MULTIFUNCTIONAL PROPERTIES OF *SPIRULINA* (*ARTHROSPIRA PLATENSIS*): A REVIEW ON ITS ANTIMICROBIAL AND HYPOLIPIDEMIC POTENTIAL

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Abstract

Spirulina (*Arthrospira platensis*), a filamentous cyanobacterium, has gained significant attention as a functional food and nutraceutical due to its dense nutritional profile and diverse bioactivities. This review critically explores the antimicrobial and hypolipidemic properties of *Spirulina*, emphasizing its relevance in therapeutic and preventive health applications. Taxonomically distinct from the genus *Spirulina*, *Arthrospira platensis* dominates commercial products, accounting for 81.2–100% of cyanobacterial content in marketed supplements. It exhibits broad-spectrum antibacterial and antifungal activities, particularly against Gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus subtilis*, and fungal pathogens like *Candida albicans*. Solvent-specific extracts, especially methanol-based, demonstrate higher bioactivity, attributed in part to volatile compounds like heptadecane and tetradecane. The purified compound ($C_{15}H_{18}NO_8$) further highlights *Spirulina*'s antimicrobial efficacy. In the hypolipidemic context, *Spirulina* supplementation has shown promising results in lowering serum lipids across human and animal studies. Mechanistically, it promotes fecal excretion of bile acids and cholesterol, possibly through inhibition of intestinal absorption. However, the

precise active components remain unidentified, pointing to the need for further molecular and mechanistic investigations. Overall, *Spirulina* emerges as a promising candidate for integrative health strategies targeting microbial infections and lipid metabolism disorders.

Keywords

Spirulina; *Arthrospira platensis*; Antimicrobial activity; Hypolipidemic effect; Functional foods; Nutraceuticals; Bioactive compounds; Cyanobacteria

1. Introduction

Spirulina, scientifically known as *Arthrospira platensis*, is a filamentous, multicellular cyanobacterium that thrives in alkaline and saline aquatic environments. It is well known for its high protein content, essential amino acids, polyunsaturated fatty acids, pigments (such as phycocyanin and chlorophyll), vitamins, and minerals, which collectively contribute to its exceptional nutritional profile and wide-ranging health benefits [68].

Traditionally consumed in parts of Africa and Central America, *Spirulina* has now gained global recognition as a leading natural supplement. Its applications have expanded beyond nutritional uses into functional foods and nutraceuticals, supported by increasing evidence of its bioactive properties including antioxidant, anti-inflammatory, immunomodulatory, and detoxifying effects [68]. Recent studies have reported that in the majority of commercial *Spirulina* food supplements, *Arthrospira platensis* was the predominant taxon, constituting 81.2–100% of cyanobacterial content [68]. This dominance underlines its rising use as a functional ingredient across food and pharmaceutical industries.

Beyond nutrition, *Spirulina platensis* is being actively investigated for its therapeutic potential, particularly in relation to antimicrobial and hypolipidemic properties. Several in vitro studies have demonstrated its ability to inhibit the growth of both Gram-positive and Gram-negative pathogens [69–73], as well as fungi such as *Candida albicans* [70,71]. Moreover, recent developments have explored the integration of *Spirulina*-derived compounds into bio-functionalized nanoparticles with antibacterial effects, offering new directions for medical applications [72,74].

In parallel, *Spirulina* has shown significant potential in modulating lipid metabolism. Preclinical and clinical studies suggest that it may lower serum cholesterol levels, possibly through the binding of bile acids, reduction of cholesterol solubility, and enhancement of fecal

cholesterol excretion [75]. Despite growing evidence of its lipid-lowering effect, the precise bioactive compounds and mechanisms responsible remain largely uncharacterized.

The objective of this review is to present a comprehensive overview of the antimicrobial and hypolipidemic activities of *Spirulina platensis*, drawing on recent literature to explore the underlying bioactive constituents and potential mechanisms. The review aims to support the continued exploration and application of *Spirulina*-based formulations in managing microbial infections and metabolic disorders.

2. Taxonomy and Prevalence in Commercial Supplements

Arthrospira platensis, commonly referred to as *Spirulina*, belongs to the domain Bacteria, phylum Cyanobacteria, class Cyanophyceae, order Oscillatoriales, and family Oscillatoriaceae. Although historically grouped under the genus *Spirulina*, taxonomic revisions based on ultrastructural and molecular data have distinguished *Arthrospira* as a separate genus. Unlike true *Spirulina*, which is helical and non-motile, *Arthrospira* displays a loosely coiled, filamentous morphology and active gliding motility, confirming its independent taxonomic status.

In the context of commercial production, *Arthrospira platensis* has emerged as the predominant species in nearly all *Spirulina*-labeled food supplements. A comprehensive evaluation of cyanobacterial content in various commercial *Spirulina* products revealed that *Arthrospira platensis* accounted for 81.2–100% of the total cyanobacterial population, indicating its taxonomic and functional dominance in the nutraceutical market [68].

This prevalence underscores its industrial relevance, owing to its adaptability to mass culture, high biomass yield, and stable nutritional profile. Furthermore, the species' ability to produce bioactive compounds with antimicrobial, antioxidant, and immunomodulatory effects has contributed to its growing presence in functional food formulations.

3. Microbial Modulating Activities of Spirulina

3.1 Antibacterial Spectrum

Spirulina (*Arthrospira platensis*) has demonstrated broad-spectrum antibacterial activity, particularly against Gram-positive bacteria such as *Staphylococcus aureus*, *Bacillus subtilis*, *Bacillus cumulans*, and *Staphylococcus epidermidis* [69,72]. Among Gram-negative species, significant inhibitory effects have been observed against *Escherichia coli* and *Proteus*

vulgaris, while moderate to low efficacy has been reported against *Pseudomonas aeruginosa* [69,72].

3.2 Antifungal Potential

In addition to antibacterial activity, *Spirulina* exhibits antifungal effects, most notably against the pathogenic yeast *Candida albicans*. The methanolic extract of *Spirulina* was particularly effective, demonstrating strong growth inhibition [71].

3.3 Extract-Specific Activity

Antimicrobial efficacy of *Spirulina* varies significantly depending on the extraction solvent. Among tested solvents, **methanol extract** showed the **highest antimicrobial activity**, outperforming hexane [70], dichloromethane [69,70], petroleum ether [71], and ethyl acetate [71,72]. Volatile components such as **heptadecane** and **tetradecane**, though bioactive, demonstrated relatively lower antimicrobial potential [71].

3.4 MIC and Selectivity

The minimum inhibitory concentrations (MICs) of various extracts confirm selective antimicrobial action. Strong inhibition was recorded against *Candida albicans* (MIC = 30 µg/ml) and *Bacillus subtilis* (MIC = 60 µg/ml) [70]. Conversely, extracts showed minimal or no inhibitory effect (MIC ≥ 512 µg/ml) against *Pseudomonas aeruginosa*, *Salmonella typhimurium*, and *Klebsiella pneumoniae* [72].

3.5 Purified Bioactive Compounds

El-Sheekh et al. [70] successfully purified an antimicrobial compound from *Spirulina* with the molecular formula $C_{15}H_{18}NO_8$. The compound was yellowish-green, had no characteristic odor, and exhibited solubility in methanol, diethyl ether, chloroform, and dimethyl sulfoxide, while being only sparingly soluble in water and acetone. This compound exhibited notable activity particularly against *C. albicans*, *B. subtilis*, and *P. aeruginosa*.

3.6 Role in Nanotechnology

Recent studies have explored the application of *Spirulina* in green synthesis of gold nanoparticles (AuNPs). These biofunctionalized nanoparticles showed enhanced antimicrobial activity, particularly against Gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus subtilis* [72].

3.7 Therapeutic Implications

Given its potent antimicrobial profile, especially against Gram-positive organisms, *Spirulina*-derived extracts and nanoparticles present a promising frontier in the **diagnosis and** treatment of infectious diseases [74]. Its selectivity and compound-specific activity offer avenues for developing targeted therapeutics in medical microbiology and pharmaceutical biotechnology.

4. Hypolipidemic Activity of Spirulina

4.1 Evidence from Clinical and Preclinical Studies

The hypolipidemic potential of *Spirulina* (*Arthrospira platensis*) has been extensively investigated in both clinical and preclinical models, revealing consistent lipid-lowering effects. Several human intervention studies have demonstrated significant reductions in total cholesterol, LDL-C (low-density lipoprotein cholesterol), and triglycerides, along with increases in HDL-C (high-density lipoprotein cholesterol) following *Spirulina* supplementation [69,74]. Similar findings have been reported in rodent models, where *Spirulina* administration resulted in amelioration of hyperlipidemia and protection against cardiovascular risks associated with high-fat diets [74].

4.2 Mechanistic Insights

Proposed mechanisms underlying these effects include the binding of *Spirulina*-derived compounds to bile acids and cholesterol metabolites, thereby interrupting their enterohepatic recirculation [74]. This leads to a notable increase in fecal excretion of bile acids and cholesterol, as shown in both animal and in vitro studies. Consequently, the liver utilizes more cholesterol to synthesize new bile acids, effectively lowering serum cholesterol levels. Additionally, the inhibition of intestinal cholesterol absorption has been suggested as a contributing mechanism [74].

4.3 Gaps in Knowledge

Despite promising results, current understanding of the specific bioactive constituents responsible for these effects remains limited. While pigments (such as phycocyanin) and peptides have been proposed, isolation and characterization of the active hypolipidemic agents is lacking [69,74]. Moreover, mechanistic and molecular-level studies are sparse, underscoring the need for focused research to unravel the pathways and receptors involved in *Spirulina*'s

hypolipidemic action. Elucidating these mechanisms could support targeted nutraceutical development and precision dietary interventions for lipid disorders.

Conclusion

Spirulina (*Arthrospira platensis*) stands as a compelling example of a multifunctional cyanobacterium with profound antimicrobial and hypolipidemic potential. Its dominance in commercial supplements and robust bioactivity across different biological systems underscore its significance as a nutraceutical agent. The wide antibacterial and antifungal spectrum, along with the lipid-lowering effects observed in both preclinical and clinical settings, support its utility in dietary and therapeutic applications. Nonetheless, the exact bioactive components and underlying molecular mechanisms responsible for these effects remain poorly defined. Future research must aim at the identification, isolation, and characterization of these functional compounds, along with rigorous clinical validation to establish safety, efficacy, and dosage standards. Such insights will enhance the formulation of targeted *Spirulina*-based interventions for infectious and metabolic diseases.

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