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Review Article

THERAPEUTIC USES OF SPIRULINA: A REVIEW

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ABSTRACT

Spirulina are multicellular and filamentous blue-green algae that has gained considerable popularity in the health food industry and increasingly as a protein and vitamin supplement. It carries lot of clinical importance as it is used to cure many disorders. Due to the presence of certain pigments and secondary metabolites it gains paramount importance in the cure of diabetes, hypertension, cancer, immune booster and acts as an antiviral agent also. The body surface of spirulina is smooth and without covering so it easily digestible by simple enzymatic systems. Several animal studies in vivo and in vitro followed by human trials have proved the importance of spirulina to be commercialized and sold for therapeutic purposes. Spirulina appears to have considerable potential for development, especially as a small-scale crop for nutritional enhancement, livelihood development and environmental mitigation.

INTRODUCTION

In the last few years, this microscopic organism has attracted people and scientists from all over the world due to its special properties. Spirulina has found wide applications in agriculture, food, pharmaceuticals, perfumeries, medicine and science. It is also used as a food supplement and is marketed in the form of pills, capsules and powder or incorporated into various types of food like cakes, biscuits, noodles and health drinks, etc. (Hayashi *et al*., 1996). The microorganism called "spirulina" was so named because of its spiral filament-like appearance under the microscope, classified as cyanobacterium. Spirulina, now named Arthrospira, is a blue-green alga with an old history. Its name derives from the spiral or helical nature of its filaments (Belay, 2002).

Structure: Spirulina is packed with chlorophyll and chlorophyll has the exact same structure as hemoglobin except for the center atom where iron is present in hemoglobin and magnesium is present for chlorophyll. Hemoglobin is the protein that transports oxygen in our red blood cell, but it's not its only job (Cheng- Wu *et al*., 1994). Spirulina does a lot too with the chlorophyll like structure. It can rebuild and replenish our red blood cells, boost our energy, help in the detox process, stop bacterial growth in the digestive tract, stop the production of yeasts and fungi and eliminates bad breath (Ghaeni and Roomiani, 2016). The nutritional composition of spirulina may vary according to the growing conditions. For example, the iodine content will vary as a function when the spirulina is grown in sea water vs. fresh water. It should be noted that the cell wall of spirulina is composed of protein, carbohydrates and fat and not from indigestible cellulose. Therefore, the bioavailability of nutrients from spirulina might be more than from other food sources, especially plant food sources (Selmi *et al*., 2011). Uses: Spirulina can help prevent and reverse anemia. It can also help to maintain your body in a more alkaline state for an optimal health! It is a great anti-aging, anti-oxidant and anti-inflamatory agent. Nowadays, a lot of people suffer from high level of cholesterol. Here too, spirulina comes to the rescue.

The high chlorophyll content helps to flush out toxins from the blood, acting as a natural detox. It also helps to boost your immune system (Capelli, 2010). Safety Measures: Many toxicological studies have proven Spirulina's safety. It belongs to the substances that are listed by the US Food and Drug Administration under the category Generally Recognized as Safe (GRAS). Also, 3,4-Benzopyrene has been measured in spirulina because it serves as a good indicator of the presence of aromatic polycyclic hydrocarbons, which are powerful mutagens and carcinogens. The quantities observed (2-3ppb) are well below those found in most common vegetables (Chamoro, 1980).

Effects against Diabetes, Obesity and Hypertension: Water-soluble fraction of Spirulina was found effective in lowering the serum glucose level at fasting while the water-insoluble fraction suppressed glucose level at glucose loading. In a human clinical study with 15 diabetics, a significant decrease in the fasting blood sugar level of patients was observed after 21 days of 2 g/day Spirulina supplementation (Akao, 2009). Cholesterol-lowering effects and effects on diabetes, cardiovascular disease, remains most important risk factors. Nakaya *et al*. (1988), in the first human study, gave 4.2 g on day 1 of Spirulina to 15 male

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volunteers and, although there was no significant increase in high-density lipoprotein (HDL) levels, they observed a significant reduction of high-density lipoprotein (LDL) cholesterol after 8 weeks of treatment. The atherogenic effect also declined significantly in the above group proving spirulina to be candidate responsible for this effect.

Ramamoorthy *et al*. (1996) in a more recent study administered Spirulina supplements in ischemic heart disease patients and found a significant reduction in blood cholesterol, triglycerides and LDL cholesterol and an increase in HDL cholesterol. Mani *et al*. (2000) in a clinical study, found a significant reduction in LDL:HDL ratio in 15 diabetic patients who were given Spirulina. However, this study was small and better studies are needed before Spirulina can be recommended in diabetes.

Antidiabetic effect was also seen by supplementing spirulina 2 g/day doses for two months on blood glucose levels, glycosylated hemoglobin and lipid profile. The lowering of fasting and postprandial blood glucose levels and in the HbA1c level showed the antidiabetic property of spirulina (Parikh *et al*., 2001).

Trace Metal and micronutrient Supplement: Trace metals are essential nutrients required in very small amounts in the daily diet which play key roles in various activities of the cell. One of the important trace metals is selenium involved in immune function, reproduction, cardiovascular disease, cancer, viral infection control and metal toxicity. Another essential trace element is iodine, whose deficiency affects thyroid function, cardiovascular function, IQ and other brain disorders. Spirulina platensis has the potential to be used as a matrix for the production of selenium- and iodine-containing compounds (Desai and Sivakami, 2004). The relative proportion (Ca:P) of these micronutrients is compatible with the preservation of bone health since it reduces decalcification risk. Moreover, as it was previously stated, the cyanobacteria of interest is an oxalate-free plant food, thus –as with iron- it provides calcium with high availability, thus it improves its absorption (Craig and Mangels, 2009). It is also a great source of many other micronutrients, such as vitamin B6, vitamin C, vitamin D and vitamin A. It is also a source of potassium, chromium, copper, magnesium, phosphorus, manganese, selenium and zinc. (www.myprotein.com /thezone/nutrition/ spirulina-the-miracle-food).

Protein source for Malnutrition: Spirulina has no cellulose in its cell walls, being composed of soft mucopolysaccharides. This makes it easily digested and assimilated. It is 85 to 95% digestible making it important for people suffering from intestinal malabsorption, typically, older people. They find spirulina's protein easy to digest (Branger *et al*., 2003). Spirulina is effective for victims of malnutrition diseases like kwashiorkor, where the ability of intestinal absorption has been damaged. For malnourished children, it is more effective than milk powders because milk's lactic acid can be difficult to absorb Kelly *et al*. (2011). Spirulina is 65% protein which is extremely high for a plant, and one of the reasons it is becoming more popular. It also contains sources of all 8 essential amino acids. It's an easy, healthy way to boost your protein intake, and a great source of protein for vegetarians. Furthermore, this protein is highly absorbable (Sharoba, 2014)

Antiviral Activity: There is a strong therapeutic research involving spirulina, its strong antibacterial and antimycotic substance which is isolated from S.platensis (Funteu F, 1996). These results demonstrate excellent in vitro inhibition of HIV-1 virus both in human T-cell lines and in human monocytes. The therapeutic index of the extract is reported to be over 100 and concentrations as low as 5-10 µg/ml evidently reduce the production of virus in any system and hence proves to be highly antiviral in activity. Ingestion of spirulina contributes to the functional preservation of the intestinal epithelium which acts as a first line of mucosal barrier against infections (Sheahan *et al*., 2003). Inhibition of humoral immune response, cell mediated immune response (delayed type hypersensitivity) and TNF-alpha was noticed in a dose-dependent manner in mice. (Shklar *et al*.,1988). Spirulina has also been found to protect against hay fever (Simpore *et al*., 2005) .

Cures Eye disease: Spirulina is rich in beta-carotene that can overcome eye problems caused by vitamin A deficiency. It provides the daily dietary requirement of beta-carotene which can help prevent blindness and eye diseases (Seshadri, 1993). The protein and B-vitamin complex makes a major nutritional improvement in an infant's diet. It is the only food source other than breast milk containing substantial amounts of essential fatty acid, essential amino acids and GLA that helps to regulate the entire hormone system (Ramesh *et al*., 2013).

Substitute for Animal meat: Algal foods offer one of the few vegetarian alternatives for cobalamin (vitamin B12) in the diet. Cobalamin is not required or synthesized by higher plants (Croft *et al*., 2005) so fruits and vegetables are poor sources of vitamin B12, which explains why vitamin B12-deficiency is common among people following strict vegetarian or vegan diets (Wagner-Döbler *et al*., 2010).Of all the vitamins, vitamin B12 is the largest and most complex; it represents all of the biologically active cobalamins. The fact that Spirulina has an exceptionally high content of vitamin B12 –as other sea weed do- is of great importance because such vitamin is contained only in animal origin foods. Thus it is considered as a good source for vegans for B12 vitamins (Gutierrez *et al*., 2015).

Effects against Nephrotoxicity: The hepatoprotective action of Spirulina fusiformis is against GalN induced hepatotoxicity in mice. The protective efficacy of Spirulina fusiformis is very promising as evidenced by the reversal of the altered values following administration probably by promoting regeneration of hepatocytes that restore integrity and it was confirmed by the histopathological studies. The hepatoprotective property of the extract may be attributed to the presence of various constituents which are present in Spirulina fusiformis (Mathew *et al*., 1995). Still extensive research is required for understanding of the mechanism of action of Spirulina fusiformis for providing protection against galactosamine induced hepatotoxicity (Sharma and Dunkwal, 2012).

Anti-Inflammatory Effects: Recent research reveals that free bilirubin functions physiologically as a potent inhibitor of NADPH oxidase activity. The chromophore phycocyanobilin (PCB), found in blue-green algae and cyanobacteria such as Spirulina, also has been found to be a potent inhibitor of this enzyme complex, likely because in mammalian cells it is rapidly reduced to phycocyanorubin, a close homolog of bilirubin (Helliwell, 2011). Orally administered Spirulina or phycocyanin (the Spirulina holoprotein that contains PCB) can exert a wide range of anti-inflammatory effects. Until PCB-enriched Spirulina extracts or synthetically produced PCB are commercially available, the most feasible and least expensive

way to administer PCB is by ingestion of whole Spirulina (McCarty, 2007)

Radiation Protective Effects: Radiation protection offered by Spirulina may be due to the phytopigments (carotenoids, chlorophyll, phycocyanin) and polysaccharides. Spirulina can elevate the activity of all the antioxidant related enzymes viz., superoxide dismutase, catalase, glutathione peroxidase and glutathione reductase significantly. The effect may be due to the high phytopigments (carotenoids, chlorophyll, phycocyanin) in Spirulina (Hirahashi, 2002). Feeding children subjected to low level of radiation over a long period of time with 5 grams of Spirulina a day resulted in the reduction of Cesium-137 in urine by 50%. The c-phycocyanin and polysaccharide extracts of Spirulina stimulate recovery of white blood cells and bone marrow cell counts. The anaemic condition induced by irradiation was also reduced (Karkos *et al*., 2008).

Role of Spirulina in Immunity: Spirulina helps in building immunity and improving resistance to viral infections, enhance components of the mucosal and systemic immune system as it activates the cells of innate immune system. Spirulina has also been shown to activate macrophages, T and B cells (Swartz *et al*., 1987). Sulfolipids derived from spirulina have also proved effective against HIV. Extracts from Spirulina biomass have also been found active against herpes virus, cytomegalovirus, influenza virus, etc. Spirulina extracts have also been shown capable of inhibiting carcinogenesis (Blinkova, 2001). Spirulina use leads to higher levels of natural killer cells, interferon gamma and more potent production of interleukins (Hirahashi *et al* 2002). Immune system strengthening: Several experiments have shown that spirulina has a favorable regulatory effect on the immune system (Borchers, 2007). It stimulates the activation of macrophages, as well as the activity of T cells and NK cells. This process induces the release of interferon-gamma (IFN-γ), which can eventually lead to virus inactivation. These actions are thought to be mediated by polysaccharides (Borchers 2009).

Antioxidant and Nutrient profile: Spirulina contains phenolic acids, tocopherols and ßcarotene which are known to exhibit antioxidant properties. Miranda *et al*., (1998) evaluated the antioxidant capacity of a Spirulina extract indicated that Spirulina provides some antioxidant. Accumulative data from those studies concluded that Spirulina ingestion significantly relieved or totally prevented the oxidative stress or inflammation, and their associated pathological damages induced by insulting compounds (Deng and Chow, 2010). Although those studies were not directly investigating Spirulina's effects on cardiovascular conditions, the findings clearly demonstrated the antioxidant and anti-inflammatory activities of Spirulina. 180% more calcium than whole milk, 670% more protein than tofu, 3100% more beta carotene than carrots, 5100% more iron than spinach, more antioxidant and anti-inflammatory activity in 3 g of Spiurlina than in five servings of fruits and vegetables (Moorhead *et al* 2005). Spirulina is also very high in calcium, meaning it is excellent for growing children to help their bones and teeth develop. It contains over 26 times the calcium in milk.

Spirulina in Anaemia: Spirulina possibly enhances red cell production and function. Over a 12-week study period, there was a steady increase in average values of mean corpuscular haemoglobin with spirulina intake. Older women benefitted more rapidly from Spirulina supplements (Mohan *et al*., 2014). Levels of anaemia also decreased in children when their diet was supplemented with spirulina (Branger *et al*., 2003). Spirulina is a fantastic source of Iron, meaning it is excellent for women during pregnancy. In face, 100g of Spirulina contains 158% of your daily Iron requirements!

Anticancer Effects: Many researchers find phycocyanin to be a truly potent antioxidant, anti-inflammatory and anti-cancer properties pigment found only in Spirulina and other species of blue green algae. (Subbashini *et al*., 2004). It has been argued that the combined antioxidant and immune modulation characteristics of Spirulina may have a possible mechanism of tumor destruction and hence play a role in cancer prevention. The effects of Spirulina on oral carcinogenesis, in particular leukoplakia showed tumor regression after topical application or enteral intake of Spirulina extract (Shaklee and Schartz 1988). Jalaja *et al*., 2011 studied the effect of Spirulina on chemoprevention of cancer in tobacco chewers in Kerala, India. It was found supplementation with Spirulina at 1 g/day for 1 year resulted in complete regression. If Spirulina proves to have such effect, it can easily be incorporated in the daily diet as a therapeutic agent.(Baley, 2002).

CONCLUSION

Spirulina shows potent immune stimulating effects, shows anti-viral activity against a variety of harmful viruses. It shows promise as a cancer preventative agent and in the treatment of tumors. Spirulina shows far ranging cardiovascular benefits including improvement of blood lipid profiles, prevention of atherosclerosis, and control of hypertension. In addition to high levels of provitamin A, dried micro algae can provide various other nutrients including proteins, minerals, vitamins, and antioxidants. World production of consumable algae and algae products to be used as dietary supplements, food additives, functional foods, and medicines has reached thousands of tons per year after research which has proved its importance (Tang and Suter 2011).

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