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Multiple Potential Roles of *Spirulina* in Human Health: A Critical Review

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ABSTRACT

Spirulina is a freshwater blue-green microalgae which has been used as a food supplement for centuries. It is a rich source of several macro- and micro-nutrients. Several studies have demonstrated the potential nutraceutical, pharmaceutical and health benefits of *Spirulina*. The focus of this article is to highlight the multiple potential roles of *Spirulina* in human health. Studies have demonstrated *Spirulina*'s roles in boosting immunity through increasing resistance to various infections. Potential health benefits of *Spirulina* in association with its antioxidant, antiviral and anti-inflammatory properties have also been reported. Owing to its nutrient profiles and nutraceutical properties, *Spirulina* has been shown to have potential therapeutic roles in metabolic diseases, hypertension, anaemia, and acquired immune deficiency syndrome

Keywords: Antioxidant and anti-inflammatory properties, health, microalgae, *Spirulina*

INTRODUCTION

Spirulina is a primitive organism originating some 3.5 billion years ago (Ahsan *et al.*, 2008). In the sixteenth century, Spanish chroniclers described fishermen with fine nets collecting this blue coloured "techuitlatl" from the lagoons and making a blue-green cake from it. This conventional food, known as "Dihé" or "Die'', was rediscovered in Chad by a European scientific mission and later on, it spreaded to all over the world (Ahsan *et al.*, 2008; Saleh, 2014).

Arthrospira spp. known as *Spirulina* is a ubiquitous spiral-shaped blue-green unicellular microalgae (Figure 1). It grows in fresh water, salt water, as well as in brackish water (Mohan *et al.*, 2014). It belongs to the class Cyanophyceae, order Nostocales and family Oscillatoriaceae (Sethi & Naik, 2007).

Almost 35 different strains of *Spirulina* have been identified (Jassby, 1998). Of this, some are commercially exploited. These include *Spirulina maxima, Spirulina platensis* and *Spirulina pacifica* (also known as *Arthrospira maxima* and *Arthrospira platensis* (Mohan *et al.*, 2014). *Arthrospira platensis* is the predominant species cultivated worldwide (Thomas, 2010). It gained popularity in the nutraceutical industries due to its high protein content and almost all micronutrients as required for growth and development of the body system (Ahsan *et al.*, 2008). *Spirulina* products contain bioactive compounds that stimulate the immune system (Khan, Bhadouria & Bisen, 2005). In addition, it contains high levels of provitamin A

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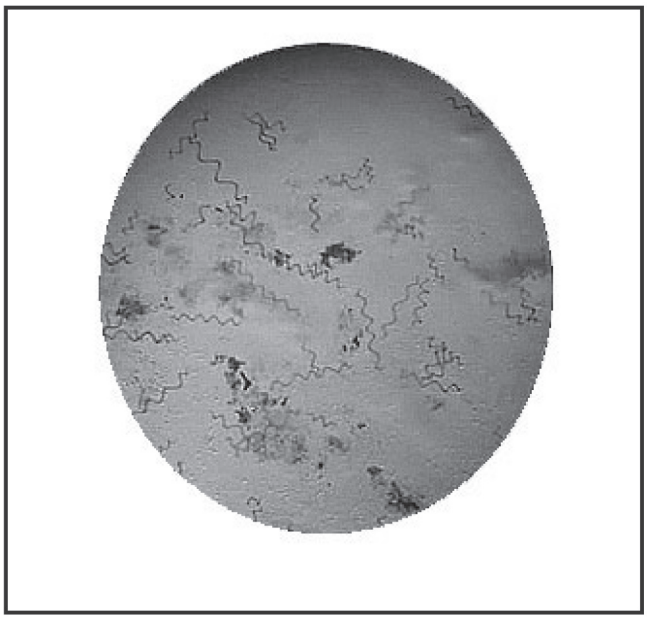

Figure 1. *Spirulina platensis* (10x magnification)

(a precursor of vitamin A). *Spirulina* is marketed as a health supplements in over 100 countries, and its beneficial health effects have been recognised by several international organisations including World Health Organisation (WHO), Food and Agriculture Organisation (FAO), United Nations Industrial Development Organisation (UNIDO), and United Nations International Children's Emergency Fund (UNICEF) (Fukami, Nishijima & Hata, 1992). There are also collaborative inter-governmental and institutional scientific spirulina research programmes (CISRI-ISP) to promote the use of *Spirulina* against severe malnutrition (Habib *et al.*, 2008).

NUTRIENT PROFILES

Chemical composition of *Spirulina* showed that it is an excellent source of proteins, vitamins, minerals, and pigments (Table 1) (Sotiroudis & Sotiroudis, 2013). Dried *Spirulina* contains about 60% (51–71%) protein (Campanella, Russo & Avino, 2002; Khan *et al.*, 2005). It is a complete protein containing all essential amino acids and is 85 to 95% digestible (Ciferri, 1983). The polysaccharide present in the cell wall of *Spirulina* is also 86% digestible. Hence it could be easily absorbed by the human body (Habib *et al.*, 2008). Phycocyanin C is the most important pigment and is considered as the precursor of chlorophyll and haemoglobin. *Spirulina* contains both fat and water soluble vitamins such as vitamins A, C, D, E, B1, B_2, B_3 B_6, B_9 and B_{12}, with particularly high amounts of Vitamin B_{12} and β-carotene (pro-vitamin A). *Spirulina* is one of the highest sources of Vitamin B_{12}, higher than the beef liver. The β-carotene is 10 times more concentrated than in carrots (Ahsan *et al.*, 2008). Vitamin A is toxic to the health if taken in high amounts but β-carotene is safe to the human body. Interestingly, *Spirulina* stores vitamin A in the form of β-carotene, which can be converted to vitamin A as per the needs of the body.

In addition to vitamins, *Spirulina* contains most of the minerals required in our daily diet. The calcium content of *Spirulina* is 1.8 times higher than in whole

Table 1. General composition of *Spirulina*

Components	*Relative dry weight%*
Proteins	50-70
Carbohydrates	15-25
Lipids	6-13
Nucleic acids	4.2-6
Minerals	8-13
Vitamins	0.08-0.12
Ash	3-11
Moisture	4-9
Minerals (mg/100g)	
Calcium	922.278
Potassium	2085.28
Magnesium	1.1902
Sodium	1540.46
Phosphorus	2191.71
Copper	1.2154
Iron	273.197
Manganese	5.6608
Zinc	3.6229
Chromium	0.325
Selenium	0.0394
Boron	2.875
Molybdenum	0.372
Phytopigments (mg/100g)	
Total carotenoids	400-650
Beta Carotene	150-250
Xanthophylls	250-470
Zeaxanthin	125-200
Chlorophyll	1300-1700
Phycocyanin	15000-19000
Vitamins (mg/100g)	
Vitamin B1 (Thiamine)	0.15-0.30
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

Source: Sotiroudis & Sotiroudis (2013); Thomas (2010); Saleh (2014)

milk; similarly iron is 10 times higher than in spinach (Moorhead, Capelli & Cysewski, 2005).

Spirulina is reported to be the richest source of the essential fatty acid Gamma-linolenic acid (GLA), which is the precursor of hormone arachidonic acid (Desai & Sivakami, 2004). The eicosapentaenoic acid synthesised from omega-3 and the GLA synthesised from omega-6 acids are converted in the body into eicosanoids, which are hormone-like compounds having important roles in many bodily functions, including vital organ functions

and intracellular activities (Holub, 2002).

Spirulina has a positive impact on growth and development and the parameters like arm circumference, height, albumin, pre-albumin, protein and haemoglobin are improved after *Spirulina* supplementation (Azabji-Kenfack *et al.*, 2011). In 1947, UN declared *Spirulina* as "the best food for tomorrow" (Sethi & Naik, 2007).

In *Spirulina* the nucleic acid content is less than 5% and this makes it desirable as food. Excess nucleic acid leads to accumulation of uric acid due to purine catabolism, which in turn results in pathological conditions such as gout.

The colour of *Spirulina* is due to two pigments: phycocyanin (blue) and chlorophyll (green). These two pigments are combined with another group of pigments known as carotenoids (red, orange and yellow) (Ahsan *et al.*, 2008). This phycocyanin extracted from *Spirulina* was first marketed in 1980 by the Dainippon Ink & Chemicals Inc. under the brand name "Lina Blue-A". This was mainly used as a food colorant, as an edible dye in ice creams and as a natural dye in the cosmetics industry. *Spirulina platensis* strain pacifica contains the highest levels of β-carotene and zeaxanthin than any natural source, both of which are converted to astaxanthin through an oxidation process, the red pigment desired by consumers.

Phycocyanin has been reported to have significant antioxidant, anti-inflammatory, hepatoprotective and broad-spectrum radical scavenging properties. Studies have shown that phycocyanin stimulates production of white blood cells and red blood cells (Selmi *et al.*, 2011). *Spirulina* is nature's highest source of chlorophyll pigment. Chlorophyll shows various anti-bacterial and antiseptic properties. It is effective in removing body odours, improving calcium absorption and counteracting toxins (Desai & Sivakami, 2004). UNIDO documents in the toxicological evaluation of *Spirulina* state that when administered at 10%, 20%, and 30% levels in the diet, it does not produce any subacute chronic toxicity, changes in reproduction, lactation or mutagenicity and teratogenicity. *Spirulina* contains high amount of carotenoid that is effective in the treatment of certain skin conditions such as psoriasis, acne and even herpes (Falquet & Hurni, 2006).

POTENTIAL HEALTH BENEFITS

Spirulina has a long history in human nutrition studies involving *in vitro* and *in vivo* conditions. Results of various studies and clinical trials have shown that it has multiple benefits to human health and the environment (Figure 2). *Spirulina* has been generally recognised as safe (GRAS) because it is safe for human consumption (Gouda, Kavitha & Sarada, 2015).

Potential health benefits associated with consumption of *Spirulina* have been reported in association with its antioxidant activity, anticancer and antiviral effects, antihyperlipidemia and cholesterol, effects against hepatotoxicity, as well as in reducing obesity, allergies, arthritis, immunomodualtion, inflammation and diabetes (Kamenidou, Aggelopoulos & Batzios, 2011). Moreover, *Spirulina* has been shown to enhance immune functions, reproduction and increased growth (Ngo-Matip *et al.*, 2015). In addition, *Spirulina* is claimed to help against heavy metal intoxications, and protects against radiation. These multiple beneficiary effects of *Spirulina* are shown in Figure 2. However, the current article is focused on the nutraceutical and medical aspects of *Spirulina*.

NUTRACEUTICAL ASPECTS

Antioxidant properties

Antioxidants are the substances that neutralise the free radicals generated during oxidative stress and normal cell processes (Mohan *et al.*, 2014). Free radicals damage the affected cell leading to death

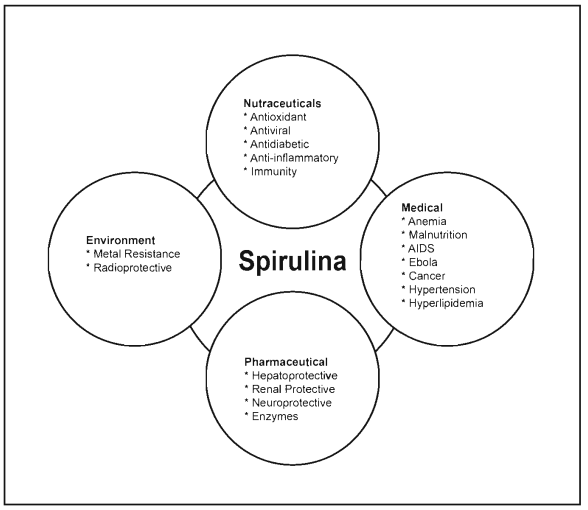

Figure 2. Multiple roles and beneficial effects of *Spirulina*

of the cell. The antioxidant properties of *Spirulina* are mainly related to the strong antioxidant and free radical scavenging activities of 'phycocyanin', although other antioxidant constituents such as β-carotene and SOD also contribute to the total antioxidant potential (Sotiroudis & Sotiroudis, 2013). An aqueous extract of *Spirulina* has been shown to exert a protective effect against apoptotic cell death due to free radicals (Chu *et al.*, 2010). Antioxidant properties of *Spirulina* extract have been demonstrated in the inhibition of lipid peroxidation (Lee *et al.*, 2008).

Liver fibrosis is a chronic liver disease which, if aggravated, causes cirrhosis (Wu *et al.*, 2005). A potential treatment for liver fibrosis is to inhibit the activated hepatic stellate cell (HSC) proliferation and subsequently to induce HSC apoptosis. It has been reported that antioxidants are able to inhibit the proliferation of HSCs. Thus, it is believed that *Spirulina* with its high amounts of combined antioxidants namely, phycocyanin, β-carotene, tocopherol and SOD render *Spirulina* as a very good source of natural antioxidants to address adverse conditions including liver fibrosis.

Antiviral activities

Spirulina possesses constituents for enhancing a healthy immune system (Saleh, 2014). The extract of *Spirulina* is reported to posses inhibitory activities against a wide range of viruses such as herpes simplex virus (HSV) type 1 and 2, human cytomegalovirus (HCMV), human immune deficiency virus (HIV) type-1, influenza type A, measles, etc. This is due to a novel sulfated polysaccharide named calcium spirulan (Ca-SP), which acts as an antiviral component (Hayashi *et al.*, 1996). This polysaccharide is composed of rhamnose, ribose, mannose, fructose, galactose, xylose, glucose, glucuronic acid, galacturonic acid, sulfate, and calcium. *Spirulina* extract containing calcium spirulan prevents the viral penetration into the cell membrane which is required to infect the cell and the virus gets stuck and becomes unable to replicate even inside the host. Further, the virus is eventually eliminated by the body's natural defences (Rechter *et al.*, 2006).

Ca-SP has been found to inhibit the replication of several enveloped viruses, including HSV-1, HCMV, mumps virus, influenza A virus, and HIV-1 (Hayashi *et al.*,

1996). In addition, the advantage of algal products with proven antiviral properties in fighting certain viruses is that they can be used in immunomodulation even when the infection is established (Ramamoorthy & Premakumari, 1996).

Anti-diabetic effects

Diabetes mellitus is a major metabolic disorder globally. *Spirulina* supplements taken for two months have been shown to lead to an appreciable lowering of fasting blood glucose and postprandial blood glucose levels (Parikh, Mani & Iyer, 2001). The anti-hyperglycemic effect of *Spirulina* is suggested to be due to the down-regulation of NADPH and NADH, cofactors in fat metabolism (Mohan *et al.*, 2014). Recently, the biomass and phycocyanin of the *Spirulina fusiformis* have been shown to inhibit increasing blood glucose levels in rats (Setyaningsih, Bintangb & Madinaa, 2015).

In addition, *Spirulina* given at a dose of 15 mg/kg body weight to streptozotocin diabetic rats increased the hexokinase activity and decreased the glucose-6-phosphatase activity (Layam, Lekha & Reddy, 2006). The decreased activity of glucose-6-phosphatase through pentose phosphate shunt results in a high reduced glutathione to oxidised glutathione ratio (GSH/GSSG), which is coupled with conversion of NADPH to NADP. *Spirulina* may produce high $NADP^+$, which results in down regulation of lipogenesis and a lower risk of the tissues for oxidation stress and offers high resistance for diabetes. Interestingly, *Spirulina* supplementation to Korean patients with type 2 diabetes for 12 weeks resulted in a significant reduction in plasma triglycerides and malondialdehyde level, whereas an increase in plasma adiponectin level was observed (Lee *et al.*, 2008).

Anti-inflammatory property

Spirulina exhibits anti-inflammatory properties by inhibiting the release of histamine from mast cells (Yang, Lee & Kim, 1997). GLA showed anti-inflammatory properties because of its metabolism to dihomogamma linolenic acid (DGLA). DGLA is a competitive inhibitor of prostaglandins. DGLA has also been shown to be a competitive inhibitor of leukotrienes. Leukotrienes are synthesised in the cell from arachidonic acid by 5-lipoxygenase and function to sustain inflammatory reactions. Dietary GLA has the potential to prevent the formation and therefore the negative inflammatory effects of arachidonic acid.

The chromophore phycocyanobilin (PCB), found in blue-green algae and cyanobacteria such as *Spirulina*, has been found to be a potent inhibitor of NADPH oxidase activity (McCarty, 2007). NADPH oxidase is considered as ROS-generating inflammatory oxidative enzyme. In mammalian cells, it is rapidly reduced to phycocyanorubin, a close homolog of bilirubin, an antioxidant and anti-inflammatory agent (Vitek, 2012).

Immunity enhancement

Spirulina helps in building immunity and can enhance components of the mucosal and systemic immune system as it activates the cells of the innate immune system (Mohan *et al.*, 2014). It actually enhances the body's ability to generate new blood cells (Kozlenko & Henson, 1996). It is also effective in increasing the level of immunoglobulin A (IgA) and immunoglobulin M (IgM) (Habib *et al.*, 2008). In humans, chicken and fish, *Spirulina* produces an immune stimulating effect by enhancing the resistance to infections, the capacity of influencing hemopoiesis and stimulating the production of antibodies and cytokines. *Spirulina* accelerates production of the humoral system, thus allowing better protection against invading germs. It has been shown that NF-kappa B (NF-kB) directed luciferase expression was enhanced by *Spirulina* treatment when cells were co-transfected with

vectors expressing proteins supporting toll-like receptor (TLR)2- (CD14 and TLR2) but not TLR4- (CD14, TLR4, MD-2) dependent activation (Balachandran *et al.*, 2006). The mechanisms of *Spirulina*-mediated immune potentiation appear to be mediated through TLR2 receptors. TLR2 was found to mediate the effects of *Spirulina* as cells expressed TLR2 showed NF-kB activation in response to *Spirulina* and those expressing MD-2 and TLR4 failed to do so.

Two pilot studies using *Spirulina* at 400mg daily (but with a higher concentration of Braun's lipoproteins, those found in gram-negative bacteria cell walls) noted that natural killer (NK) cell activity increased by 40% as assessed by tumor killing ability and mRNA production of NK cells increased by 37-55% (200mg and 400mg, respectively) after a week of supplementation (Nielsen *et al.*, 2010). Enhanced NK cell cytotoxicity function was noted elsewhere with a *Spirulina* hot water extract (Hirahashi *et al.*, 2002). In addition, some studies measured serum Myeloperoxidase (MPO) as a biomarker of neutrophil activation and found dose-dependent reduction in serum MPO with near abolishment of oxidative stress-induced MPO increased at 6g/kg *Spirulina* in rats (Pak *et al.*, 2012).

Immune-enhancing effect was also demonstrated in mice fed *Spirulina*-containing diet (Lee *et al.*, 2008). *Spirulina* became famous after it was successfully used by National Aeronautics and Space Administration (NASA) as a dietary supplement for astronauts on space missions; it inhibited the release of histamine by mast cells and this algae has been suggested to improve several symptoms of anti-allergic effects (Karkos *et al.*, 2011). In addition, *Spirulina* up regulates cells and organs of the human body system, improving their ability to function even under stresses from environmental toxins and infectious agents.

HEALTH ASPECTS

Anaemia

Deficiency in micronutrients including iron and vitamin B_{12} leads to clinical manifestations, microcytic and hypo-chromic anaemia, owing to lack of haemo-globin in the erythrocytes (Salmean, Castillo & Cevallos, 2015). Various studies have suggested that *Spirulina* may ameliorate anaemia in all age groups of the population (Simpre *et al.*, 2005; Selmi *et al.*, 2011; Maccio & Madeddu, 2012). This is primarily due to its high contents of vitamin B_{12} and iron. It is the only plant source with such a high vitamin B_{12} content, two and half times the content of vitamin B_{12} in liver. It has been recommended that daily intake of 1-2 gm of *Spirulina* for more than six to seven weeks results in significant increase in haemoglobin levels (Rucklidge, Harrison & Johnstone, 2011). The daily ingestion of 1 gm of *Spirulina* is claimed to be sufficient to meet the daily requirement of vitamin B_{12}. *Spirulina* is sold as a health food particularly owing to its a large amount of vitamin B_{12} (Van den Berg, Dagnelie &van Staveren, 1988).

Malnutrition

In developing countries, malnutrition leads to numerous harmful consequences for young children including a weakened immune system, delayed motor development, diminished cognitive capacity (intellectual disability) and school performance, and increased risk of mortality. *Spirulina* has been shown to be an adequate protein source to aid in the recovery of protein malnutrition. Various studies have shown that incorporation of *Spirulina* in the diet helps to overcome micronutrient deficiency. On the basis of its micronutrient composition, and the fact that it can be esily cultivated, *Spirulina* has been proposed as a potential food to fight against malnutrition (Falquet & Hurni, 2006; Udayasree, Manjula & Sowjanya, 2013).

In addition, *Spirulina platensis* given for a 4-month period showed improved attention, cognition, and impulse control in attention-deficit/hyperactivity disorder (ADHD) and severe mood deregulation (Rucklidge *et al.*, 2011).

Hyperlipidemia

Cardiovascular disease remains the number one cause of death in developed countries. Despite increased awareness, high cholesterol is one of the most important risk factors in atherosclerosis. Administration of *Spirulina* supplements in ischemic heart disease was found to significantly reduce blood cholesterol, triglycerides, low-density lipoprotein (LDL) cholesterol and an increase in HDL cholesterol levels (Ramamoorthy & Premakumari, 1996). A study conducted in Japan on 30 male employees with high cholesterol, mild hypertension and hyperlipidemia concluded that *Spirulina* lowered the serum cholesterol, triglycerides and LDL particles (Habib *et al.*, 2008). In an another study, 52 adults (ages 37 to 61 years) who had high cholesterol levels were examined for the effects of *Spirulina*. Study participants took 1 gm of *Spirulina* supplements a day for 12 weeks and gave fasting blood samples at the beginning and at the end of the study. By the end of the experiment, average levels of triglycerides, total cholesterol and the potentially harmful LDL (low-density lipoprotein) cholesterol decreased (Mazokopakis *et al.*, 2014). Heart disease is not just a disorder of high cholesterol and triglycerides, but also a chronic inflammatory disease and *Spirulina* is reportedly able to reduce the risk of heart disease through its antioxidant properties (Deng & Chow, 2010).

Antiviral activities

Spirulina has also shown promise as an adjunct therapy. HIV is associated with insulin resistance in addition to other abnormalities due to highly active antiretroviral therapy (HAART). One such study with HIV patients with insulin resistance, 19g of *Spirulina* over 2 months was associated with an increased rate of glucose deposition and an improvement in insulin sensitivity (Marcel *et al.*, 2011).

A potential anti-EboV and anti-HIV compound Cyanovirin-N (CVN) has been found in the blue-green algae *Spirulina* (Raja *et al.*, 2015). CVN present in *Spirulina* is a novel cyanobacterial carbohydrate-binding protein which has shown a significant antiviral activity against enveloped viruses such as HIV and Ebola. The aqueous extract of *S. platensis* was found to inhibit HIV-1 replication in human T-cell lines, peripheral blood mononuclear cells (PBMCs), and Langerhans cells (Ayehunie, 1998). Moreover, *Spirulina* also prevents to some extent the transfer of AIDS virus from mother to child (Simpre *et al.*, 2005).

The antiviral action of *Spirulina* involves CVN binds to N-linked high-mannose oligosaccharides on the viral glycoprotein rendering it an ineffective CVN, a protein with a highly complicated structure, binds to sugars attached to the cover of the virus, envelopes its proteins and prevents it from binding to the mucosal cell surfaces. Thus, this interaction inhibits binding of a virus to a cell and reduces their ability to further infect healthy cells. The CVN is an entry inhibitor of HIV and many other viruses, and it represents a new generation of microbicides that has specific and potent activity (Nuhu, 2013). Anti-HIV effect of CVN is stronger than a well-known gp120-targeted antibody (2G12) and another microbicide candidate, PRO2000 (Xiong, Fan & Kitazato, 2010).

Anticancer properties

Spirulina is one of the richest natural sources of β-carotene and phycocyanin pigments. *Spirulina* has also been considered to be a potent cancer-fighting phytonutrient. Various animal studies have demonstrated the anti-cancer effect

of *Spirulina* (Akao *et al.*, 2009, Grawish *et al.*, 2010). Chemoprevention of cancer and reduced incidence of liver tumours were also documented for *Spirulina* (Hamidah *et al.*, 2009). The chemopreventive capacity to reverse precancerous lesions of *Spirulina* is attributed due to its antioxidant property (Mathew *et al.*, 1995). C-phycocyanin of *Spirulina*, a selective cyclooxygenase-2 inhibitor, induces apoptosis in lipopolysaccharide-stimulated RAW 264.7 macrophages. Phycocyanin inhibits the growth of human leukemia K562 cells when supplemented with diet (Habib *et al.*, 2008). It is also known to exhibit anti-inflammatory and anticancer properties (Reddy *et al.*, 2003).

It is suggested that combined antioxidant and immune modulation characteristics of *Spirulina* may have a possible mechanism of tumour destruction and hence play an important role in cancer prevention (Ramamoorthy & Premakumari, 1996). In addition, *in vitro* studies suggest that the unique polysaccharides of *Spirulina* enhance cell nucleus enzyme activity and DNA repair synthesis (Saleh, 2014). Moreover, prevention of experimental oral cancer by extracts of *Spirulina-Dunaliella* algae has also been also reported (Schwartz *et al.*, 1988).

Recently, a study on the use of *Spirulina* in the treatment of oral leukoplakia has been conducted in India and has shown promising results (Mohan *et al.*, 2014). In a novel recent clinical trial, *Spirulina* was used in the treatment of oral submucous fibrosis (Mulk *et al.*, 2013). The *Spirulina* extract showed significant reduction in oral cancer (Mathew *et al.*, 1995). In another recent case report of relapsed verrucous vulvar cancer (VVC), the patient showed a complete response to radiotherapy combining it with *Spirulina* in a 750 mg/dose at 2 doses/day and the tumour disappeared at the 2400 cGy radiation dose without any toxicity to the skin or the woman's general health (Kiziltan *et al.*, 2015).

SAFETY ASPECTS

Spirulina consumtion has been shown to lead to neither acute nor chronic toxicity. However, *Spirulina* may become contaminated with toxic metals, harmful bacteria and microcystins (i.e. toxins produced from some algae) due to its open pond cultivation. Therefore, quality control in the growth and processing of *Spirulina* to avoid contamination is imperative to safeguard safety of *Spirulina* products (Deng & Chow, 2010). Contaminated *Spirulina* can cause liver damage, nausea, vomiting, thirst, weakness, rapid heartbeat, damage to the nervous system, shock and even death, especially in children (Sotiroudis & Sotiroudis, 2013). The most common adverse effects are headache, muscle pain, flushing of the face, sweating and loss of ability to focus (Ravi *et al.*, 2010). A case of anaphylaxis after ingestion of *Spirulina* was also reported (Le, Knulst & Rockmann, 2014). Therefore, it is necessary to assess the source of *Spirulina* supplements to ensure they are grown in safe conditions and subject to tests for toxins.

Individuals with autoimmune conditions are suggested to avoid *Spirulina* supplements (Sotiroudis & Sotiroudis, 2013), since *Spirulina* enhances the immune system. *Spiruluna* supplements might worsen the symptoms of multiple sclerosis (MS), systemic lupus erythematosus (SLE), rheumatoid arthritis (RA) and other conditions linked to hyperactive immune systems. A case of acute rhabdomyolysis after ingestion of *Spirulina* supplements was also reported (Mazokopakis *et al.*, 2008). *Spirulina* should be avoided by people who have the metabolic disorder phenylketonuria, as phenylalanine content can be harmful (Ravi *et al.*, 2010).

Spirulina may also interfere with drugs that slow blood clotting, including blood thinners such as warfarin as well as non-steroidal anti-inflammatory (NSAIDS) pain medications. The slow blood clotting

effect might be due to Ca-SP. It has been suggested that Ca-SP enhances the anti-clotting effects of heparin (Hayakawa *et al.*, 1996).

CONCLUSION

Spirulina has been recommended as a good source of vitamins and minerals, antioxidants and for its potential antiviral and immunological properties. Studies so far suggest that *Spirulina* is a safe food supplement but its role as a drug remains to be confirmed. More clinical studies should be undertaken to confirm the role of *Spirulina* as a drug therapy.

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