

and other health benefits. This can come from nutritional intake, as well as supplemental intake.

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Spirulina

DESCRIPTION

In its commercial use, Spirulina refers mainly to the dried biomass of the cyanobacterium *Arthrospira platensis*. *Arthrospira platensis* (*Spirulina platensis*) is a genus of the phylum *Cyanobacteria*. *Cyanobacteria* are classified as either blue-green algae or as blue-green bacteria. Spirulina is a popular food supplement in Japan and is marketed as a nutritional supplement in the United States. Spirulina, wheat grass, barley grass and chlorella are sometimes referred to as "green foods." There are several cyanobacteria species; however, Spirulina usually refers to only two of them, *Arthrospira platensis* (*Spirulina platensis*) and *Arthrospira maxima* (*Spirulina maxima*). The term Spirulina is commonly used for both the dietary supplement and the genus *Arthrospira*.

Spirulina used for the production of nutritional supplements is either grown in outdoor tanks or harvested from lakes in such places as Mexico, Central and South America, and Africa.

Spirulina is a rich source of protein. It also contains chlorophyll, carotenoids, minerals, gamma-linolenic acid (GLA) and some unique pigments. The pigments give Spirulina its bluish tinge. Phycocyanin is a blue, light-harvesting pigment in cyanobacteria. It belongs to a group of light-harvesting proteins, called phycobiliproteins. All phycobiliproteins are multi-chain holoproteins, comprised of apoproteins with covalently bound phycobilins. Phycobilins are open-chain tetrapyrrole chromophores. The three common phycobiliproteins are phycoerythrin, with phycoerythrobilin chromophores, and phycocyanin and allophycocyanin, with phycocyanobilin chromophores. Phycocyanorubin, a reduced form of phycocyanobilin, is similar in structure to the bile pigment bilirubin.

ACTIONS AND PHARMACOLOGY

ACTIONS

Spirulina has putative antiviral, hypocholesterolemic, antioxidant, hepatoprotective, antiallergic and immune-modulatory activities.

MECHANISM OF ACTION

A sulfated polysaccharide called calcium spirulan isolated from *Arthrospira platensis* (*Spirulina platensis*) was found to inhibit a number of membraned viruses. The viruses inhibited by the polysaccharide included herpes simplex

virus 1 (HSV-1), cytomegalovirus, measles virus, mumps virus and HIV-1. Calcium spirulan appears to inhibit the penetration of these viruses into host cells. These studies were performed *in vitro*.

Spirulina has been shown to have hypocholesterolemic activity in experimental animals. The mechanism of this activity is unknown.

Phycocyanorubin, a reduced form of phycocyanobilin, is similar in structure to the bile pigment bilirubin. Those with borderline elevated bilirubin levels—for example, those with Gilbert's syndrome—have been noted to have a lower incidence of cardiovascular disease, reduced stroke prevalence and improved stroke outcomes, among other health benefits. Bilirubin has a number of antioxidant activities, including the inhibition of formation of superoxide anion radicals by NADPH oxidase. The antioxidant and radical scavenging activities of phycocyanin are well documented. The activities are mainly attributed to the phycocyanobilin moiety. Phycocyanorubin has also been demonstrated to have radical scavenging activity and might also possess NADPH oxidase inhibitory activity as well.

Phycocyanin has been found to protect against hepatotoxins in rats. The mechanism may be via its antioxidant activity. An extract of *Spirulina maxima* also protected against carbon tetrachloride hepatotoxicity in rats. The phycocyanin contained in the extract, as well as other antioxidants, probably account for the hepatoprotective effect.

Spirulina was found to inhibit mast-cell mediated immediate-type allergic reactions in rats. It is speculated that there are substances in Spirulina that may inhibit mast-cell degranulation, possibly by affecting the mast-cell membrane.

Spirulina platensis extracts have been demonstrated to enhance macrophage function in cats and to enhance humoral and cell-mediated immune functions in chickens. The mechanism of these effects is unknown.

It was shown that *in vitro* culture of Spirulina with human blood mononuclear cells modulated the production of some cytokines. Another study by the same group evaluated the impact of a Spirulina nutritional supplement on subjects with allergic rhinitis by assessing the production of the cytokines interleukin (IL)-4, interferon (IFN)-gamma and interleukin (IL)-2. These cytokines are critical to the regulation of immunoglobulin E-mediated allergic reactions. In a randomized, double-blinded, crossover study versus placebo, it was found that Spirulina modulated the Th (T-helper lymphocyte) profile in subjects with allergic rhinitis by suppressing the differentiation of Th2 cells, mediated, in part, by inhibiting the production of IL-4. Spirulina appeared not to

be effective at modulating the secretion of the Th1 cytokines IFN-gamma and IL-2.

PHARMACOKINETICS

The pharmacokinetics of Spirulina in humans has not been studied. However, the proteins, lipids and carbohydrates in Spirulina should be digested, absorbed and metabolized by normal physiological processes.

INDICATIONS AND USAGE

Spirulina has shown some indication of having antiviral effects in preliminary *in vitro* and animal studies. There is also evidence of a preliminary nature that it might favorably affect some immune functions and have some hepatoprotective capability. It has shown some promise of inhibiting some allergic reactions in recent experimental studies. Hypocholesterolemic effects have been reported in some animal studies.

RESEARCH SUMMARY

An extract of Spirulina inhibited *in vitro* replication of HSV-1 simplex virus type 1. It also significantly prolonged survival time of HSV-1-infected hamsters. It seemed to act, not through direct virucidal effects, but rather through inhibition of viral penetration into cells. Subsequently, further experiments demonstrated that Spirulina extract significantly inhibited *in vitro* replication of several enveloped viruses, including human cytomegalovirus, measles virus, mumps virus, influenza A virus and HIV-1. Again, the mechanism of action was said to be selective inhibition of viral penetration into host cells.

More recently still, other researchers have focused specifically on the ability of a Spirulina extract to inhibit HIV-1 replication in human T-cell lines, peripheral blood mononuclear cells (PBMC) and Langerhans cells (LC). The researchers stated: "We conclude that aqueous *A. platensis* extracts contain antiretroviral activity that may be of potential clinical interest."

Spirulina and some of its constituents have shown an ability to favorably affect various immune functions. In one animal experiment, it boosted phagocytic activity and increased natural killer (NK)-cell activity two-fold, compared with controls.

Spirulina has significantly inhibited chemically induced anaphylactic shock and serum histamine levels in rats, leading to the conclusion that Spirulina may inhibit mast-cell degranulation. In another animal experiment, Spirulina significantly inhibited local allergic reactions induced by anti-dinitrophenyl (DNP) IgE. It demonstrated, more specifically, a significant inhibitory effect on anti-DNP IgE-induced tumor necrosis factor-alpha production, leading the researchers to conclude that Spirulina inhibits mast-cell

mediated immediate-type allergic reactions both *in vitro* and *in vivo*.

Finally, a constituent of *Spirulina*, administered intraperitoneally, significantly reduced the hepatotoxicity of a carbon tetrachloride challenge. A more recent study confirmed this finding.

CONTRAINDICATIONS, PRECAUTIONS, ADVERSE REACTIONS

CONTRAINDICATIONS

Spirulina is contraindicated in those who are hypersensitive to any component of a *Spirulina*-containing supplement.

PRECAUTIONS

Pregnant women and nursing mothers should avoid *Spirulina*-containing supplements.

Spirulina can accumulate heavy metals, such as mercury, from contaminated waters. Those who use *Spirulina* supplements should select reputable products that are free of any heavy metal contamination.

ADVERSE REACTIONS

Occasional gastrointestinal symptoms, such as nausea, have been reported. Also, there are a few reports of allergic reactions to *Spirulina*-containing supplements.

DOSAGE AND ADMINISTRATION

There are various forms of *Spirulina* supplements, including capsules, tablets, flakes and powders. *Spirulina* is also found in some functional foods and in combination "green food" products with barley grass, chlorella and wheat grass. Doses range from 250 mg to 5 grams daily.

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Spruce Lignans (7-hydroxymatairesinol)

DESCRIPTION

Lignans are phenylpropanoid dimers widely distributed in the plant kingdom. Flaxseed and sesame seed are two of the