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A detailed analysis of Spirulina's therapeutic properties in liver protection, oxidative stress reduction, and cancer management

Zahraa Salam Al-Tameemi[1,2], Hany A. Al-Hussaniy[1*], Ali Mahmoud Al-Samydai[3], Meena Akeel Naji[2], Fuaad I. Iraqi[2], Fatima A Naji[2]

[1] Department of Pharmacy, Al-Nisour University College, Baghdad, Iraq
[2] Dr. Hany Akeel Institute, Iraqi Medical Research Center, Baghdad, Iraq
[3] Pharmacological and Diagnostic Research Centre, Faculty of Pharmacy, Al-Ahliyya Amman University, Amman, Jordan

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ABSTRACT

Spirulina, a cyanobacterium recognized for its nutritional benefits, has recently garnered attention for its potential therapeutic properties. This review aims to comprehensively consolidate current knowledge on the pharmacological attributes of *Spirulina* species, focusing on their hepatoprotective, antioxidant and anticancer effects. An exhaustive literature search was conducted, collating data from empirical studies, clinical trials and reviews pertaining to the pharmacological effects of Spirulina.

Spirulina exhibits significant hepatoprotective activities, evidenced by its ability to mitigate toxin-induced liver damage, primarily attributed to its rich antioxidant components (among others, phycocyanin, beta-carotene and tocopherol). These constituents counteract oxidative stress, making Spirulina a potent antioxidant agent. Additionally, numerous studies have pinpointed the anticancer potential of Spirulina. It impedes tumor growth and proliferation through various mechanisms, including the modulation of cell cycle, induction of apoptosis and inhibition of angiogenesis.

Spirulina offers a trifecta of pharmacological benefits: hepatoprotection, antioxidant activity and anticancer properties. These findings underscore the need for further research and clinical trials to validate the therapeutic applications of Spirulina in modern medicine.

INTRODUCTION

The quest for natural remedies has been a perpetual endeavor, tracing back to ancient civilizations where plants, algae and microorganisms were deemed sources of holistic medicine [1]. One such natural wonder, gaining momentum in both the scientific and wellness communities, is Spirulina. Recognized primarily as a dietary supplement, Spirulina has transcended its initial reputation to be acknowledged for its myriad of pharmacological properties [2,3].

Spirulina, a blue-green microalga, belongs to the Cyanobacteria group. Historically, it has been consumed by ancient civilizations in Africa and America for its high protein content and nutritional value. Fast forward to the 21st century, Spirulina's prominence is not solely anchored on its nutritive benefits. Scientists and researchers are delving deep into its biochemical composition, discerning properties that could potentially catapult Spirulina into the forefront of therapeutic agents [4].

* **Corresponding author**
e-mail: hani.oqil1106b@comed.uobaghdad.edu.iq

Hepatoprotection, one of the most celebrated properties of Spirulina, comes as a ray of hope in the realm of liver diseases. The liver, an organ subjected to a plethora of toxins, undergoes oxidative stress, often leading to conditions like hepatitis, fatty liver disease and cirrhosis. The contemporary lifestyle, punctuated with processed food, alcohol and environmental pollutants, only amplifies the liver's vulnerability. Herein lies the relevance of Spirulina. Its hepatoprotective qualities, as initial studies suggest, can mitigate toxin-induced liver damages, offering a natural safeguarding mechanism against hepatotoxins [5,6].

Yet, the marvel of Spirulina does not end with hepatoprotection. As the world grapples with the increasing prevalence of chronic diseases, the need for potent antioxidants is more pressing than ever. Oxidative stress, resulting from an imbalance between free radicals and the body's ability to counteract their harmful effects, is a precursor to various maladies, including cardiovascular diseases, neurodegenerative diseases and even cancer. Spirulina's rich reservoir of antioxidants, including phycocyanin, beta-carotene and

tocopherol, makes it a formidable opponent to oxidative stress. These components not only neutralize free radicals but also enhance the body's innate antioxidant defenses [7].

The domain of oncology is another sphere where Spirulina's potential is being earnestly explored [8]. The global burden of cancer, both in terms of mortality and morbidity, underscores the need for novel anticancer agents. Spirulina, with its bioactive compounds, has demonstrated anticancer potential in preliminary studies. By modulating cell cycles, inducing apoptosis in malignant cells and inhibiting the formation of new blood vessels in tumors (angiogenesis), Spirulina exhibits multifaceted anticancer activities [9,10].

As researchers continue to unravel the mysteries of this blue-green alga, it becomes paramount to understand its origins, properties and the potential it holds for the future of medicine.

MATERIALS AND METHODS

Literature search

Comprehensive literature searches were conducted using electronic databases including PubMed, Scopus, Web of Science and Google Scholar.

The search was restricted to articles published in English from January 1990 to December 2022.

Search strategy

Keywords used in the search strategy included “Spirulina”, “hepatoprotective effects”, “antioxidant activity”, “anticancer properties”, “bioactive compounds” and “pharmacological properties”.

Boolean operators (AND, OR) were used to refine the search. For example, “Spirulina AND hepatoprotective effects”.

Inclusion and exclusion criteria

Inclusion criteria

Original research articles, reviews, and clinical trials reporting on the pharmacological properties of Spirulina.

Studies that provided detailed methodologies and conclusive results.

Exclusion criteria

Articles not published in peer-reviewed journals.

Studies that did not focus specifically on the pharmacological properties of Spirulina.

Duplicate studies or those with overlapping datasets.

Data extraction

Relevant information was extracted from each selected study, including the authors, year of publication, study design, sample size, methodologies used, key findings and conclusions.

Quality assessment

The quality of each selected article was assessed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

Studies that did not meet the minimum quality requirements were excluded from the review.

Data synthesis

Extracted data were systematically synthesized and categorized based on the specific pharmacological property (hepatoprotective, antioxidant, anticancer) being discussed.

RESULTS

Our comprehensive review of the literature on the pharmacological properties of Spirulina species yielded a significant number of studies highlighting its hepatoprotective, antioxidant and anticancer effects.

Hepatoprotective effects of Spirulina

Multiple studies have assessed the hepatoprotective potential of Spirulina. One recurrent observation was the ability of Spirulina to attenuate liver damage in subjects exposed to hepatotoxic agents. A study in 2021 by Mahmmod *et al*. reported that rats pre-treated with Spirulina showed reduced levels of serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) after exposure to carbon tetrachloride (CCl4), a known hepatotoxin. Another study in 2003 by Ahmed *et al*. found similar hepatoprotective effects against alcohol-induced liver toxicity in mice. These findings suggest that Spirulina can mitigate liver damage induced by various toxic agents [11].

Antioxidant activity of Spirulina

The antioxidant properties of Spirulina have been well-documented. Studies consistently report that Spirulina is rich in phycocyanin, beta-carotene and other compounds that possess strong free radical scavenging properties. Indeed, in a study conducted by Kuhad *et al*. in 2006, Spirulina was found to increase superoxide dismutase (SOD) and catalase activity in rats, suggesting enhanced antioxidant defenses. Another key study by Gargouri *et al*. in 2011 emphasized that the daily administration of Spirulina to human participants led to a significant reduction in malondialdehyde, a marker of oxidative stress [12,13].

Anticancer properties of Spirulina

Spirulina's anticancer potential has sparked significant research interest. Several *in vitro* and *in vivo* studies have shown that Spirulina extracts and its active constituents can inhibit the growth of various cancer cell lines [14]. A groundbreaking study by Li *et al.* demonstrated that Spirulina extracts induced apoptosis in breast cancer cells, thereby reducing their proliferation. Another remarkable study in 2021 by Mahmoud *et al*. showcased Spirulina's potential to suppress tumor growth in a murine model of colorectal cancer [15,16].

Further analysis of the selected studies revealed some common mechanisms through which Spirulina exerts its pharmacological effects:

1. Modulation of Inflammatory Pathways: Several studies reported that Spirulina can modulate key inflammatory pathways, such as the NF-κB pathway, thereby reducing inflammation [17].

2. Enhancement of the Immune Response: A few studies highlighted that Spirulina supplementation could enhance the activity of natural killer cells and macrophages, suggesting a boost in immune response [18-20].
3. Reduction of DNA Damage: Some studies reported that Spirulina possesses the ability to reduce DNA damage, a significant factor in preventing carcinogenesis [21-23].

The pharmacological versatility of Spirulina is further highlighted when compared with other natural compounds exhibiting antioxidant and anticancer activities. For instance, the work by Haleem *et al*. (2024) on Ganoderma lucidum extracts demonstrated similar anti-tumor and antioxidant properties *in vitro*, reinforcing the potential of bioactive natural products in managing cancer and oxidative stress-related conditions [24]. Additionally, the integration of Spirulina or its active constituents into novel delivery systems, such as nanoemulsions, could enhance its therapeutic efficacy and bioavailability, as discussed by Al-Hussaniy *et al*. (2023) in the context of poorly soluble drugs [25]. While Spirulina itself is a rich source of secondary metabolites, the research by Al-Tameemi and Hamad (2022) on the isolation of novel secondary metabolites from Eucalyptus camaldulensis supports the ongoing exploration of plant-derived compounds with pharmacological relevance [26]. These comparative insights underscore Spirulina's unique position among natural agents with hepatoprotective, antioxidant, and anticancer potentials.

CONCLUSION

Spirulina species have long been recognized for their nutritional value and health-promoting properties. As elucidated in this review, the overwhelming evidence underscores the multifaceted pharmacological benefits of Spirulina, with a distinct emphasis on its hepatoprotective, antioxidant and anticancer attributes.

The hepatoprotective capability of Spirulina has potential therapeutic implications for individuals exposed to hepatotoxins or those suffering from chronic liver ailments. Meanwhile, the robust antioxidant properties are indicative of its potential to counteract oxidative stress, which is implicated in numerous degenerative diseases. Additionally, the emerging evidence supporting the anticancer properties of Spirulina presents a promising avenue for further research, especially considering the global burden of cancer and the continuous search for effective and safe anticancer agents.

Despite these encouraging findings, it is imperative to approach the data with a balanced perspective. The discrepancies among various studies, the differences in methodologies and the diverse populations studied emphasize the need for more comprehensive, large-scale and standardized research. Only then can the full therapeutic potential of Spirulina be mapped out and harnessed for clinical applications.

Furthermore, while the *in vitro* and *in vivo* studies provide essential insights, clinical trials in humans will be the gold standard to evaluate the safety, efficacy and optimal dosages of Spirulina-based interventions.

In summation, Spirulina stands as a remarkable natural agent with a spectrum of pharmacological properties that can benefit human health. However, for its transition from a health supplement to a therapeutic agent, rigorous scientific validation and comprehensive clinical evaluations are essential. The journey of Spirulina, from ancient food to potential modern medicine, is a testament to Nature's bounty and the ongoing efforts of the scientific community to unravel its mysteries.

Limitations and discrepancies

While most studies reported positive effects of Spirulina, there were discrepancies in the results. For instance, the extent of hepatoprotection varied across studies, with some showing only marginal benefits. Similarly, while some studies touted the anticancer potential of Spirulina, others suggested the need for higher doses to achieve significant anticancer effects.

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CONFLICT OF INTEREST

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ORCID iDs

Zahraa Salam Al-Tameemi https://orcid.org/0000-0002-0365-745X
Hany A. Al-Hussaniy https://orcid.org/0000-0003-2647-8574
Ali Mahmoud Al-Samydai https://orcid.org/0000-0003-0093-2310
Meena Akeel Naji https://orcid.org/0009-0000-6823-2471
Fuaad I. Iraqi https://orcid.org/0000-0001-5525-206X
Fatima A Naji https://orcid.org/0000-0002-7414-3376

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