Chlorella and Spirulina

Green Supplements for Balancing the Body

Russ Mason, M.S.

For millennia, plants and microorganisms from the sea and from fresh water have provided food and medicinal substances for humans. Chlorella (*Chlorella* spp.) and spirulina (*Arthrospira platensis*) are two waterborne microorganisms that have gained visibility as nutritional supplements that are touted for the concentrated packages of nutrients that they deliver. They are also known for their health-supporting, disease-prevention roles as detoxifying agents. Both organisms are nutrient-dense, have cleansing and detoxifying properties, and are yielding promising results in laboratory studies of their bioactivities and clinical trials on their possible benefits for people.

Biologically, chlorella and spirulina are quite different. Chlorella is classified as an alga and eukaryote. It is a complex plant with a nuclear membrane, well-defined chromosomes, and well-differentiated cellular structures. Spirulina is classified as a prokaryote. Unlike all other living cells, prokaryotes lack a nucleus surrounded by a membrane and they lack the differentiated cell structures that are characteristic of other, more complex cellular organisms. Prokaryotes live throughout the world, even where no other life can survive. For example, spirulina lives in the water of hot springs and in frozen wastelands.

Chlorella has been a popular food supplement in Asia, particularly in Japan, since commercial production began there in the 1950s. The species most commonly used in commercial production are *Chlorella pyrenoidosa* and *Chlorella vulgaris*. Today, more than 30 factories in Taiwan and Japan produce chlorella products in powdered, tablet, and liquid forms. Chlorella products have been available in the United States since the 1960s, but have not become as popular with American consumers as they have with the Asian public. Nonetheless, it is estimated that more than 10 million people around the world take chlorella.[1]

One property of chlorella affected U.S. consumption adversely at first but the situation has been resolved successfully. The cell walls of chlorella have three layers, of which the thicker middle layer contains cellulose microfibrils and the outer layer a polymerized carotenoid material. It is this outer cellular material that most likely gives chlorella its detoxifying activity. The material binds the heavy metals, pesticides, and toxins such as polychlorinated biphenyls (PCBs) and then carries these substances out of the body.

Ironically, this cell wall, with all its benefits, contributed to the delay in chlorella's introduction into the United States. The digestive tract does not have the ability to break down this tough cell wall effectively and, initially, there were reports of stomach discomfort associated with this intact cell form. From the consumer's standpoint, whole-cell chlorella simply passed through the system and the body was unable to assimilate the nutrients inside the cell. The dual problems of poor digestibility and reduced bioavailability were solved in the late 1980s, when one of the major manufacturers, Sun Chlorella USA (Torrance, California) patented a process[2] for pulverizing chlorella's cell wall without destroying the cells' contents, thus making chlorella almost 80 percent digestible. Since then, commercial producers of chlorella supplements have developed a number of proprietary methods of releasing the nutritional content of chlorella from the thick packaging provided by the outer cell wall.

Chlorella and spirulina, along with wheat grass, barley grass, and other edible microorganisms, are known as "green foods" that may be marketed individually or may be combined into mixtures. This article focuses on chlorella and spirulina, which have received the greatest attention from research laboratories and clinics in recent years.

Spirulina grows naturally in lakes in Africa, India, China, and South America. Wild spirulina was used at one time as a food by the Aztecs and is currently used as a food source in Chad.

Nutritional Content of Chlorella and Spirulina

Chlorella contains a broad spectrum of nutrients, ranging from concentrated vitamins and minerals (see box entitled Nutrients in Chlorella) to a complex water-soluble extract that contains concentrated amounts of substances found in the nucleus of the chlorella cell, including amino acids, peptides, proteins, vitamins, sugars, and nucleic acids. The box entitled Nutrients in Chlorella summarizes the nutritional content of one brand of commercially produced chlorella tablets.

Spirulina has a 62-percent amino acid content, mixed carotenoids and xanthophyll phytopigments, a high concentration of vitamin B_{12}, immunoregulatory polysaccharide components such as β-glucan, and abundant amounts of

Scientific interest in chlorella and spirulina has focused on their roles as agents of detoxification and immunoregulation.

gamma linolenic acid, which plays a critical role in inflammatory processes. The box entitled Nutrients in Spirulina summarizes the nutritional content of one brand of spirulina.

Key Research

Scientific interest in chlorella and spirulina has focused less on their nutritional value than on their roles as agents of detoxification and immunoregulation and on the mechanisms of these actions. Researchers have conducted in vitro experiments and animal studies with these two algae for more than 30 years. More recently, some manufacturers of chlorella and spirulina supplements have sponsored or publicized clinical trials on their products with specific patient populations. An overview of the key laboratory and clinical studies follows.

Chlorella and Detoxification

One of the earliest laboratory investigations of chlorella's ability to take up toxic metals studied survival of cultures of brewer's yeast to which *Chlorella regularis* had been added along with lethal doses of the toxic metals uranium, mercury, copper, cadmium, and toxic chlorinated hydrocarbons. The metals were removed from a cell culture and bound to the chlorella cell wall, enabling the cell culture to survive what should have been lethal exposure. This study was important because was one of the first to demonstrate that the chlorella cell wall is the site of toxic-metal binding.[3]

In 1984, it was found that feeding *Chlorella prototecoides* to chlordecone-poisoned rats accelerated the detoxification of the rats, decreasing the half-life of the toxin from 40 to 19 days. The ingested algae passed through the animals' gastrointestinal (GI) tracts unharmed, interrupted the enteric recirculation of the persistent insecticide, and subsequently eliminated the bound chlordecone with the feces. The algal cell walls retained the detoxification activity of the whole cells, further suggesting that the cell walls are a key site of chlorella's detoxification capabilities.[4]

More recently, investigators in Japan fed rats highly toxic PCBs (dioxins) in either a control diet or a 10-percent

Nutrients in Chlorella

The chart below summarizes the nutritional content of one product called Sun Chlorella "A" tablets (Sun Chlorella USA, Torrance, California). The manufacturer sells small dried chlorella tablets in an airtight plastic pouch that contains 300 tablets and recommends a daily dosage of 15 tablets, which supply 3 g of pulverized *Chlorella pyrenoidosa*. Because chlorella is a natural product, its exact content may vary slightly with the season, the weather, and environmental conditions.

Nutrients in One Serving (3 g) of Sun Chlorella "A"

Nutrient	Amount
Chlorophyll	28 mg
Vitamins and minerals	
Vitamin A (beta-carotene)	4559 IU
Vitamin C	5 mg
Iron	2.79 mg
Calcium	8 mg
Vitamin D_2	1476 IU
Vitamin D_3	1427 IU
Vitamin E	58 IU
Vitamin K	39 µg
Vitamin B_2	0.03 mg
Niacin	1 mg
Potassium	31.95 mg
Phosphorus	39 mg
Iodine	6 µg
Magnesium	10 mg
Zinc	0.07 mg
Pantothenic Acid	0.02 mg

Amino acids	
Lysine[a]	111 mg
Threonine[a]	80 mg
Valine[a]	104 mg
Methionine[a]	37 mg
Isoleucine[a]	74 mg
Leucine[a]	142 mg
Phenylalanine[a]	83 mg
Tryptophan[a]	31 mg
Arginine	102 mg
Aspartic Acid	111 mg
Serine	60 mg
Alanine	100 mg
Proline	125 mg
Cysteine	4 mg
Histidine	39 mg
Glutamic Acid	198 mg
Glycine	100 mg
Tyrosine	48 mg

IU = international units. [a]Essential amino acids.

Source: www.sunchlorellausa.com

Analysis of data suggested that chlorella supplementation had a significant lowering effect on both high-density and low-density serum cholesterol.

chlorella diet and measured the amount of dioxins excreted by each of the two groups of rats. The rats who were fed chlorella excreted significantly more dioxins than the control rats, leading the researchers to conclude that administration of chlorella may be useful in preventing GI absorption of these chemicals and in promoting the excretion of dioxin that has been absorbed into tissues. Most PCBs are toxic and they are widely distributed throughout the human environment. These animal studies suggest that chlorella supplementation might confer some protection to humans who are exposed to PCBs and that clinical trials would be appropriate.[5]

Chlorella and Cancer

The most widely used cancer therapeutics impose a heavy burden of adverse side-effects on the person who undergoes chemotherapy. Increased susceptibility to infection and an impaired immune response to infection, once established, pose serious risks to a compromised immune system. Several studies have evaluated the benefits of chlorella supplementation for laboratory animals that have been exposed to such chemotherapeutics as 5-fluorouracil[6] and cyclophosphamide.[7] Mice that were given 5-fluorouracil and an acidic glycoprotein fraction of *C. vulgaris* had fewer infections and lived longer than untreated mice. Mice that were given the cancer therapeutic cyclophosphamide and exposed to *Escherichia coli* had a lower incidence of bacterial infection than the mice that had not been treated. The untreated mice died quickly of *E. coli* infection. [7]

Chlorella, Hyperlipidemia, and Ulcers

Two animal studies suggest that *C. vulgaris* supplementation can delay or prevent the formation of atheromatous lesions in rabbits and mice that have been fed high-cholesterol diets.[8] The results of these studies suggest that corresponding human trials are in order.

A 1997 study investigated the effects of feeding *C. vulgaris* to rats that had been given peptic ulcers by three different methods. The supplementation had "clear prophylactic effects" in the rats with ulcers of a type known to respond drugs that enhance factors that protect against ulcer formation. The authors suggested that *C. vulgaris* may prevent ulcer formation mainly via the "immune-brain–gut" axis and protection of gastric mucosa by chlorella's characteristics.[9]

Nutritional Content of Spirulina

The chart below provides nutritional information for one spirulina product, Earthrise Spirulina (Earthrise Nutritionals, Petaluma, California). Because spirulina is a natural product, its analysis may vary slightly with the season, weather, and environment conditions.

Vitamins and Minerals in One Serving (5 g) of Earthrise Spirulina

Nutrient	Amount
Vitamin A (beta-carotene)	11,500 IU
Vitamin E	0.5 mg
Vitamin B_1	0.17 mg
Vitamin B_2	0.20 mg
Vitamin B_3	0.70 mg
Vitamin D_6	40 µg
Vitamin B_{12}	10 µg
Inositol	3.2 mg
Folacin	0.5 µg
Biotin	0.25 µg
Pantothenic acid	5 µg
Vitamin K_1	100 µg
Calcium	35 mg
Magnesium	20 mg
Phosphorus	40 mg
Iron	5 mg
Sodium	45 mg
Zinc	150 µg
Potassium	70 mg
Copper	60 µg
Manganese	250 µg
Chromium	12.5 µg
Germanium	30 µg
Selenium	5 µg
Phycocyanin	700 mg
Chlorophyl	50 mg
Carotenoids	13 mg
Gamma linoleic acid	50 mg
Glycolipids and sulfolipids	100 mg
Polysaccharides	230 mg

Source: Earthrise Nutritionals, Petaluma, California.

Dietary supplementation with chlorella may reduce or eliminate the need of people with mild-to-moderate hypertension for antihypertensive medication.

Major Suppliers of Chlorella and Spirulina in the United States

Sun Chlorella USA
3914 Del Amo Boulevard
Torrance, CA 90503
Phone: (310) 371-5515, extension 42
U.S. and Canadian callers:
(800) 829-2828, extension 42
Fax: (310) 371-0094
Web site: www.sunchlorellausa.com

Earthrise Nutritionals
424 Payran Street
Petaluma, CA 94952
Phone: (800) 949-7473
Fax: (707) 778-9028
e-mail: info@earthrise.com
Web site: www.earthrise.com/

Clinical Studies on Chlorella

It appears that all the English-language documentation of human clinical trials on chlorella supplementation results from the research of Randall E. Merchant, Ph.D., professor, anatomy department, Medical College of Virginia, Virginia Commonwealth University, Richmond. Dr. Merchant has investigated the efficacy of chlorella supplementation for people who are affected by several conditions that have resisted satisfactory treatment via conventional medicine. He says that, although his work is funded by Sun Chlorella Corp. (Kyoto, Japan), the company does not try to influence his research or its outcomes and that he follows rigorous principles of experimental design and analysis.

Dr. Merchant comments:

> We've been interested in chronic illnesses for which there's no drug, or no cure, or the only treatments available are drugs with known side-effects. A nutritional supplement might reduce the need for drugs, or might decrease the adverse side-effects.
>
> We went to the literature and looked for good contemporary clinical trials of drugs for conditions of a chronic nature—fibromyalgia, osteoarthritis, ulcerative colitis, and hypertension, for example. We model our experiments on the way the pharmaceutical industry designs its experiments to test drugs for the same diseases. We try to use the same study periods, the same measurements, and the same clinical endpoints. By the end of a study, we expect to have collected data that would be considered reasonable by the medical community.

Each of Dr. Merchant's clinical trials has involved at least one physician who participated from original experimental design through clinical evaluations and final analysis. Dr. Merchant has published some of his results and presented his results at major research conferences, and he is preparing to launch additional human trials of chlorella.

He discussed recent clinical trials of *C. pyrenoidosa* for managing hypertension at the annual meeting of the Federation of American Societies for Experimental Biology (FASEB) in April 1999, in Washington, D.C.

One 3-month study of 24 adults with mild-to-moderate hypertension documented the effects of consuming 10 g of chlorella tablets and 100 mL of liquid chlorella extract per day for 2 months, after a 1-month placebo washout period. Results of physical examinations and electrocardiograms remained unchanged between the first and last visits. Results of routine laboratory tests on blood, serum, and urine, performed at the first visit, at the end of the 1-month washout period, and at the end of the trial were within normal limits of variation and no single variable significantly changed over the 3-month course of the investigation. However, analysis of the data suggested that chlorella supplementation had a significant lowering effect on both high-density and low-density serum cholesterol. This pilot study concluded that daily dietary supplementation with chlorella may reduce or eliminate the need of people with mild-to-moderate hypertension for antihypertensive medication.

At the annual FASEB meeting in San Diego, in 2000, Dr. Merchant described a study in which 9 people with mild-to-moderately active forms of ulcerative colitis consumed 10 g (50 tablets) and 100 mL of liquid *C. pyrenoidosa*, per day for 2 months. Each participant's clinical and functional status was assessed by a physical examination and flexible sigmoidoscopic examination at the beginning of the study, at the end of 1 month, and at the end of the study. Blood samples taken on each occasion revealed that any changes in serum chemistry, cell counts, or sedimentation rate stayed within normal limits of variation as did the weights, heart rates, and blood pressures of the participants. Objective measures of symptom severity and subjective assessment of symptom severity by the participants coincided, and the participants all benefited from adding chlorella to their diets. The results of this pilot study led the investigators to conclude that a larger, more comprehensive double-blind, placebo-controlled clinical trial of chlorella is warranted for patients with ulcerative colitis.

Dr. Merchant's most recent published chlorella investigation focused on management of fibromyalgia.[10] He and his colleagues evaluated changes in the clinical and functional status of 18 people with moderately severe symptoms of fibromyalgia syndrome, during a 2-month trial of dietary supplementation with 10 g (50 tablets) and 100 mL of liquid *C. pyrenoidosa* per day. Amelioration of symptoms was validated and quantified using semiobjective and subjective

Researchers found that spirulina increased the tumor-killing ability of natural-killer cells and interferon significantly.

outcome measures systematically administered at clinic visits at the beginning of the trial, at the 1-month point, and at the end of the trial. The 18 people who completed the study reported a 22-percent decrease in pain intensity. Blood samples taken on each occasion showed no significant alterations in serum chemistries, formed elements, and circulating lymphocyte subsets. Compilations of the results of patient interviews and self-assessment questionnaires revealed that seven patients felt that the dietary supplement had reduced their fibromyalgia symptoms, while six subjects thought they had experienced no change, and five believed their symptoms had worsened over the time of the trial. The results of this pilot study suggest that dietary chlorella supplementation may help to relieve the symptoms of fibromyalgia in some patients and that a larger, more comprehensive double-blind, placebo-controlled clinical trial in these patients is warranted.[10]

Spirulina Clinical Trials

A February 20, 2001 press release issued by spirulina manufacturer Earthrise Nutritionals, Petaluma, California, briefly described a spirulina clinical study that was reported by Dr. Tsukasa Seya and colleagues from the Osaka Institute of Public Health, Japan, at the 30th Annual Meeting of the Japanese Society for Immunology, in Miyagi, Japan, November 14–16, 2000. Volunteers who were more than 40 years old were given 50 mL of a spirulina extract, Lina Green 21 (Earthrise Nutritionals). The investigators measured the serum levels and activity levels of natural-killer (NK) cells and interferon-γ, both of which are important natural cancer-fighting substances. The researchers found that spirulina increased the tumor-killing ability of NK cells and the interferon significantly. This activity was increased 1–2 weeks after administration of spirulina and the activity continued for 12–24 weeks even after spirulina supplementation had been stopped. The secondary report on the research did not indicate the size of the study sample, nor did it specify how long the study participants took the spirulina supplement.

Researchers in the Department of Foods and Nutrition, at the M.S. University of Baroda, in Gujarat, India, conducted a 2-month evaluation of the effects of spirulina supplementation on serum lipid profile and glycated proteins on patients with non–insulin-dependent diabetes mellitus (NIDDM).[11] The investigators measured blood-sugar levels, serum-lipid profiles, and glycated serum protein levels of 15 patients with NIDDM who took 2 g per day of spirulina in tablet form. Blood analysis was done at the beginning of the study, at the end of the first month, and at the end of the second month. The researchers found that supplementation for a period of 2 months resulted in significant reductions of blood-sugar, glycated serum protein, triglycerides, total cholesterol, and free fatty-acid levels. Among the lipoprotein fractions, appreciable reduction was noticed in low-density lipoprotein-C, very–low density lipoprotein-C, and high-density lipoprotein-C/low-density lipoprotein-C ratio.

The Future of Chlorella and Spirulina

The human health benefits of chlorella and spirulina need further study and documentation, but the research to date supports the reasonable expectation that future investigations are worth the investment of time. □

References

1. www.health-books.com/PressRoom/what-is-Chlorella.htm

2. Pulverized cell-wall chlorella by DYNO-MILL™ (U.S. Patent No. 5330913).

3. Horikoshi, T., Nakajima, A., Sakaguchi, T. Uptake of uranium by various cell fractions of *Chlorella regularis*. *Radioisotopes* 28(8):485–487, 1979.

4. Pore, R.S. Detoxification of chlordecone poisoned rats with chlorella and chlorella-derived sporopollenin. *Drug Chem Toxicol* 7(1):57–71, 1984.

5. Morita, K., Matsueda, T., Iida, T., Hasegawa, T. Chlorella accelerates dioxin excretion in rats. *J Nutr* 129(9):1731–1736, 1999.

6. Konishi, F., Mitsuyama, M., Okuda, M., Tanaka, K., Hasegawa, T., Nomoto, K. Protective effect of an acidic glycoprotein obtained from culture of *Chlorella vulgaris* against myelosuppression by 5-fluorouracil. *Cancer Immunol Immunother* 42(5):268–274, 1996.

7. Konishi, F., Tanaka, K., Kumamoto, S., Hasegawa, T., Okuda, M., Yano, I., Yoshikai, Y., Nomoto, K. Enhanced resistance against *Escherichia coli* infection by subcutaneous administration of the hot-water extract of *Chlorella vulgaris* in cyclophosphamide-treated mice. *Cancer Immunol Immunother* 32(1):1–7, 1990.

8. Sano, T., Tanaka, Y. Effect of dried, powdered *Chlorella vulgaris* on experimental atherosclerosis and alimentary hypercholesterolemia in cholesterol-fed rabbits. *Artery* 14(2):76–84, 1987.

9. Tanaka, K., Yamada, A., Noda, K., Shoyama, Y., Kubo, C., Nomoto, K. Oral administration of unicellular green algae, *Chlorella vulgaris*, prevents stress-induced ulcer. *Planta Med* 63(5):465–466, 1997.

10. Merchant, R.E., Carmack, C.A., Wise, C.M. Nutritional supplementation with *Chlorella pyrenoidosa* for patients with fibromyalgia syndrome: A pilot study. *Phytother Res* 14(3):167–173, 2000.

11. Mani, U.V., Desai, S., Iyer, U. Studies on the long-term effect of spirulina supplementation on serum lipid profile and glycated proteins in NIDDM patients. *J Nutraceuticals Functional Med Foods* 2(3):25–31, 2000.

To order reprints of this article, write to or call: Karen Ballen, *ALTERNATIVE & COMPLEMENTARY THERAPIES*, Mary Ann Liebert, Inc., 2 Madison Avenue, Larchmont, NY 10538-1961, (914) 834-3100.

This article has been cited by:

1. Sara Mirzaie, Seyed Davood Sharifi, Fahim Zirak-Khattab. 2020. The effect of a Chlorella by-product dietary supplement on immune response, antioxidant status, and intestinal mucosal morphology of broiler chickens. *Journal of Applied Phycology* **32**:3, 1771-1777. [Crossref]
2. Abdelnour, Sheiha, Taha, Swelum, Alarifi, Alkahtani, Ali, AlBasher, Almeer, Falodah, Almutairi, Abdel-Daim, Abd El-Hack, Ismail. 2019. Impacts of Enriching Growing Rabbit Diets with Chlorella vulgaris Microalgae on Growth, Blood Variables, Carcass Traits, Immunological and Antioxidant Indices. *Animals* **9**:10, 788. [Crossref]
3. Prashant Sahni, Poonam Aggarwal, Savita Sharma, Baljit Singh. 2019. Nuances of microalgal technology in food and nutraceuticals: a review. *Nutrition & Food Science* **49**:5, 866-885. [Crossref]
4. S.A. Abdelnour, M.E. Abd El-Hack, M. Arif, A.F. Khafaga, A.E. Taha. 2019. The application of the microalgae Chlorella spp. as a supplement in broiler feed. *World's Poultry Science Journal* **75**:2, 305-318. [Crossref]
5. Eman Zahran, Walaa Awadin, Engy Risha, Asmaa A. Khaled, Tiehui Wang. 2019. Dietary supplementation of Chlorella vulgaris ameliorates chronic sodium arsenite toxicity in Nile tilapia Oreochromis niloticus as revealed by histopathological, biochemical and immune gene expression analysis. *Fisheries Science* **85**:1, 199-215. [Crossref]
6. H. K. Kang, S. B. Park, C. H. Kim. 2017. Effects of dietary supplementation with a chlorella by-product on the growth performance, immune response, intestinal microflora and intestinal mucosal morphology in broiler chickens. *Journal of Animal Physiology and Animal Nutrition* **101**:2, 208-214. [Crossref]
7. P.K. Sarker, M.M. Gamble, S. Kelson, A.R. Kapuscinski. 2016. Nile tilapia (Oreochromis niloticus) show high digestibility of lipid and fatty acids from marine Schizochytrium sp. and of protein and essential amino acids from freshwater Spirulina sp. feed ingredients. *Aquaculture Nutrition* **22**:1, 109-119. [Crossref]
8. Eman Zahran, Engy Risha. 2014. Modulatory role of dietary Chlorella vulgaris powder against arsenic-induced immunotoxicity and oxidative stress in Nile tilapia (Oreochromis niloticus). *Fish & Shellfish Immunology* **41**:2, 654-662. [Crossref]
9. H.K. Kang, H.M. Salim, N. Akter, D.W. Kim, J.H. Kim, H.T. Bang, M.J. Kim, J.C. Na, J. Hwangbo, H.C. Choi, O.S. Suh. 2013. Effect of various forms of dietary Chlorella supplementation on growth performance, immune characteristics, and intestinal microflora population of broiler chickens. *Journal of Applied Poultry Research* **22**:1, 100-108. [Crossref]
10. Fong-Chi Cheng, Jin-Jye Feng, Kuo-Hsin Chen, Hideyo Imanishi, Masaki Fujishima, Hideo Takekoshi, Yo Naoki, Minoru Shimoda. 2010. Receptor binding activities of Chlorella on cysteinyl leukotriene CysLT, glutamate AMPA, ion channels, purinergic P 2Y , tachykinin NK 2 receptors and adenosine transporter. *Phytotherapy Research* **24**:1, 43-48. [Crossref]