
SPIRULINA –THE SMART FOOD

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During the past decade, mankind has undergone a radical change in its quest to improve the quality of life. After years of taking vitamin supplements simply to meet the Recommended Dietary Allowances, the rationale has now shifted to disease prevention and performance enhancement. This strategy involves switching from avoiding unhealthy food ingredients and balancing one's diet to "positive eating" or seeking out foods and ingredients that offer a demonstrated health benefit.¹ One such food supplement that has begun to carve its own niche in the world of nutritional foods is *Spirulina* - often proclaimed as the "Strongest Food on Earth".

From Sacred Power Plant Of The Aztecs To Space-Age Food For NASA

The use of *Spirulina* dates back to Aztec in central Mexico, where it was harvested from natural habitats for human consumption. An African tribe Kanembou in Northern Chad collected *Spirulina* and dried it to form a cake called 'die'. Both Kanembou and Aztecs used *Spirulina* with whole grain cereals and thus maintained nutritional value of the diet when meat was scarce. Around 1940's, this nutritional food was rediscovered by a botanist Jean Leonard. In 1980, when *Spirulina* was first made commercially available, it was called the food of the future. NASA has now chosen *Spirulina* as an ideal food to grow on space stations.²

The Blue Green Algae

Spirulina is a blue-green algae belonging to the kingdom-Prokariotae, group-Cyanobacteria and genus-*Spirulina*. The most commonly found species are *S.maxima*, *S.fusiform*, *S.platensis* and *S.geitleri*. It is a relatively large prokaryotic microorganism forming long cell aggregations. One cell has an average diameter of ca. 15mm. The helical structure is formed by numerous cells connected by plasmatic filaments. This type of cellular organization is called a 'trichome' and can grow up to several millimeters in length. The blue refers to the blue pigment, a protein called phycocyanin. The green pigment is chlorophyll which helps plant cells capture and convert sunlight into energy.³

Production

Single cell algae like *Spirulina* are produced by a variety of methods ranging from cultivation in lakes, earth ditches or ponds to highly sophisticated fermentors and bioreactors⁴.

Mass culture open systems: At Sosa Texcoco Company in Mexico, an alkaline lake (pH 9-11) of about 900 hectares surface area produces up to 1000 metric tons per year of *Spirulina maxima* (equivalent to 0.111 kg/m²). Weather conditions in central Mexico and high alkalinity of the water favours effortless predomination of *S.maxima* on lake Texcoco.

Photobioreactors : Photobioreactors are closed systems working either outdoors or indoors, in which a single species is inoculated to keep a clean culture operation. Closed cultivation systems offers better control in terms of contamination and cell physiology, leading to higher growth and better quality of the harvested product but increased manufacturing costs. A design constructed in Chile up to 110m² solar irradiation area consists of a cement pond lined with epoxy resin and covered with a polyethylene dome. The agitation system is a paddlewheel and produces *Spirulina* biomass up to a density of 450-750 mg/L. *Spirulina* is easily skimmed off or harvested by filtration through cloth or screen. After harvesting the biomass is dewatered by centrifugation and/or dried by drum drying.

Nature's Richest Whole Food

Spirulina naturally contains some of the highest amounts of the following nutrients ever found in foods⁵:

Table 1: Chemical composition of spray dried *Spirulina* spp

Proteins	60 -70%
Carbohydrates	10 - 20%
Fats	5%
Ash (Minerals)	7%
Fiber	2%
Moisture	6%

Vitamins	mg/kg
b Carotene (provitamin A)	1700
Cyanocobalmin (Vitamin B12)	1.6
D-Ca-Panθοthenate	11
Folic acid	0.5
Inositol	350
Niacin (B3)	118
Pyridoxine (B6)	3
Thiamine (B1)	55
Tocopherol (E)	190

Minerals	mg/kg
Calcium	1180
Phosphorous	8280
Iron	528
Sodium	344
Chloride	4200
Magnesium	7663
Zinc	33
Potassium	14353

Fatty Acids	mg/kg
Linoleic acid (C18)	12352
g-Linoleic acid (C18)	10360

Amino Acids	mg/kg
Isoleucine	5.7
Leucine	8.7
Lysine	5.1
Methionine	2.6
Phenylalanine	5.0
Threonine	5.4
Tryptophan	1.5
Valine	7.5
Alanine	79
Arginine	7.6
Asparatic acid	9.1
Cysteine	0.9
Glutamic acid	12.7
Glycine	4.8
Histidine	1.5
Proline	4.1
Serine	5.3
Tyrosine	4.6

Others	
Superoxide dismutase	15000 units/kg
Carotenoids	3.7 g/kg
Chlorophyll	10 g/kg
Phycocyanine	140 g/kg
RNA	3.6 g/100g
DNA	0.8 g/100g
Lysine availability	85%
Pepsin digestibility	85%
Protein Efficiency Ratio (PER)	2.2-2.6
Net Protein Utilisation (NPU)	57
Biological Value (BV)	70

What Makes *Spirulina* So Remarkable?

This amazing vegetable microorganism is nature's most nutritious whole food containing hundreds of nutrients, all working synergistically to maximize potency and effectiveness.

A superior source of biological protein: *Spirulina* is a high-biological value protein with a superior, complete amino acid profile which contains all eight essential amino acids in addition to ten non-essential amino acids. Though animal proteins are complete proteins like *Spirulina*, they are of questionable quality because of their: (1) high levels of saturated fats and cholesterol, and (2) high residues of toxic pesticides, herbicides, drugs and hormones. *Spirulina* contains no saturated fats or cholesterol and therefore is remarkably low in calories.

Table 2: Comparison of *Spirulina's* protein content with other common proteins

<i>Spirulina</i>	60 -70 %
Eggs	12-16 %
Soybeans	30-35 %
Tofu	8 %
Beef	18-22 %
Milk	3 %

Superior assimilation and digestibility: Other plant foods have nutrients which are largely unavailable (unless cooked or sprouted) because they are encased like microscopic nuts within walls of tough indigestible cellulose. *Spirulina*, on the other hand, has unmatched digestibility and hence no tedious laboratory synthesizing is required to extract its nutrients. *Spirulina's* cell walls are bubble-thin mucopolysaccharides (complex natural sugars) which dissolve upon contact with moisture and digestive enzymes. Its amino acids are delivered in an essentially free form state for instantaneous

assimilation. Within moments, its concentrated nutrients, enzymes, and living essences are absorbed into the bloodstream without the momentous loss of energy incurred in the digestion of ordinary foods. Other high protein foods are characteristically difficult to digest (e.g., beef, chicken, fish, milk).

Dynamic energy and endurance: Nutritionally enlightened fitness enthusiasts, bodybuilders, professional coaches, and competitive athletes who use *Spirulina* experience exciting performance improvements. They report increased energy and enhanced endurance. People suffering from Chronic Fatigue Syndrome and hypoglycemia also report a significant increase in their energy levels and overall vitality from regular use of *Spirulina*.

Leanness and aliveness: *Spirulina* offers a natural, easy way to stay fit and trim while maintaining a high energy level, without the physical and mental exertion, stress or strain often associated with most fitness regimes and weight-reduction programs. *Spirulina's* supernutrition satisfies hunger because it fulfills the body's biochemical needs thus facilitating low-calorie eating. And since *Spirulina* is one of nature's richest sources of phenylalanine, dieters claim that *Spirulina* effectively suppresses their appetite and boosts their energy levels.

Therapeutic Values of *Spirulina*

Anticancer activity : In vitro studies suggest that *Spirulina* enhances cell nucleus activity and DNA repair synthesis and can prevent and even reverse certain types of cancer without access to fresh fruits and vegetables. According to Dr. Sameer Kaul, senior consultant with Apollo hospitals, *Spirulina* increases the vitality of cancer patients and also helps them to withstand the chemotherapy. Studies on *Spirulina* as a potential cancer preventing agent in humans was conducted on 60 tobacco chewers in a village in Kerala. A complete regression of oral leukoplakia (precancerous mouth lesions) was observed among 45 % of subjects fed on 1gm of *Spirulina* per day for one year⁶. Phycocyanin, the blue protein in *spirulina*, is demonstrating positive results with treating cancer and in stimulating the immune system⁷. *Spirulina* is a naturally rich source of Superoxide Dismutase (SOD) which is a metallo protein. By scavenging free radicals in human system, it offers protection from cancer and tissue damage.⁸

Antiviral/anti AIDS activity : Recent research conducted with *Spirulina* on the AIDS virus indicates that small concentrations of a *Spirulina* extract decreased the HIV-1 viral replication in cells and larger concentrations actually stopped the replication

of the viral cells altogether.⁹ Elsewhere, other in-vitro studies with a purified water extract of *Spirulina* demonstrated the same inhibiting effect on viral cell replication with a variety of other infections including herpes simplex, Influenza A; and mumps and measles viruses. Glycolipids extracted from *Spirulina* have been found to combat the AIDS virus.

Immune system : Essential nutrients in *Spirulina*, including the blue pigment phycocyanin, stimulate the immature or damaged immune system to grow or to repair itself when injured or weakened by infection or toxic chemicals.¹⁰ Selenium and zinc the major players in a robust immune system are also be found in *spirulina*. Selenium works synergistically with vitamin E as an antioxidant. A deficiency in this mineral causes a drop in the B-cell response, resulting in lower levels of antibodies. Zinc is critical to the immune system because it is an essential co-factor in more than 100 enzymes. A zinc deficiency leads to low levels of blood immunoglobulins and increases the body's susceptibility to infections. Phycocyanins help to regulate the production of red blood cells and WBCs even when chemicals or radiation damages bone marrow cells.

Other Nutritional And Therapeutic Values

Spirulina supplies three times more **vitamin E** than raw wheat germ. Vitamin E is believed to have the ability to destroy free radicals because of its antioxidant properties. Vitamin E bolsters the production of antibodies and helps build up resistance to degenerative diseases such as arthritis.¹¹

Another unique nutrient is **gamma linolenic acid (GLA)**, found only in the seeds of a few flowers, human breast milk, and *Spirulina*. GLA stimulates the production of prostaglandins which regulate growth and function of the heart, blood and musculature. GLA is critically important to cell function. Research has shown that cells deficient in GLA are fragile and have diminished growth, loss of tone, impaired water balance and a variety of degenerative changes, all of which can impair functioning of the immune system. GLA has been found to have a positive effect in the treatment of arthritis, and premenstrual syndrome and in protecting the body against degenerative diseases.¹²

Spirulina is nature's richest whole-food source of **chlorophyll**, the key ingredient in green super foods. With a chemical structure similar to human hemoglobin, chlorophyll helps to build the blood, renew tissues and counteract radiation.

Spirulina is the only plant food that contains **glycogen**. Glycogen is not ordinarily available through our diet. Muscles store glycogen and use it as a principal source of both immediate and long-

term energy. The more glycogen available during intense or sustained exercise, the greater the potential for improved functioning. *Spirulina* shortcuts the metabolic process of synthesizing glycogen from our food and supplies it directly pre-formed, thus sparing the body's own glycogen reserves.

The vitamin -- B12 in *Spirulina* is of particular interest to vegetarians since it is the most potent and reliable source of vitamin B12 in the vegetable kingdom. Dietary epidemiological studies have consistently shown that risk of cancer is inversely linked to levels of β -carotene intake.¹³

Toxicological Problems⁴

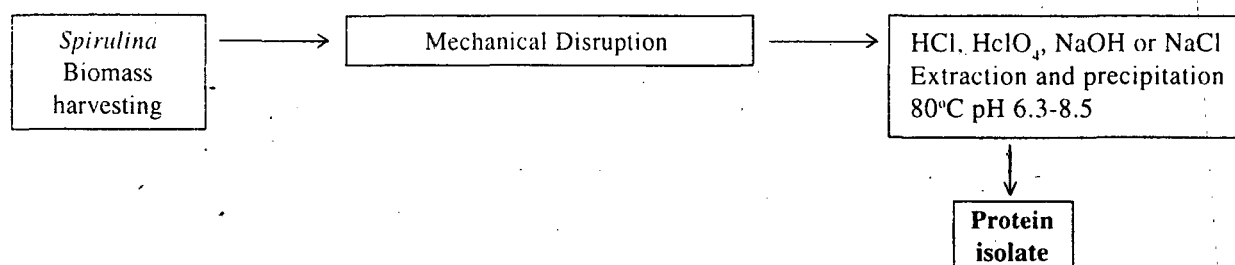
Algae like *Spirulina* have been consumed as food for generations without ill-effects and no toxic effects have been reported in animal evaluations, nevertheless following considerations must be taken into account:

- A common problem is the high content of nucleic acid in such microbial cells. Consumptions of nucleic acids in amounts higher than 2 gms/day can lead to accumulation of uric acid, which

develops into gout and kidney stones. In order to reduce nucleic acid content, protein concentrates or isolates can be prepared by cell disruption and protein separation. (Fig. 1.) This process may also help to lyse the cell walls, which contain indigestible carbohydrates and compounds such as murein, thereby enhancing bioavailability of proteins.

- Since algae have the ability to remove heavy metals from polluted waters, similar physiological phenomenon account for accumulation of pesticides and organochlorinated compounds.
- Another problem is the possibility of contamination by pathogenic organisms, if *Spirulina* is cultured in open systems. However, efficient downstream processes can be designed to destroy most viable forms present.

Fig.1: Process of Spirulina protein recovery¹¹



Conclusion

Spirulina is thus an invaluable weapon in the cell's artillery, which fights against harmful and deadly diseases, and at the same time provides concentrated nutritional support for optimum health and fitness. The commercialization of *Spirulina* in India has been painfully slow in spite of competent technology being available with various possibilities of applications. The potential for using *Spirulina* is immense and it will be a disappointment if the available database and resources are not used effectively.

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