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Review on Spirulina (Green Alage)

Bhushan G. Rajput[1,*], Bhushan S. Kanade[2], Bhagyashri Ishi[3], Bhagyashri Dhangar[4], Paresh A. Patil[5]

Abstract

Spirulina is an edible blue-green algae that is a plant protein source. In recent years, its health benefits have attracted scientific Attention, including micro-level examinations of the algae's bioactive components. As proof of concept, investigations conducted in vitro, in vivo, and ex vivo have shown how spirulina works and how it affects immunity. Spirulina has been used as a whole food and as a nutritional supplement for many years. It has been shown to have positive effects on a variety of human health problems, such as malnutrition, metabolic syndrome, and more. The bioactives in Spirulina, including essential amino acids, Phycocyanins, Polysaccharides, Carotenoids, Chlorophylls, Vitamins, and trace Minerals, play a holistic role in its anti-oxidative, anti-inflammatory, antibacterial, immune-modulating, and anti-malignancy actions. Phenolic compounds, extracellular metabolites, and Spirulina whole food has been shown to have anti-bacterial effects on the epithelial lining of the gut. This is thought to be due to the phenolic compounds, extracellular metabolites, and antibacterial properties of Spirulina that are released after digestion. The prebiotic effect of Spirulina on the gut microbiota is thought to be increased due to the fiber content. In this study, Spirulina was determined to be digestible by measuring free amino acid and peptide release at each stage of digestion in a model of a static digestive system. The hypothesis that poor gut health can lead to low level inflammation and metabolic syndrome and that nutritional supplementation such as Spirulina can help address these issues in the long term can be beneficial in reducing comorbid illnesses associated with the current coronavirus disease pandemic.

Keywords: Algal proteins, amino acids, antioxidants, Arthrospira platensis, bioactive, chronic disease, digestion, gut health, immune system, metabolic syndrome, microbiome, peptides, spirulina

INTRODUCTION

The term “nutraceutical” is a reference to its nutraceutical and supportive function. Nutraceuticals are becoming more popular around the world as chronic diseases become more common and people become more aware of their health. Consumer demand for nutritional supplements is on the rise. The current COVID-19 pandemic has caused a surge in consumer demand for nutraceutical and dietary supplements. In 2020, the U.S. market for nutraceutical products and dietary supplements grew by $345 million year-on-year [1]. Similar trends can be seen in other countries around the world, including India and China, as well as New Zealand and France.

***Author for Correspondence**
Bhushan G. Rajput
E-mail: bhushanrajput2001@gmail.com

[1-4]Student, Department of Ethnopharmacognosy, Ahinsa Institute of Pharmacy, Dondaicha, Maharashtra, India
[5]Professor, Department of Ethnopharmacognosy, Ahinsa Institute of Pharmacy, Dondaicha, Maharashtra, India

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PURPOSE

An examination of the scientific and clinical research regarding the overall health advantages of Spirulina, particularly its impact on gut health, immune system modulation, and antiviral properties, in relation to its nutritional content and antioxidant characteristics. Furthermore, a static in vitro digestive model was used to assess the digestibility of spirulina. The exceptional digestibility and bioavailability of the beneficial

nutrients in Spirulina could account for its numerous favorable physiological outcomes.

BACKGROUND ON SPIRULINA

Spirulina, also known as blue-green algae, is a member of the Cyanobacteria family and is recognized for its abundant nutrients that offer various health benefits [2, 3]. Recent reports indicate a significant growth in the global Spirulina market, with its size increasing from $393.6 million in 2019 to an estimated $897.61 million by 2027 [4]. Consequently, the production of Spirulina has become a crucial industry worldwide. Due to its dense nutrient content, Spirulina has gained the reputation of being a superfood [5-7]. It is a plant-based protein that is enriched with phytopigments such as carotenoids, chlorophyll, and phycocyanin. Moreover, it is considered safe for consumption [8, 9]. The use of phycocyanin, a pigment protein obtained from spirulina, as a natural blue colorant addition in food has grown in favor. It also holds medicinal value due to its proven pharmacological actions in numerous preclinical studies. Spirulina primarily consists of proteins, essential amino acids, fatty acids, vitamins (including 302,000 IU/100 g of Vitamin A as carotenes and 26 mg/100 g of Vitamin B complex), and minerals (3.67 g/100 g) [10, 11]. Its antioxidant properties can be attributed to the presence of phenolics, tocopherols, β-carotenes (0.29 g/100 g), chlorophyll a (1 g/100 g), gamma linolenic acid (1.1 g/100 g), polysaccharides (4.6 g/100 g), and crude phycocyanin (14 g/100 g) [12].

General Health Benefits

Spirulina has been shown to have multiple benefits in illnesses like dyslipidemia, diabetes, hypertension, immunological function, inflammation, and viral infections, according to a 2018 comprehensive review by de la Jara et al [13]. The studies analyzed in this review were categorized based on the clinical outcomes and the dosage administered, which ranged from 2 to 20 g/day. This classification allows readers to interpret the data on an individual basis. Spirulina's high protein, polysaccharide, and carotenoid content are responsible for its efficiency in controlling diabetes and dyslipidemia, according to a similar meta-analysis carried out in 2019 by Hamedifard et al [14]. Spirulina's high protein content stimulates the pancreatic beta cells to generate insulin and lowers interleukin (IL)-6 levels, which are particularly high in abdominal obesity and contribute to insulin resistance. Additionally, it's thought that spirulina's fiber content may improve cholesterol esterification by lecithin-cholesterol acyltransferase, decrease the absorption of fat and glucose in the small intestine, and raise high-density lipoprotein cholesterol levels. Spirulina enhances insulin sensitivity, metabolic syndrome, and cholesterol homeostasis via a number of different pathways, to name a few. The body's immune system, gastrointestinal health, and antiviral functions may be impacted by these metabolic alterations in addition to the physiological effects of spirulina.

GUT HEALTH

The term "gut health" may not have a precise definition in the field of medicine, but various studies have highlighted the molecular connections between optimal gastrointestinal function and overall well-being. Research involving animals and some human subjects has underscored the significance of food digestion and the utilization of digested nutrients by the gut microbiota and local immune system, which in turn regulate both local and systemic inflammation [15]. Therefore, the key factor in determining a healthy gastrointestinal system begins with the process of digesting and absorbing nutrients, ultimately contributing to a state of holistic well-being. In a comprehensive review authored by Ercolini and Fogliano [16], it was noted that food which is only partially digested and has limited bioavailability for absorption in the small intestine is utilized by the gut microbiota in the large intestine, thereby supporting microbial diversity. On the other hand, readily absorbed nutrients with a high bioavailability that come from Western diets are mostly used as energy sources and do not support colonic fermentation or act as a microbiota food supply. The impact on gut microbiota can result in gut dysbiosis, low-level inflammation, nonalcoholic steatohepatitis/nonalcoholic fatty liver disease, and metaflammation, given the rise in diseases linked to dietary changes and the early adoption of Western lifestyles. To address the growing concerns surrounding lifestyle-related diseases, it is imperative to develop food components and nutraceuticals that not only provide essential nutrients to the host but also support the gut microbiota, thereby enhancing the body's ability

to combat oxidative stress resulting from infections or inflammation. Spirulina microalgae, known for its high protein content, has been suggested to play a crucial role in promoting gut health. Research encompassing in vitro, animal, and human studies has explored the mechanisms of action and the impact of Spirulina on increasing gut microbial divers [17].

IMMUNE –MODULATING EFFECTS

Several studies have shown that Spirulina has immunostimulatory and immunomodulatory properties, inhibiting the release of cytokines such as IL-4, IgE, leukotrienes, prostaglandins, and chemoattractants triggered by allergens. A study conducted on rats revealed that [18].

HISTORY

Spirulina platensis is a type of multicellular and filamentous cyanobacteria that is rich in carbonate and bicarbonate. It thrives in water, making it easy to harvest and process, and is packed with a high concentration of micronutrients and macronutrients. This species can be found in various regions such as Lake Texcoco in Mexico, around Lake Chad in Africa, Asia, and South America, while Spirulina platensis Maxima is specifically located in Central America. Arthrospira platensis is its scientific name, and it's one of the earliest known species on Earth. In recent years, significant investments have been made by both the government and private sector to develop this blue-green algae for biodiesel extraction, as it is 20 times more productive In 1940, a French scientist made the discovery of harvesting Spirulina platensis near the shallow Lake Chad in Africa are shown in Figure 1. But Spirulina platensis was not well known as a food source at that time. It would be several years before the health benefits of Spirulina were rediscovered. By 1967, Spirulina platensis was officially recognized as the "Ultimate source of food" by the International Association of Applied Microbiology. Upon analyzing its nutritional properties, it was found that Spirulina platensis contained a high amount of protein. This discovery led to the initiation of research projects aimed at producing protein in a cost-effective manner. Microorganisms such as bacteria, yeast, and Spirulina platensis were identified as the direct means for producing single-cell protein. However, over time, it became apparent that no single microorganism could produce a sufficient amount of protein. Spirulina platensis emerged as a reliable source of protein, serving as a dietary supplement for humans, animals, and aquatic life.

Composition of Microalgae from SPIRULINA

Microalgae, particularly those belonging to the Spirulina genus, possess a fascinating nutritional profile. They contain essential macronutrients like carbohydrates, lipids, proteins, vitamins, and minerals, all of which are crucial for human nutrition. In addition to these macronutrients, Spirulina also contains various bioactive compounds with biological functions. The primary bioactive compounds found in cyanobacteria, including Spirulina, consist of unsaturated fatty acids, amino acids, carotenoids, and phenolic compounds. These compounds exhibit diverse biological activities, such as antioxidant properties, anticarcinogenic effects, and neuroprotective function [19].

Figure 1. Harvesting Spirulina platensis near the shallow Lake Chad in Africa.

Macronutrients

The three types of fatty acids that make up the lipid profile are polyunsaturated (PUFA), monounsaturated (MUFA), and saturated fatty acids (SFA). As a result, the fatty acids found in Spirulina, particularly the polyunsaturated fatty acids, have the potential to be utilized in specialized diets for individuals with lipid metabolism disorders (Li et al., 2019) [20]. Additionally, Spirulina contains all nine essential amino acids and other amino acids that contribute to the formation of proteins in this microalgae. This food source provides essential amino acids like tryptophan, threonine, leucine, lysine, methionine, phenylalanine, histidine, and valine, which are not naturally produced by the human body. Therefore, Spirulina can be considered as a valuable source of both essential and non-essential amino acids, offering the potential to enhance the nutritional value of low-protein foods [21].

CONCLUSION

The increasing interest in healthy foods is driving research focused on discovering functional foods. This review highlights the potential of Spirulina, a microalga with a rich nutritional and phytochemical composition, for the development of functional products. Among the various species of Spirulina, our research indicates that S. platensis and S. maxima are the most extensively studied and applied, primarily due to their high productivity. S. platensis, in particular, has received more attention in published studies. Spirulina exhibits a promising composition, including carotenoids, phenolic compounds, phycocyanin, and chlorophylls. It is commonly used as a nutritional supplement in the form of powder, flakes, or capsules, and has also been incorporated into easily accepted food products such as cookies, pasta, sauces, ice cream, and snacks [22]. However, incorporating Spirulina into food formulations poses challenges due to its taste, odor, and the need to ensure an appealing color for sensory acceptance. Furthermore, new techniques for nutrient and phytochemical protection are necessary to preserve Spirulina's important biological properties. Further study is still needed to get beyond these obstacles, even with the growing number of publications on Spirulina [23]. For example, exploring microencapsulation as a solution and utilizing Spirulina biomass as a valuable ingredient in different formulations hold potential. The studies reviewed in this article demonstrate that Spirulina exhibits various biological activities, including immunostimulant, antioxidant, antitumor, neuroprotective, anti-inflammatory, hypoglycemic, and probiotic effects. These properties make Spirulina a potential additive in the formulation of products in the medical, chemical, cosmetic, and pharmaceutical industries. Therefore, the synthesis of literature on the effects of Spirulina spp. confirms that this microalga is an excellent ally for human health and can be incorporated into various applications [24].

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