

## Spirulina: A Contemporary Food Supplement

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### Abstract

India is a country with heterogenic population having diverse food habits. Cost of health care has become a driving force in the shift towards a greater recognition between diet and health care. This has spawned a new era of research leading to the use of few natural unprocessed foods like blue-green algae “spirulina” which has a galaxy of nutrients as diet supplements. The purpose of the present review is to compile evidence regarding the health benefits of spirulina. This review reveals that the greatest amount of evidence on health benefits are its effect in preventing anaemia, blood sugar and obesity. Relevant papers were identified from Science Direct, Google Scholar and pubmed by using all combinations of the search terms related to spirulina and health.

**Keywords:** Spirulina; Blue-Green Algae.

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### Introduction

Spirulina. is a unique blue green algae that is rich in chlorophyll and many other life-giving nutrients. The name spirulina comes from a Latin word meaning tiny spiral. It is microscopic, spiral-shaped, blue green algae (Figure 1) belonging to the phylum cyanobacteria. This microscopical single celled blue green spiral algae has been living on our planet since the appearance of life on earth. The green color of spirulina is derived from chlorophyll and the blue color is derived from the exotic pigment phycocyanin (7-8%), a potent health-building pigment that helps produce stem cells [1].

Spirulina is a “micro-vegetable” that can provide some of the antioxidants needed. Green and yellow vegetables are important foods for good health. One of the most well known important natural anti-cancer substances is beta carotene. Spinach and kale with their dark green leaves, broccoli, carrots, cantaloupes, squash, papayas and pumpkin all contain this important substance. Spirulina is very rich in beta-

carotene and the antioxidant zeaxanthin, the most important antioxidant for vision [2].

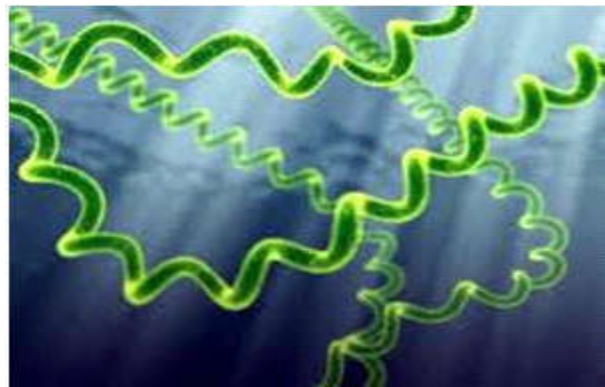


Fig. 1a: Spirulina



Fig. 1b: Spirulina products

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It is one superfood that stands out among the rest and should be taken every single day to ensure good health: Spirulina species has been used as food for centuries by different populations and only rediscovered in recent years. The first documented report on spirulina dates back to the 16th century and is believed to have been a nutritional source for the Aztecs and Meso Americans. The Mayans specifically farmed spirulina as a crop. The Kanembu who live along lake Chad in Africa, were found to be taking spirulina in the form of dihe -"a true filamentous, spiral shaped blue alga from the lake and drying it for food [3].

Nutritional Profile of cyanobacterium, spirulina is amazing. Research suggests that spirulina has a galaxy of nutrients. It is rich in eight essential amino acids, 10 non-essential amino acids, B complex vitamins, zeaxanthin, the antioxidants beta carotene, the essential fatty acid gamma linolenic acid, beneficial probiotic bacteria, dozens of trace minerals and pathogen-targeting proteins. Spirulina also has unmatched ability to boost the immune system and help in detoxification of body tissues from various toxins such as arsenic, mercury, radiation, pesticides, cadmium, environmental carcinogens and synthetic food chemicals [4].

Spirulina platensis is a commercial product and one of the important 'super food' with pharmaceutical and nutraceutical properties. Spirulina contains many bioactive compounds with therapeutic activity including antitumor property. It has been stated by NASA that the nutritional value of 1000 kg of fruits and vegetables equals one kg of spirulina. In long-term space missions NASA (CELSS) and European space agency (MELISSA) proposed that spirulina serves as a major source of food and nutrition [5].

### **Spirulina as a Natural Therapeutic Intervention**

Studies suggest that spirulina is also effective in the treatment of anemia. In his book *Healing with Whole Foods - Asian Traditions and Modern Nutrition*, Paul Pitchford [6] explains how spirulina boosts the production of red blood cells, particularly when taken in combination with vitamin B12. Rich in chlorophyll and phycocyanin, spirulina is also a powerful blood purifier.

Aside from promoting blood cell growth, these two vital nutrients also rejuvenate the existing blood supply. In fact, the structure of chlorophyll is nearly identical to hemoglobin, an important molecule responsible for transporting oxygen to the cells and cleaning the blood.

Few studies have examined that spirulina to ameliorate anemia and immunosenescence in older subjects. In a 12 weeks study by Selmi Carlo et al. [7] enrolled 40 volunteers of both sexes with an age of 50 years or older who had no history of major chronic diseases. Participants were told to take spirulina regularly, as well as submit comprehensive dietary questionnaires outlining all other foods they ate during this time. Thirty study participants completed the entire study and the data obtained were analyzed. Upon analysis, the research team found that, throughout the 12-week study period, patients' mean corpuscular hemoglobin, or average hemoglobin mass per red blood cell, increased significantly in both sexes. Both mean corpuscular volume and mean corpuscular hemoglobin concentration increased in male participants as well, but older women were found to derive health benefits from spirulina more quickly compared to men. Similar studies were carried by Uliyar V.M et al [8].

In one of the earliest studies, Bhat VB and Madyastha KM. [9] reported that spirulina provides an adequate amount of a spectrum of carotenoid pigments, especially beta carotene (associated with cancer prevention) and zeaxanthin (associated with prevention of age-related macular degeneration (AMD)). In this respect spirulina is a "micro-vegetable" that can provide some of the antioxidants needed. Many studies have also revealed that antioxidants like the carotenoids in fruits, vegetables, and spirulina have a synergistic effect.

Specifically, there is evidence suggesting that spirulina helps in lowering the serum glucose level. Takai et al [10] found a water-soluble fraction of spirulina to be effective in lowering the serum glucose level at fasting while the water-insoluble fraction suppressed glucose level at glucose loading.

Similar results were found in other studies. In a human clinical study involving 15 diabetics, a significant decrease in the fasting blood sugar level of patients was observed after 21 days of 2 g/day spirulina supplementation. In a double-blind-crossover study versus placebo Becker et al [11] found that a supplementary diet of 2.8 g of spirulina 3 times d-1 over 4 weeks resulted in a statistically significant reduction of body weight in obese outpatients.

A study was planned by Mani UV. et al [12] to observe the long-term effect of spirulina tablet supplementation (2 g/ day) on blood sugar levels, serum lipid profile and glycated serum protein levels of 15 non-insulin dependent diabetes mellitus (NIDDM) patients. Blood analysis was done at baseline, 1 month, and 2 months interval and during

the study period the patients were advised not to change their life style, dietary pattern and drugs.

Supplementation for a period of 2 months resulted in a significant reduction of blood sugar levels and glycated serum protein levels, thus confirming the hypoglycemic effect of spirulina. A significant reduction was observed in triglycerides, total cholesterol and free fatty acid levels. Appreciable reduction was noticed in LDL-C, VLDL-C and HDL-C/ LDL-C ratio.

It was concluded that spray dried spirulina tablets, rich in gamma linolenic acid, antioxidants, amino acid pattern, fatty acid profile and superoxide dismutase helps in reducing hyperglycemia and shifts the metabolism of lipids towards a favorable side thereby helping in the control of diabetes.

Hirahashi T et al [13] identified the molecular mechanism of the human immune potentiating capacity of Spirulina by analyzing blood cells of volunteers with pre and post oral administration of hot water extract of Spirulina. Some interesting findings reported from the study are ;

1. NK(Natural killer cells that control several types of tumors and microbial infections )functions represented by IFN gamma (IFN $\gamma$ , or type II *interferon*, is a cytokine that is critical for innate and adaptive immunity against viral, some bacterial and protozoal infections)production and cytotoxicity were enhanced after administration of Spirulina in >50% subjects.
2. IFN gamma was produced in an IL-12/IL-18-dependent fashion. These observations indicated that in humans Spirulina acts directly on myeloid lineages and either directly or indirectly on NK cells. The presence of co-operative IL-12 and IL-18 is critically important for NK-mediated IFN gamma production.

Few studies have examined the in vitro culture of Spirulina with human peripheral blood mononuclear cells (PBMCs) modulating the production of cytokines. Mao TK et al [14] evaluated the spirulina-based dietary supplement (Earthrise Nutritionals, Inc., Irvine, CA) on patients with allergic rhinitis by assessing the production of cytokines [interleukin (IL)-4, interferon (IFN)-gamma, and IL-2] critical in regulating immunoglobulin E-mediated allergy.

In a randomized double-blinded crossover study versus placebo, allergic individuals were fed daily with either placebo or Spirulina, at 1,000 mg or 2,000 mg, for 12 weeks. PBMCs (peripheral blood mononuclear cells) isolated before and after the spirulina feeding were stimulated with phytohem-

agglutinin (PHA) prior to determining the levels of cytokine from cell culture supernatants. These results indicate that spirulina can modulate the Th profile in patients with allergic rhinitis by suppressing the differentiation of Th2 cells mediated, in part, by inhibiting the production of IL-4. This is was the first human feeding study that demonstrates the protective effects of spirulina towards allergic rhinitis.

A. Ramamoorthy and S. Premakumari [15] found the hypercholesterolemic effect of spirulina. Thirty ischaemic heart disease patients without any complications with blood cholesterol levels above 250mg/ dl were selected for the study and divided into three groups of 10 each for supplementation of spirulina. Subjects in groups A and B received 2g and 4g spirulina per day, respectively for three months. Group C served as control. The study has revealed that spirulina plays a key role in weight reduction, lowering the blood cholesterol levels and improving the lipid profile of patients.

A study was planned by Uma M.Iyer et al[16] to develop recipes supplementing spray-dried spirulina at three different levels (1 g, 2.5 g, and 5 g) and to rank them according to the degree of acceptance. The recipes were

- Different types of parathas with curd
- Different types of vegetables with chapati
- Different types of rice with curd
- Snack

It was found that all the 22 Indian recipes incorporated with spirulina were acceptable with regard to appearance/color, texture, taste/ flavor, and overall acceptability at 1 g and 2.5 g levels. Finally it was concluded that:

1. Spray-dried spirulina can be effectively incorporated into various Indian recipes, which would help in the dietary management of diabetes as well as hyperlipidemia as it is low in carbohydrate, has gamma linolenic acid, high in protein, and high in antioxidant content.
2. Owing to its multinutrient property, various recipes that can be supplied in the supplementary feeding programs can be tried out for combating various nutritional disorders such as vitamin A and iron-deficiency anemia.

#### **Production of Spirulina and its Social Acceptance, in India**

- Spirulina (*Arthrospira*) fusiformis was grown in small mud pots to provide food supplements for a family and acceptability of the method as a

family enterprise was evaluated by Jeeji and Seshadri [17].

- Value added extruded product with 5% Spirulina + 95% Wheat flour + 5% Corn flour was developed by Vijayarani et al [18] and sensory parameters like taste, odour, texture, color, appearance were found to be at acceptable level.

### Clinical Studies for Combating Malnutrition Using Spirulina in India

- 1 gram of dried spirulina fusiformis was given every day as nutritional supplement to 5000 pre-school children by Seshadri [19] for a period of 6 to 13 months and clinical parameters were evaluated. Based on the survey at the end of the study, 4% reduction in incidence of Bitot's spots was observed.
- 900 mg of spirulina was administered to 100 girls with age 11 to 13 years for 6 months and significant improvement anthropometric measurements and hemoglobin, serum ferritin, serum zinc, serum protein and serum albumin levels was observed. by Ramesh et al [20].
- 200 adolescent girls (13-15 years) from Shimla were divided into equal groups by Dewan [21] and one group was given 1 gram spirulina + 40 grams wheat besan laddoo (an Indian recipe) for 6 days a week for two months and other group was given placebo for the same period. The group with spirulina supplementation showed less prevalence of common ailments (paleness of skin, conjunctiva, dental caries, fatigue) when compared with other group Children.

Spirulina contains more natural proteins when compared to other natural foods. The true protein digestibility and the biological activity of spirulina protein calculated by Narasimha et al. [22] is 75.5 and 68 respectively. The Recommended Dietary Allowance (RDA) for protein consumption is 0.8g/kg body weight and for athletes, RDA ranges from 1.2 to 1.4 g/kg/day [23]. The advantage of spirulina protein is it can withstand up to 67°C without denaturation.

### Conclusion

India is a country with heterogenic population having diverse food habits. The present review revealed that spirulina has potential for being a 'wonder food supplement'. One concern is the culture conditions of the spirulina that is being utilized. Blue-

green algae harvested in uncontrolled culture conditions may be contaminated with heavy metals that can lead to liver damage, diarrhea, and vomiting. One approach to circumvent this is to grow spirulina in an 'organic' way. Development of various spirulina fortified foods are required to create nutritional awareness and increase the acceptance level in developing countries like india where there are lot of deficiency disorders in the population. Considerable potential exists for spirulina to be used as a food supplement, in therapeutic management of various disorders.

### Key Messages

Spirulina is a boon to man-kind. It can be used as a food supplement, in day-to-day life and therapeutic management of various disorders in a better and processed form in recipes and food supplements.

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