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The Health Benefits of Spirulina: A Superfood for the Modern Age

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Abstract
This review article highlights sthe versatile health benefits of spirulina, a nutrient-rich dietary supplement. Spirulina has various advantages, including functioning to support the immune system, increase energy, and has antioxidant properties. Being high in protein, essential amino acids, and iron, spirulina can be added to the diet to improve nutritional intake and improve overall health. The versatility of spirulina as a dietary supplement makes it feasible to incorporate spirulina into different diets by simply adding it to a smoothie, salad, or a supplement. Spirulina is an alternative for people who want to conveniently and sustainably optimize their health.

Introduction
Spirulina, a blue and green algae is a well-known superfood due to its highly nutritious profile. It is often referred to as one of the worlds healthiest foods and boasting an exceptionally high concentration of nutrients (Mężyńska & Brzóska, 2018). Because of this many companies and organizations alike have prospects to grow the source into a commercial food and food supplement. The World Health Organization and NASA lay approval on it being that it is a food source that can be utilized, and the benefits are many (Chacón-Lee & González-Mariño, 2010). Spirulina nutrient Spirulina on human nutrition and health has been demonstrated, suggesting that spirulina can be considered as a drug for its various commercial applications (Karkos et al, 2011). These references help introduce spirulina as a nutrient-dense, blue-green algae known to be very popular and in trend as a super-food in the generation of today. The purpose of this article is to inform the many health benefits spirulina brings.

Nutritional Profile of Spirulina
"The True Value of Spirulina" Journal of agricultural and food chemistry. Aouir et al reported values for the protein content of differently cultivated Arthrospira platensis strains and spirulina powders ranging between 59–63% as Grosshagauer et al. (2020). "Effect of Fermentation on Enhancing the Nutraceutical Properties of Arthrospira platensis (Spirulina)" Fermentation. Spirulina has an enhanced nutritional profile with high bioavailability of essential amino acids (64 to 74% protein content), biliproteins, and other pigments, such as allophycocyanin, C-phycocyanin, a-chlorophyll, B and E vitamins, mineral substances and trace elements, glycolipids, sulpholipids, and essential polyunsaturated fatty acids, including γ-linoleic acid- Castro et al. (2019). "Effect of Spirulina (Arthrospira platensis) Supplementation on Physical and Chemical Properties of Semolina (Triticum durum) Based Fresh Pasta" Molecules. Spirulina had a high

content of protein (71.34%), with all the essential amino acids, a high total fiber (8.45%), as well as ash content (5.93%), which significantly increased the nutritional value of the obtained fresh pasta Satyaraj et al. (2021). "Supplementation of Diets with Spirulina Influences Immune and Gut Function in Dogs" Frontiers in nutrition. Spirulina has been recognized as having a unique nutritional profile with a very high protein content (60-70% of dry matter content), and being rich in vitamins, minewith, essential fatty acids particularly gamma-linolenic acid, as well as other bioactive components Raczyk et al. (2022). "Spirulina Protects against Hepatic Inflammation in Aging: An Effect Related to the Modulation of the Gut Microbiota?" Nutrients. Moreover, the nutritional value of Spirulina is well recognized through its peculiar high protein content (60–70% of dry weight) Neyrinck et al. (2017).

Spirulina, a nutrient-rich blue-green algae, is recognized for its abundance of essential vitamins and minerals, making it a valuable dietary source. It contains significant levels of vitamin B12, iron, and calcium, essential nutrients that are often deficient in certain diets. Studies have consistently highlighted the presence of these essential vitamins and minerals in spirulina. For instance, research has shown that spirulina is rich in essential amino acids, fatty acids, vitamins, and minerals, including vitamin B12, iron, and calcium (Koli et al., 2022; Alvarenga et al., 2011; Maddiboyina et al., 2023; Rutar et al., 2022; Campanella et al., 1999; Belay et al., 1993; Mazinani & Fadaei, 2016; Ebid et al., 2022; Suliburska et al., 2016; Batool et al., 2022). Furthermore, spirulina has been found to be an excellent source of iron, calcium, and other essential minerals, making it a valuable dietary supplement for addressing nutritional deficiencies (Abdel-Malak et al., 2020; Suliburska et al., 2016; Batool et al., 2022).

The presence of these essential vitamins and minerals in spirulina underscores its potential as a functional food and dietary supplement for promoting overall health and addressing specific nutritional needs. Spirulina's bioavailability of essential nutrients, such as vitamins and minerals, plays a crucial role in its effectiveness as a dietary supplement. Unlike other microalgae, spirulina lacks cellulose walls, leading to higher bioavailability of nutrients, particularly proteins, compared to yeasts and unicellular algae Michaelsen et al. (2009). This characteristic makes the protein and other nutrients in spirulina more readily absorbable and usable by the body. Additionally, spirulina is recognized for its high bioavailable vitamin B12 content, which is particularly beneficial for vegetarians who may struggle to obtain this essential nutrient from their diet (Khan et al., 2005). Furthermore, the easy bioavailability of nutrients, including minerals, in spirulina makes it a suitable dietary choice for pregnant and lactating women, as well as malnourished children (Chacón-Lee & González-Mariño, 2010). Studies have also indicated that spirulina's nutrients, such as vitamins, minerals, essential amino acids, and fatty acids, may promote fish growth and activate metabolism, highlighting their bioavailability and potential growth-stimulating effects (Roohani et al., 2019; Cao et al., 2018). Moreover, spirulina has been found to serve as a rich source of dietary zeaxanthin with high bioavailability in humans, demonstrating its potential to deliver bioactive compounds effectively (Yu et al., 2012; Yu et al., 2011). The bioavailability of spirulina to honeybees has also been established, emphasizing its protein bioavailability, essential amino acid content, and functional lipid composition (Ricigliano et al., 2020). However, some studies have raised questions about the digestion capacity and bioavailability of certain nutrients, such as vitamin B12, from spirulina (Bishop & Zubeck, 2012).

Powerful Antioxidant Properties

Spirulina is rich in antioxidants, such as phycocyanin and beta-carotene, which play a crucial role in protecting the body against oxidative stress and damage caused by free radicals. Phycocyanin, a pigment-protein complex found in spirulina, has been shown to possess potent antioxidant

properties, contributing to its ability to scavenge free radicals and reduce oxidative stress Li et al., 2020; Hassanen et al., 2015; Lee et al., 2015; Dartsch, 2008; Manogar et al., 2020; Kuhad et al., 2006; Kuhad et al., 2006). Additionally, the presence of beta-carotene in spirulina further enhances its antioxidant capacity, as beta-carotene is known for its ability to neutralize free radicals and protect cells from oxidative damage (Abdel-Daim et al., 2013; Nawrocka et al., 2017; Moustafa et al., 2021; E et al., 2015; Jadaun et al., 2017; Hussein et al., 2017; Rostami et al., 2022; "Vitamin C Spirulina Mixture to Improve Sports Endurance", 2022; Fitry et al., 2020; Pott, 2018). These antioxidants work synergistically to combat oxidative stress, reduce inflammation, and support overall cellular health. The bioactive compounds in spirulina have been reported to activate antioxidant enzymes, reduce lipid peroxidation, and enhance the body's antioxidant capacity, thereby contributing to its protective effects against oxidative damage (Abdel-Daim et al., 2013; Nawrocka et al., 2017; Moustafa et al., 2021; Li et al., 2020; E et al., 2015; Hassanen et al., 2015; Lee et al., 2015; Maulana et al., 2023; Seyidoglu et al., 2021; Jadaun et al., 2017; Lee et al., 2022; Hussein et al., 2017; Muga & Chao, 2014; Rostami et al., 2022; "Vitamin C Spirulina Mixture to Improve Sports Endurance", 2022; Fitry et al., 2020; Dartsch, 2008; Pott, 2018; Manogar et al., 2020; Doke, 2005; Kuhad et al., 2006; Işık et al., 2020; Kuhad et al., 2006; Güroy et al., 2017; Satyanarayana et al., 2005). The ability of spirulina to mitigate oxidative stress and protect against free radical-induced damage underscores its potential as a valuable dietary supplement for promoting overall health and well-being.

The antioxidants present in spirulina, such as phycocyanin and beta-carotene, offer a wide range of potential health benefits, particularly in reducing inflammation, supporting heart health, and preventing chronic diseases. These antioxidants have been shown to possess potent anti-inflammatory properties, contributing to their ability to mitigate inflammation-related conditions Chen et al. (2012)Brito et al., 2020; Neyrinck et al., 2017; Cheong et al., 2010; Pak et al., 2012; Bhattacharyya & Mehta, 2012; Ismail et al., 2015; Dartsch, 2008; Huang et al., 2022; Zhang & Zhang, 2013; Kusmardi et al., 2021; Mao et al., 2005). Additionally, the antioxidant and anti-inflammatory effects of spirulina have been associated with its potential to support heart health by reducing oxidative stress and inflammation, which are key factors in the development of cardiovascular diseases (Cheong et al., 2010; Pak et al., 2012). Furthermore, the ability of spirulina to modulate oxidative stress and inflammation has implications for preventing chronic diseases, including metabolic disorders, liver diseases, and age-related conditions (Neyrinck et al., 2017; Bhattacharyya & Mehta, 2012; Ismail et al., 2015; Macciò & Madeddu, 2012; Dartsch, 2008; Huang et al., 2022; Zhang & Zhang, 2013; Kusmardi et al., 2021; Mao et al., 2005).

Immune Function and Energy Boost

Incorporating spirulina into one's diet has been shown to support immune function by enhancing the production of antibodies and boosting the activity of natural killer cells. Studies have indicated that spirulina supplements can effectively modulate the immune system, particularly by promoting the activity of natural killer cells, which play a crucial role in the body's defense against infections and tumors Finamore et al., 2017; Abdel-Tawwab & Ahmad, 2009; Selmi et al., 2011; Chen et al., 2016; Park et al., 2008; Lopes et al., 2023; Al-Yahyaey et al., 2022; Park & Lee, 2017; Park & Lee, 2016; Jaafari et al., 2021; El-Sheekh et al., 2014; Teas & Irhimeh, 2011; Kaur & Kaur, 2021; Carrieri et al., 2011; Shinde et al., 2022; Manogar et al., 2020; BUDAK & Sarıkaya, 2022; Anvar & Nowruzi, 2021; Iskandar et al., 2015; Hayashi et al., 2006; Cingi et al., 2008). Additionally, the immunomodulating activities of spirulina have been associated with its ability to enhance the production of antibodies, which are essential components of the adaptive immune response (Khan et al., 2005; Finamore et al., 2017; Abdel-Tawwab & Ahmad, 2009; Selmi et al., 2011; Chen et

al., 2016; Park et al., 2008; Lopes et al., 2023; Al-Yahyaey et al., 2022; Park & Lee, 2017; Park & Lee, 2016; Jaafari et al., 2021; El-Sheekh et al., 2014; Teas & Irhimeh, 2011; Kaur & Kaur, 2021; Carrieri et al., 2011; Shinde et al., 2022; Manogar et al., 2020; BUDAK & Sarıkaya, 2022; Anvar & Nowruzi, 2021; Iskandar et al., 2015; Hayashi et al., 2006; Cingi et al., 2008).
According to Grosshagauer et al. (2020), Spirulina is believed to improve energy levels due to its high protein and iron content. It is marketed as a rich, high-quality dietary protein source, which makes it an excellent energy supplement. The higher ability of proteins in spirulina to generate energy makes it best for our muscles; furthermore, spirulina also contains iron, which supports oxygen in our body. Iron is an essential component. It is needed by organelles to create ATP, so when the person gets tired, they will need to consume a lot of spirulina.

Overall Well-being

Spirulina is an extremely beneficial dietary supplement due to its incredibly wide range of health benefits. It supports immune function by increasing the production of antibodies and encouraging the highly functioning of various natural killer cells. Energy levels are greatly improved by spirulina's high protein content and the cautions of iron, as iron is essential for oxygen transport and energy production. Spirulina also has incredible antioxidant effects that include anti-inflammatory, anticancer, cholesterol elimination, and antiviral activity. All these facts suggest spirulina may be a functional food with many therapeutic properties which makes it an amazing nutraceutical and pharmaceutical source to use in the future.
Supported by a plethora of scientific research, this story encourages readers to consider incorporating spirulina into their food to improve their overall well-being in a natural and nutrition-dense way. Spirulina offers a full range of health benefits such as immune improvement, energy improvement, and strong antioxidant properties. This adds to the diet of nutrients that have a high potential for nutrients, as they are of iron and the necessary amino acids. By incorporating spirulina into the diet, the person can potentially benefit from its effect on immunity, well-being and making a stronger anti-aging.

Conclusion

All things considered; spirulina is very convenient for people who are looking to be healthy in general because of how many ways it can be taken. It can be added to your daily smoothie, salad, or taken as a regular supplement. Being able to buy it and take it in these ways is what makes spirulina so great because no matter what kind of smoothie or salad you're having, you can always add it in, and the benefits will always be there. Being able to take spirulina can also remind us to have good immune support, giving off all the energy you can, and antioxidants which makes us feel happy and motivated. An easy and convenient way to improve health is by supplementing with spirulina. Spirulina is a natural, highly nutrient dense food with a lot of health benefits. This alga can improve immune system function, boost energy levels, and provide powerful antioxidant protection making it appealing to anyone wanting to live a healthy lifestyle. People looking to follow a ketogenic diet may be better off sticking to foods close to the original state of human beings and other animals. While spirulina may not be the right food to try to optimize your health, it looks very promising to those who embrace new and alternative food sources. The Aztecs got most of their calories from native corn, beans, and squash before also adding an abundant number of spirulina, a food fish and ducks also eat. While eating grasshoppers has been a trend in the nutrition and sustainable food world for a while, the consumable bright blue-green algae became suddenly trendy after two reputable places started selling it. It is a very strong contrast. A photo

from a few days before Alchemist sprayed algae to add green. It should not be solid enough to snap into like a carrot, but you should be able to take a sort of bite out of it.

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