The Role of Parry Organic Spirulina in Health Management

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Introduction

Arthrospira, commonly known as Spirulina is one of the most nutritious and concentrated microalgal food sources available in the market. Arthrospira platensis is the predominant species commercially cultivated worldwide though Arthrospira maxima is produced in the South and Central American regions. This multicelluar microalga is popular as an ingredient in functional foods and beverages like green foods and drinks, energy bars and as a food supplement in the form of powder, tablets and capsules.

Spirulina has a long history of human consumption (**1**). Currently Spirulina is used as a nutraceutical ingredient due to its unique combination of phytonutrients like phycocyanin, carotenes, xanthophylls, GLA, galactolipids, sulfolipids, chlorophyll and minerals. Spirulina produced as per the organic standards or conventional methods are available in the world market to meet varied customer preferences. Parry Organic Spirulina is produced as per USDA NOP norms and also meeting private organic standards like Naturland (Germany), Ecocert (France) and OCIA (USA).

Table 1: Specifications of Parry Organic Spirulina *(Arthrospira platensis)*

Physical Properties	
Appearance	Fine, uniform powder
Colour	Blue green to green
Odour & Taste	Mild
Bulk density	0.62 - 0.85 g/cc
Particle size	100% 60 mesh
General Composition	
Protein	60 % - 69 %
Carbohydrates	16 % - 20 %
Lipids	5% - 7 %
Minerals	6 % - 9%
Moisture	2.5% - 6.0%
Phytopigments	**mg / 100g**
Total Carotenoids	400 – 650
Beta Carotene	150 – 250
Xanthophylls	250 – 470
Zeaxanthin*	125 – 200
Chlorophyll	1300 – 1700
Phycocyanin	15000 –19000
	Units /100g
ORAC (µmole TE)	24400
Superoxide Dismutase	392000
Fatty Acids	**g / 100g**
Myristic acid	0.01 – 0.03
Palmitic acid	2.0 – 2.5
Stearic acid	0.01 – 0.05
Oleic acid	0.10 – 0.20
Linoleic acid	0.75 – 1.2
Gamma -Linolenic acid	1.00 – 1.50

Amino Acids	g / 100 g
Alanine	4.0 – 5.0
Arginine	3.0 – 5.0
Aspartic acid	1.5 – 3.0
Cystine	0.5 – 0.75
Glutamic acid	6.0 – 9.0
Glycine	2.0 – 4.0
Histidine	0.5 – 1.5
Isoleucine	3.0 – 4.0
Leucine	3.0 – 5.0
Lysine	3.0 – 6.0
Methionine	1.0 – 6.0
Phenyl Alanine	2.5 – 3.5
Proline	2.0 – 3.0
Serine	3.0 – 4.5
Threonine	1.5 – 3.0
Tryptophane	1.0 – 2.0
Tyrosine	1.0 – 3.0
Valine	1.0 – 3.5

Vitamins	mg / 100g
Vitamin B1 (Thiamine)	0.1.5 – 0.30
Vitamin B2 (Riboflavin)	4.0 – 7.0
Vitamin B3 (Niacin)	10.0 – 25.0
Vitamin B6(Pyridoxine)	0.5 – 1.5
Vitamin B12 (Analogue)	0.10 – 0.30
Folic acid	0.05 – 0.30
Inositol	70 – 90
Vitamin K	0.90 – 1.05

Minerals	mg/100g
Calcium	60 – 110
Phosphorus	700 – 1000
Magnesium	200 – 300
Iron	25 - 40
Sodium	700 – 1000
Potassium	1000 – 1500
Zinc	1.0 – 3.0
Copper	0.2 – 0.4
Manganese	1.0 – 3.0
Chromium	0.1 – 0.3
Selenium	0.003 – 0.010

* Some producers and Analytical Laboratories report Total Xanthophyll value as Zeaxanthin value. Total xanthophylls in Spirulina include zeaxanthin, myxoxanthophyll, echininone, hydroxy-echininone and cryptoxanthin.

Health Benefits of Spirulina

The health benefits of Spirulina are widely researched. This paper will mainly focus on review of literature in regards to potential role of Spirulina in age related health conditions such as age-related macular degeneration (ARMD), type 2 diabetes, non-alcoholic fatty liver disease (NAFLD), neurodegenerative disorders and cerebrovascular disease.

Age-Related Macular Degeneration (ARMD)

ARMD is the leading cause of blindness in the developed world. AMD occurs late in life and its prevalence is likely to rise because of increasing longevity (**2**).

In the middle of the retina is a depression called the fovea and macula is the retinal region surrounding the fovea for a radius of 3-4 mm. Fovea has the highest visual acuity. ARMD reduces the acute vision of fovea (**3**). The macular membranes of human retina contain principally two polar carotenoid pigments- lutein and zeaxanthin (**4,5**). Zeaxanthin present in retina is a mixture of two stereoisomers – zeaxanthin and meso-zeaxanthin. Meso-zeaxanthin is formed in the retina by isomerization of lutein (**6**). In the macula, zeaxanthin is the dominant pigment, with a lutein: zeaxanthin ratio of 1:2.4 (**4**).

Retina accumulates zeaxanthin and lutein to the exclusion of other carotenoids like beta carotene, which are abundant in blood (**7**). This may be due to the presence of two hydroxyl groups (-OH groups) at either end of the retinal carotenoids (**3**).

Lutein and zeaxanthin slow down the UV- induced lipid oxidation, but zeaxanthin is a better photoprotector during prolonged UV exposure. The differences in the protective efficacy of lutein and zeaxanthin in lipid membranes is attributed to a different arrangement of these two pigments within lipid membranes (**8,9**). In a study involving 380 men and women, aged 66 to 75 years, risk of AMD was significantly higher in people with lower plasma concentrations of zeaxanthin. The correlation between plasma lutein and ARMD was not as strong (**10**).

Macular pigment protects against ARMD. Macular pigment density can be augmented through dietary modification. Therefore, people should be encouraged to eat a diet rich in fruits and vegetables (**2**). Lutein and zeaxanthin are found together in many foods, but the concentration of zeaxanthin is generally low. Highest zeaxanthin may be found in corn (500 mcg/100 g), spinach (200-300 mcg/100 g) and squash (200 mcg/100 g) (**11**). Eggs are excellent source of lutein and zeaxanthin. Zeaxanthin content of egg is approximately 200 mcg/yolk (**12**). Spirulina is the richest known source of zeaxanthin. Spirulina provides 3750 – 6000 mcg of zeaxanthin per serving size of 3 g. There is no RDA for lutein and zeaxanthin.

Apart from ARMD, these two xanthophylls may be effective in cataract prevention as well (**13**).

Type 2 Diabetes

Type 2 diabetes is a multifactorial disease including a cluster of pathologies – insulin resistance, obesity, dyslipidemia and hypertension.

Insulin Resistance

Insulin resistance has been defined in the last decade as being frequently associated with a state of low grade inflammation (**14**). Inflammatory cytokines like TNFα, IL-6 are elevated and levels of anti-inflammatory protein- adiponectin are reduced in insulin resistance (**15,16**).

In a randomized study with Korean subjects, Spirulina was shown to reduce serum triglycerides. Spirulina also reduced inflammatory response by reducing inflammatory cytokines IL-6 and TNF-α and increasing adiponectin (**17**). Similar reduction in inflammatory cytokines (IL-6 and TNF- α) was observed in a randomized double-blind, placebo controlled study in elderly Korean subjects. This study also showed an increase in anti-inflammatory cytokine IL-2 (**18**).

In another human study, Spirulina supplementation at 2 g/day for 2 months given to diabetic patients improved glycosylated hemoglobin (HbA_{1C}) and favorably altered the serum lipid profile (**19**).

These studies show that Spirulina can be used as a functional food to manage Type 2 Diabetes.

Dyslipidemia

In a human study, the effect of orally supplemented Spirulina (4.5 g/day, for 6 weeks) was evaluated in Mexican population. Spirulina significantly reduced serum triglyceride values and boosted HDL and lowered total cholesterol in the test subjects (**20**). The hypocholesterolemic action of Spirulina may be due to its phycocyanin content (**21**). In a rat study it was shown that phycocyanin and a glycolipid from Spirulina inhibited pancreatic lipase activity. This resulted in higher excretion of triglycerides in the faeces of the experimental animals and postprandinal increase in serum triglycerides was lowered (**22**).

Currently, consumption of fructose has increased in the U.S. from high intake of high fructose corn syrup (**23**). High fructose feeding causes insulin resistance in both humans and animal models (**24**). Analysis of National data from 1909 to 1997 found a strong association between an increased consumption of refined carbohydrates in the form of corn syrup (high in fructose), decreased consumption of dietary fiber, and an increasing trend in the prevalence of type 2 diabetes in the United States during the 20th century (**25**).

Excessive intake of sugar, and in particular fructose may be an important cause of type 2 diabetes. Fructose causes fatty liver, vascular inflammation and endothelial dysfunction (**26,27**) and increases triglyceride levels (**28**). In a preclinical study rats were fed a diet high in fructose or high in glucose. Significant increase (5 fold) was observed in hepatic triglyceride levels in fructose fed rats compared to glucose fed rats. This fructose induced triglyceride increase was reduced significantly by supplementation with Spirulina (**29**).

Hypertension

Dietary fructose was shown to increase vasoconstriction and induce hypertension in rats. Inclusion of Spirulina in the fructose rich diet prevented these effects (**30**).

In a study where rats were fed on sucrose, the rats became overweight and had elevated blood pressure and hyperlipidemia. Ethanolic extract of Spirulina reduced the vascular resistance. This effect may be due to the enhanced endothelial NO release after Spirulina supplementation (**31**). According to Reddy et al (**32**) C- phycocyanin, one of the constituents of Spirulina is a selective inhibitor of cyclooxygenase 2. This mechanism of action may inhibit the synthesis/release of cyclooxygenase-dependent vasoconstrictor metabolite of arachidonic acid and induce vasodialation.

In humans, Spirulina reduced blood pressure in hypertensive Mexican subjects when given 4.5 g Spirulina for 6 weeks. Spirulina supplementation reduced both systolic and diastolic blood pressure in subjects (**20**).

Studies were conducted to see the effect of dietary Spirulina on vasomotor reactivity of aortic rings from lean Wistar rats. Spirulina improved vasodialation in the experimental group. This effect was even more pronounced in fructose fed obese rats, suggesting that dietary Spirulina is able to prevent the effects of fructose induced obesity and vasoconstriction (**33**).

Non-Alcoholic Fatty Liver Disease (NAFLD)

NAFLD is the most common cause of chronic liver disease in North America and is closely associated with the metabolic syndrome (**34,35)** or the hepatic manifestation of metabolic syndrome (**36**). Proven therapies remain lacking for this disease (**37**). Suspected NAFLD, especially in the 45-54-yr-old age group, is a strong independent risk factor for cardiovascular disease death (**38**). Potential treatments for this condition are weight loss, insulin sensitizing agents, lipid lowering agents, antioxidants and agents to reduce inflammatory cytokines like TNF-α (**39,40**).

In animal studies, carbon tetrachloride (CCl_4) is used to induce fatty liver. In an animal study with Wistar rats, Spirulina prevented fatty liver development in experimental animals after CCl_4 treatment. The hepatotoxic effect of CCl_4 is related to free radical generation. Spirulina supplementation prevented lipid peroxidation of liver lipids after CCl_4 treatment as evidenced by data on TBARS values. Thus, hepatoprotective action of Spirulina may be due to its antioxidant content (**41**). In another study with Wistar rats CCl_4 was used to induce fatty liver. The liver lipids of CCl_4 treated rats showed high degree of unsaturation due to injury to the liver. Such higher concentrations of unsaturated fatty acids are reported in NAFLD. In Spirulina treated rats, the unsaturation of the liver lipids was significantly less. The authors concluded that this effect may be due to the ability of Spirulina to increase the synthesis/release of nitric oxide (**42**). In another animal experiment, C-phycocyanin was shown to inhibit CCl_4 induced lipid peroxidation in rats (**43**).

Spirulina was shown to reduce liver triglycerides in mice with experimental diabetes (**44**). In an animal study, fatty liver was produced in mice by administration of simavastin (statin), ethanol and hypercholesterolemic diet. Administration of Spirulina prevented the increase in liver total lipids and liver triglycerides (**45**). Spirulina showed therapeutic effect in patients with NAFLD as evidenced by ultrasonography (**46**).

Inflammatory cytokines IL-6 and TNFα are elevated while adiponectin is lowered in NAFLD (**47**). Spirulina was shown to have beneficial effects on all these three markers (**17**).

Liver Toxicity

Several other animal studies show that Spirulina is protective against damage to the liver due to heavy metals like lead and mercury (**48,49**).

Neurodegenerative Disorders

Neurodegenerative disorders like Parkinson's and Alzheimer's are associated with oxidative stress. Pre-clinical experiments with rats showed that C-phycocyanin had potential to prevent oxidative stress produced in the hippocampus of experimental animals (**50**). Neuroinflammation plays a critical role in loss of dopamine neurons in neurodegenerative diseases. Diet rich in Spirulina or blueberry was found to have enhanced striatal dopamine recovery in 6-hydroxydopamine treated rats (**51**).

Activated microglia are now suspected to play a role in induction and progression of neurodegenerative disorders (**52**). Phycocyanin may reduce this activity by reducing NADPH oxidase activity of the microglia and quenching proxinitrite (**53,54,55**). NADPH oxidase is an enzyme complex and its over activity appears to play a role in atherogenesis, hypertension, ischemia perfusion injury, insulin resistance associated with obesity, major complications of diabetes, neurodegenerative disorders such as Alzheimer's and Parkinson's diseases, hepatic fibrosis, cartilage loss associated with osteoarthritis and many more disorders. As a suppressor of NADPH oxidase, Spirulina can help in controlling age related pathologies (**56,53**).

Age related cognitive decline can be due to inflammation related oxidative damage to the central nervous system (CNS). Diet high in antioxidant activity is able to reduce this decline. Spirulina was shown to reverse age-induced decreases in cerebellar β-adrenergic function in rats, and this effect may be due to high antioxidant capacity of Spirulina (**57**).
Neurogenesis or production of new neurons is a life long occurrence, and necessary for learning. Inflammation causes decrease in neurogenesis. In a rat model, diet enriched with Spirulina was able to negate this inflammation related decrease in brain neurogenesis (**58**).

Cerebrovascular Disease (Stroke)

Stroke is the 3rd leading cause of death in the United States (**59**). During acute ischemic phase, brain is deprived of oxygen and nutrients, and during the reperfusional phase, generation of toxic compounds like free radicals, reactive oxygen or nitrogen species, and peroxinitrite can induce more damage to the brain. Chronic feeding with antioxidant rich diets (blueberry,

spinach, Spirulina) was shown to have neuroprotective effects against transient focal ischemia in rats. Among the three diets tested, Spirulina had the most neuroprotective effect (**60**). This effect could be due to the decrease in proinflammatory cytokines with Spirulina diet (**57**).

Spirulina pretreatment reversed the middle cerebral artery occlusion induced cerebral ischemia in rats in a dose dependent manner. The antioxidant status of the tissue affected by ischemia/reperfusion is of great importance against the free radical induced injury. Spirulina at a dose of 180 mg/kg body weight in rats significantly restored the decreased activities of brain superoxide dismutase, catalase and reduced-glutathione indicating that Spirulina has the protective potential against cerebral ischemia injury and its protective effects may be due to its antioxidant property (**61**).

It is well known that enhanced platelet activation plays an important role in vascular diseases. In an *in vitro* study, C- phycocyanin, the billiprotein found in Spirulina was shown to be an inhibitor of platelet aggregation (**62,63**). Thus Spirulina along with a healthy diet may be able to help in preventing thromboembolism and stroke.

Conclusion

Spirulina is a potent mixture of antioxidants and most of Spirulina's health benefits are associated with its antioxidant pigments. These are carotenoids (mixture of carotenes and xanthophylls), chlorophyll and the unique blue pigment phycocyanin. Among these pigments, the xanthophyll zeaxanthin is rare in nature, and 3 g Spirulina can provide adequate quantities of this very valuable xanthophyll. Phycocyanin is even rarer in our diet and 3 g Spirulina can provide adequate quantities of this highly beneficial pigment. Phycocyanin can provide excellent health benefits as discussed in this article, and supplementing the diet with Spirulina is the easiest way to obtain it. Spirulina supplementation may help in managing age related health conditions such as ARMD, Type 2 Diabetes, NAFLD, Neurodegenerative Disorders and Cerebrovascular Disease.

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