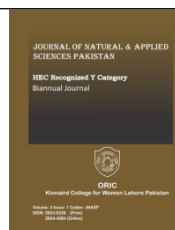




Contents list available <http://www.kinnaird.edu.pk/>

**Journal of Natural and Applied Sciences Pakistan**

Journal homepage: <http://jnasp.kinnaird.edu.pk/>



## **SPIRULINA: A MIRACLE FOOD FOR LIFE ON EARTH**

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### **Abstract**

Spirulina is filamentous multicellular blue green alga (cyanobacteria) which is used by humans and animals. Spirulina is consumed as a food supplement and has pharmaceutical value as well. The three important and popular species of Spirulina Are *Spirulina platensis*, *Spirulina maxima* and *Spirulina fusiformis*. Spirulina is the best combination of vitamins, proteins, minerals, carbohydrates, carotenes and essential fatty acids. Spirulina has also antioxidant, anticancer, cardio protective properties. The use of Spirulina has been increasing day by day as food due to its nutritional, functional and biological aspects. Spirulina also has been used as feed supplement in poultry, aquaculture and aquarium industries. Recently, Spirulina has given great attention to evaluate its therapeutic uses regarding treatment of different diseases like cancer, viral infections, inflammatory and cardiovascular diseases and hyperglyceridemia. This review entails the details of its useful purposes regarding consumption as food and feed.

### **Keywords**

Spirulina, Nutritional Aspects, Functional Food, Medicinal Uses, Dietary Supplement



## 1. Introduction

The world is now facing the challenges connected to the life sustainability as food demand is increasing day by day and to cope with the present situation it is necessary to find the alternative to provide full nutrition for well-being of living ones (Sotiroudis and Soutiroudis, 2013; Rogers *et al.*, 2014). Microalgae are considered as richest source of functional nutrients in this context that may affect positively to better sustain life needs (Al-Dhabi and Valan, 2016). Microalgae can be a best alternative to achieve food and feed of high quality with low environmental impact because microalgae cultivation is possible in cultivated and non-cultivable lands (García *et al.*, 2017). Spirulina or Arthrospira species is one of the important microalgae groups which contain macro and micronutrients and other bioactive compounds (Salmeán *et al.*, 2015). Spirulina is awarded as ideal food for mankind by The United Nations Organizations (UNO). The World Health Organization (WHO) also declared Spirulina as Safest and best food for future with excellent nutritional aspect (Kumari *et al.*, 2011; Saranraj and Sivasakthi, 2014). Spirulina is developed commercially now in the world as the “food for future” due to its amazing balance contents. Spirulina was awarded as the “Best natural food” in International Food Expo at West Germany. 5-year toxicology study was conducted on Spirulina by The United Nations and found Spirulina to be completely non-toxic. The scientists from NASA (National Aeronautics Space Administration), USA performed tests on Spirulina and found that 1kg Spirulina is nutritionally equal to 1000kg of fruits and vegetables

(Mathur, 2019). During 60th session (Second Committee, Agenda Item# 52) of United Nations General Assembly, a revised draft resolution on “Use of Spirulina to combat hunger and malnutrition and help achieve sustainable development” was initiated by International Institution for the use of Microalgae Spirulina against Malnutrition (IIMSAM). In response to this resolution The United Nations FAO prepared a draft on Spirulina and presented in 2008 (Zlateva *et al.*, 2019). This review has detail information regarding properties and health benefits of Spirulina used as both food and feed entity.

## 2. History

Spirulina, blue green algae (photosynthesizing prokaryotes) is considered as the oldest life form on earth. Spirulina genus was established in 1827 by Turpin for Spirulina oscillarioides (Morais *et al.*, 2014). Spirulina belongs to Monera Kingdom and Cyanophyta division. It refers to the dried biomass of Arthrospira species, which are photosynthetic bacterium found in marine and fresh ecosystems worldwide (Abdel-Latif *et al.*, 2022). It is multicellular cyanobacteria with nitrogen fixing symbiotic bacteria with phycocyanin as its primary photosynthetic pigment (Qamar *et al.*, 2018). Spirulina is vegetable microalgae which grow in alkaline lakes. About thousands of years ago certain Asian, African and Mexican civilizations located around these vicinities of such lakes began to unknit Spirulina’s benefits as medicines (Mohan *et al.*, 2014). Dr. Darwin: A German Scientist discovered for the first time the existence of spiral shaped algae named Spirulina (Gadoth *et al.*, 2006). It was found later by Dr. Clement of France in 1962 that people

Ganimou Kanembu of Africa living near Lake Chades used to eat blue algae due to limited resources and poor living conditions. That blue algae were *Spirulina* floating on the surface of water and was easily accessible (Abd Al Wakel *et al.*, 2017). Later, *Spirulina* gained a lot attention due to the fact that it is most promising source of compounds with biological activity and balanced chemical composition. People started using it as novel food and feed products. Now, it is considered as GRAS (generally recognized as safe) and is approved by ANVISA and FDA (USA) (Navacchi *et al.*, 2012). USFDA declared *Spirulina* safe as food additive within the range of 0.5-3.0 grams per serving. *Spirulina* is now using by formulators in powdered nutritional drinks, food bars, beverages, popcorns, condiments, frozen desserts and fruit juices (Spolaore *et al.*, 2006; Vijayarani *et al.*, 2012). First large scale production of *Spirulina* was started in 1970. There are so many companies which are now working on production of *Spirulina* among those best companies are Cyanotech (USA), Solarium biotechnology (Chile), Earthrise Farm (USA) and Genix (Cuba) (Sharma *et al.*, 2019). The market of *Spirulina* and its products are expected to rapid grow until 2028 with a compound growth rate annually upto 18.1%. European companies account for 5% approximately of the global food and feed microalgae market (Vigani *et al.*, 2015). *Spirulina* (Figure 1) is non-toxic, nutritious and have a medicinal property that's why it has commercial importance and hence its production is over 2000 tons per year. The leader countries producing *Spirulina* on commercial scale are Japan, China,

Mexico, Chile, Australia and South Africa (Baylan *et al.*, 2012).



**Figure 1:** *Spirulina* as food for humans and feeds for animals (Ahsan *et al.*, 2008)

### 2.1 Biochemical composition of *Spirulina*

The biochemical composition of *Spirulina* showed that it's a very good source of nutrients and minerals. The general composition of *Spirulina* is given in Table 1.

### 2.2 Protein

*Spirulina* is rich in protein upto 65% and is considered as safe for human and animal's consumption. Protein has all the essential amino acids which are necessary for the better production yield of biomass (Grosshagauer *et al.*, 2020).

### 2.3 Minerals

*Spirulina* contains important minerals like calcium, potassium, iron, copper, magnesium, phosphorous, sodium, chromium, manganese and zinc (Jung *et al.*, 2019). The minerals quantity in *Spirulina* powder is given in Table 2.

### 2.4 Vitamins

*Spirulina* is also rich in different vital vitamins like B1, B2, B3, B6, B12, Vitamin D, C and E (Liestianty

*et al.*, 2019). The vitamins quantity in Spirulina powder is given in Table 3.

### 2.5 Essential fatty acids

Spirulina has essential fatty acids i.e. linolenic acid, arachidonic acid, eicosapentaenoic acid and stearidonic acid (Sharma *et al.*, 2019).

### 2.6 Phytopigments

Spirulina is also enriched with different pigments like xanthophylls, chlorophyll-a, myxoxanthophyll, echinenone, beta carotene and phycobiliprotein (Bitam and Aissaoui, 2020).

**Table 1:** The general composition of Spirulina (Thomas, 2010)

Protein	60-69%
Minerals	6-9%
Carbohydrates	16-20%
Lipids	5-7%
Moisture	2.5-6%

**Table 2:** The minerals quantity in Spirulina powder

Minerals	mg/100g
Chromium	0.28
Calcium	700
Iron	100
Copper	1.2
Manganese	5.0
Magnesium	400
Potassium	1400
Phosphorous	800
Zinc	3.0

**Table 3:** The vitamins quantity in Spirulina powder

Vitamins	mg/100g
Pantothenic acid	0.10
Provitamin A	2.33x10 <sup>3</sup> IU/kg
Beta carotene	140
Vitamin K	2.20
Vitamin E	100-tocopherol equiv.
Folic acid	0.01
Biotin	0.005
Thiamin B1	3.50
Riboflavin B2	4.00
Vitamin B6	0.80
Vitamin B12	0.32
Niacin B3	14

### 2.7 Multiple roles and benefits of Spirulina

There are multiple benefits of Spirulina in different fields. These are summarized as below: Spirulina as nutritional supplement The malnutrition is the major issue in under developed countries. Due to malnutrition people cannot approach the entire required dietary intake for better health. Children are being affected by malnutrition and usually do not have a balanced diet which inhibits growth and development. The results of malnutrition represent a global issue which may result in mortality and morbidity. Spirulina is enriched with proteins, vitamins, fatty acids, carbohydrates etc and with essential minerals, so it can play a vital role in health protection. It can be consumed in the form of supplement and can fulfill nutritional requirement

and may act as “Wonder food” (Soni et al., 2017). In recent era Scientists are looking for the natural materials for the cure of painful cancer treatment. The recent research on Spirulina suggests that it may protect from various cancers and enhance immune system and also help in repair of DNA. Certain species of Spirulina showed excellent results against cancer in both humans and animals as well. Tobacco use in developing and developed countries is at peak these days and is causing different types of cancers (lung and oral). The incidence level of cancer through tobacco is upto 30%. Intravenous injection of Radachlorin which is a photosensitizer isolated from Spirulina platensis has reduced the tumor regression when experiments were performed on rats (Privalov et al., 2002).

**Table 4:** Anticancer properties of *Spirulina platensis*

Sr. No.	Cancer type	Name of extracted compound	Experimental organism	Author and Year
1.	non-small-cell carcinoma	lung Commercial <i>Spirulina</i> product	Humans	Czerwonka et al., 2018
2.	Oral-squamous carcinoma	cell <i>Spirulina</i> Phycocyanin	Humans and hamsters	Jiang et al., 2017
3.	Acute Leukemia	crude extracts of <i>Spirulina platensis</i>	Humans	Hernandez et al., 2017
4.	Anticancer activity	Polysaccharides from <i>Spirulina platensis</i> algae	In vitro	Kurd and Samavati, 2015
5.	B16 melanoma cells - Indirectly helps in oral cancers	Polysaccharides from <i>Spirulina platensis</i>	In vitro	Parages et al., 2012
6.	Lung, liver, stomach and breast cell lines	<i>Spirulina</i> Maxima ultrasonic extraction	In vitro	Oh et al., 2010
7.	B16 melanoma	Hot water extract of <i>Spirulina</i>	Human, mice	Akao et al., 2009
8.	Lung cancer	Ca-Spirulan extracted from <i>Spirulina platensis</i>	Mice	Saiki et al., 2004
9.	Leukemia	<i>Spirulina</i> Phycocyanin	Mice	Liu et al., 2000

Table 4. Anticancer properties of Spirulina platensis

Sr. No.	Cancer type	Name of extracted compound	Experimental Organism	Author and Year
1	Yearnon-small-cell carcinoma	Commercial Spirulina product	lung carcinoma	Humans
2	Czerwonka et al., 2018	Spirulina Phycocyanin	Oral-squamous cell carcinoma and hamsters	Humans
3	Jiang et al., 2017	Crude extracts of Spirulina Platensis	Acute Leukemia	Humans
4	Hernandez et al., 2017	Polysaccharides from Spirulina platensis algae	In vitro	Humans
5	Kurd and Samavati, 2015	B16 melanoma cells - Polysaccharides from Spirulina platensis	In vitro	Humans
6	Parages et al., 2012	Lung, liver, stomach and breast cell lines	Spirulina Maxima ultrasonic extraction	In vitro
7	Oh et al., 2010	B16 melanoma Hot water extract of Spirulina	Human, mice	Akao et al., 2009
8	Lung cancer	Ca-Spirulan extracted from Spirulina Platensis	Mice	Saiki et al., 2004
9	Leukemia	Spirulina Phycocyanin	Mice	Liu et al., 2000

### 2.8 Cardio protective properties of Spirulina

Spirulina reduces the levels of serum bad cholesterol (LDL) and raises good cholesterol (HDL). Spirulina itself is free from cholesterol. Spirulina increases the release and synthesis of nitric oxide by decreasing vasoconstricting substances from the epithelial cells by change in vascular tone. Spirulina may help in hyperlipidemia as in preclinical trials a significant lipase activity is found after Spirulina ingestion (Wang et al., 2020). It is given that Spirulina binds with metabolites of cholesterol and bile acids, which may increase fecal excretion of these metabolites.

People with obesity can be well treated with Spirulina.

### 2.9 Antioxidant and anti-inflammation properties of Spirulina

Antioxidant and anti-inflammatory properties may play an important role in better life sustainability. Spirulina platensis was confirmed by numerous researchers that it contains large amounts of Phycocyanin and  $\beta$ - carotene which have powerful antioxidant and anti-inflammatory activities. Spirulina also contains abundant antioxidants like sulfolipids, carotenoids, glycolipids, superoxide dismutase, DNA and RNA which have capability of joining with free radicals representing it harmless. Phycocyanin has the greatest scavenging activity due to its open chain tetraphyllores structure. Spirulina may activate antioxidant enzymes of cell, lipid peroxidation and DNA damage is inhibited. Spirulina prevents muscular and skeletal damage and produce antibodies against many diseases (Wu et al., 2016).

### 2.10 Spirulina as feed

Spirulina is being used as a balancing ingredient of diet as feed for shrimp, fish and poultry. It is also widely used as a vitamin and protein supplement for aqua feeds. Microalga is being used by China as partial substitute of imported feed to promote immunity, viability and growth of shrimp, fish and poultry. Japan is also using Spirulina as a feed for fish and other sea animals (Holman and Malau, 2013). It is edible alga and which is associated with fertility, growth, nutritional aspects, aesthetic quality of animal species. Spirulina is emerging cost-effective feed for improving animal productivity for future viable and sustainable food security. Spirulina

can be produced on small scale for animals and aquatic feeds and is potential income generating activity for villagers and householders. Spirulina can be used in dried and processed form. It can be supplemented also especially where poor dietary system needs it. An integrated system is being installed to make use of effluent from a starch producing factory using cassava at KMITT (King Mongkut's Institute of Technology Thonburi). A digester of 160-cubic meter is operated for producing biogas with algal ponds producing Spirulina. Its nutritional aspects are being studied. Similarly, Thai National Inland Fisheries Institute is working on Spirulina strains which are being isolated and are being consumed for fish feed production (Vonshak, 1997).

### 3. Conclusion

Spirulina is nontoxic, nutritious and rich in minerals. It can be used as food and feed. Different studies have proved that it is very useful supplement and is effective dose against different diseases. Currently, studies are being conducted on its genetic properties which will be useful in near future to enhance its nutritional and commercial aspects. From the above literature survey it is concluded that Spirulina is the nature's gift for life on earth to maintain health and longevity.

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