as an endpoint have logistic problems, rendering them essentially impossible to conduct for most malignancies. The study conducted by Mathew et al. on a cohort of 77 patients originates from previous trials on hamsters that showed tumor regression after topical application or enteral intake of Spirulina

extract.[9,10,11] They reported that 45% of their study cohort showed complete regression of leukoplakia after taking Spirulina supplements for 1 year. The authors also reported that there was no rise in the serum concentration of retinal $\beta$-carotene despite supplementation and concluded that other constituents within Spirulina may have been responsible for the anticancer effects. Whilst their results appear promising, it was an unblended, non-randomized trial and as such cannot be regarded as evidence of a positive effect.

**Effects on immune system**

The benefits of Spirulina in building immunity and improving resistance to viral infections are well documented. For decades, users have anecdotally reported a decrease in colds and flu from Spirulina use[4,12] Several pre-clinical animal studies have shown good immune stimulatory effects in a variety of species. In humans, mammals, chicken and fish Spirulina produces an immune stimulating effect by enhancing the resistance to infections, the capacity of influencing hemopoieses, and stimulating the production of antibodies and cytokines. Spirulina has also been shown to activate macrophages, T and B cells. Sulfolipids derived from Spirulina have proved effective against HIV. Extracts from Spirulina biomass have also been found active against herpes virus, cytomegalovirus, influenza virus, etc. Spirulina extracts have also been shown capable of inhibiting carcinogenesis.[13]

They found that subjects given the Spirulina extract had higher levels of natural killer cells interferon gamma and more potent production of interleukin-12p40. Spirulina may be involved in signaling responses through toll-like receptors in blood cells even when orally administered. Toll-like receptors are a class of proteins that play a key role in the innate immune system. This may indicate that in humans, Spirulina acts directly on myeloid lineages and either directly or indirectly on NK cells.[14]

**Cardiovascular benefits**

The cardiovascular benefits of Spirulina use are described in many papers. A review published in 2009 noted several reports suggesting that Spirulina (Arthrospira) may have a beneficial effect in the prevention of cardiovascular diseases. Decreases in blood pressure and plasma lipid concentrations, especially triacylglycerols and low density lipoprotein-cholesterol have been demonstrated as a result of oral consumption of Spirulina. Spirulina has also been shown to indirectly modify the total cholesterol and high density lipoprotein cholesterol values.[15] A recent human trial validates the above referenced review in an open sample of the population. Results showed that total cholesterol and triacylglycerols were

significantly decreased in the Spirulina group, and HDL levels saw a significant increase, while both systolic and diastolic blood pressure decreased. Again, Spirulina showed a hypolipidemic effect.[16] In Korea, a clinical trial was done on 78 elderly men and women, 60 to 87 years of age, to see the effects of Spirulina consumption on blood lipid profiles, as well as on immune markers and antioxidant capacity. As compared to placebo in this double blind, randomized trial, Spirulina users had lower cholesterol and increased interleukin-2 and decreased interleukin-6. Spirulina had a favorable effect on lipid profiles, immune variables, and antioxidant capacity in healthy, elderly males and females. The researchers concluded that Spirulina is suitable as a functional food.[17]

**Antiviral applications: In vitro studies**

There are no in vivo studies providing strong evidence supporting the possible antiviral properties of Spirulina. The active component of the water extract of S. platensis is a sulfated polysaccharide, calcium spirulan (Ca-Sp). According to Hayashi et al.[18] Ca-Sp inhibits the in vitro replication of several enveloped viruses including Herpes simplex type I, human cytomegalovirus, measles and mumps virus, influenza A virus and human immunodeficiency virus-1 virus (HIV-1). Another more recent study showed in vitro that an aqueous extract of S. platensis inhibited HIV-1 replication in human T-cells, peripheral blood mononuclear cells and Langerhans cells.[19] The advantage of using herbs and algal products with proven antiviral properties in fighting certain viruses is that they can be used through immune modulation even when the infection is established. Of course, the above promising effects need to be studied further in animal models and humans before any definitive conclusions are drawn.

Recent research on water extracts of Spirulina, on Sodium Spirulan, a novel polysaccharide isolated from Spirulina, and on a combination of phycocyanin from Spirulina with selenium have all showed cardio protective qualities. Summaries of these findings show:

- A water extract from Spirulina may inhibit the intestinal absorption of dietary fat by inhibiting pancreatic lipase activity.[20]
- The sulfated polysaccharide Sodium Spirulan significantly inhibits vascular endothelial cell proliferation.[21]
- Sodium Spirulan is a potent inhibitor of arterial smooth muscle cell proliferation.[22]
- Selenium-rich phycocyanin extracted from Spirulina prevents the development of atherosclerosis.[23]

**Nutrient levels**

Besides basic nutrients such as amino acids, essential fatty acids, vitamins and minerals, Spirulina supplies many phyto nutrients that are lacking in most of our diets. Moreover, Spirulina supplies common nutrients at high levels; comparing Spirulina with other foods shows its unusual nutrient profile (Table 1). A few examples:

**Table 1:**

| Typical analysis per 100 grams for Spirulina Pacifica® | | | |
|---|---|---|---|
| **Item** | **Amount** | **Item** | **Amount** |
| General | | **Minerals** | |
| Total Calories (Kcal) | 333 | Calcium (mg) | 333 |
| Calories from Fat (Kcal) | 50 | Iron (mg) | 217 |
| Total Fat (g) | 5 | Phosphorous (mg) | 1100 |
| Saturated Fat (g) | 2.2 | Iodine (µg) | 500 |
| Cholesterol (mg) | 0 | Magnesium (mg) | 500 |
| Total Carbohydrates (g) | 16 | Zinc (mg) | 3 |
| Dietary Fiber (g) | 7 | Selenium (µg) | 30 |
| Sugars (g) | 0 | Copper (mg) | 0.7 |
| Protein (g) | 67 | Manganese (mg) | 13 |
| **Vitamins** | | Chromium (µg) | 1333 |
| Vitamin A (as Beta carotene) (IU) | 375000 | Sodium (mg) | 1000 |
| Vitamin E (IU) | 7 | Potassium (mg) | 2000 |
| Vitamin K1 (µg) | 2000 | **Carotenoids & Phytonutrients** | |
| Vitamin K2(µg) | 500 | Gamma Linolenic Acid (GLA) (mg) | 1067 |
| Thiamin (B1) (µg) | 117 | Zeaxanthin (mg) | 300 |
| Riboflavin (B2) (µg) | 4667 | Total carotenoids (mg) | 500 |
| Niacin (B3) (µg) | 13333 | Chlorophyll (mg) | 1000 |
| Vitamin B6 (µg) | 1000 | C-Phycocyanin (mg) | 8000 |
| Folate (µg) | 200 | Superoxide dismutase (units) | 36000 |
| Vitmain B12 (µg) | 300 | | |
| Biotin (µg) | 33 | | |
| Pantothenic acid (µg) | 150 | | |

## CONCLUSION

Spirulina is so far considered as an excellent and highly nutritional food and shows great diversity and higher concentrations of nutrients compared to other food sources. Owing to its high nutritional value it is known as a superfood throughout the recent decades. In fact, it is among the most nutritious, concentrated whole food sources found in nature. In this review we have depicted the various areas of research of spirulina showing the potential of Spirulina as a food supplement. Many more studies investigated the benefits from pure Spirulina

biomass, but some studies also researched the valuable extracts of Spirulina or isolated compounds from Spirulina. Overall it can be concluded from this review that spirulina is no doubt the super food with potential health benefits such as anti-viral activity against a variety of harmful viruses. Spirulina shows promise as an anti-cancer agent and also shows far ranging cardiovascular benefits including improvement of blood lipid profiles, control of hypertension and prevention of atherosclerosis.

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