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# "*Spirulina platensis* (Cyanophycean Algae): A Sustainable Superfood with Nutritional, Medicinal and Therapeutic Applications"

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## Abstract

Spirulina is a filamentous blue-green alga belonging to the class Cyanophyceae and is widely recognised as a sustainable superfood due to its exceptional nutritional and therapeutic value. It contains high protein content (60–70%), essential amino acids, vitamins (B-complex, vitamin E), minerals (iron, calcium, magnesium), essential fatty acids, and natural pigments such as phycocyanin and carotenoids. Due to its rich biochemical composition, Spirulina has gained significant importance in nutrition, medicine, pharmaceuticals, and biotechnology. Spirulina plays a vital role in improving immune function by stimulating the production of antibodies and white blood cells. It also contributes to cardiovascular health by lowering LDL cholesterol, triglycerides, and blood pressure while increasing HDL cholesterol levels. The presence of phycocyanin provides strong antioxidant and anti-inflammatory properties, which help in reducing oxidative stress and inflammation. Recent studies suggest that Spirulina may help in managing type 2 diabetes by regulating blood glucose levels and improving insulin sensitivity. It is also used in malnutrition management, anemia treatment due to high iron content, and in enhancing athletic performance by reducing muscle fatigue and damage. In addition, Spirulina is environmentally sustainable because it requires less land, water, and resources compared to conventional crops, and it also contributes to carbon dioxide fixation. Therefore, Spirulina can be considered an important nutraceutical and therapeutic agent for future food security and health management.

**Keywords:** Spirulina, Cyanophycean algae, Nutraceutical, Phycocyanin, Antioxidant, Immunity, Sustainable superfood, Therapeutic applications, Malnutrition, Diabetes management

# 1. Introduction

*Spirulina platensis*, commonly known as Arthrospira platensis, is a filamentous, planktonic, photosynthetic cyanobacterium from the Oscillatoriaceae family and the Cyanophyceae class. It is often found in tropical and subtropical alkaline lakes with high pH and salinity. Spirulina, an ancient oxygenic photosynthetic prokaryote, has attracted global interest for its great nutritional value and medicinal potential (Ai et al., 2023; Al-Hussaniy, 2023; Ramírez-Rodrigues et al., 2021).

Spirulina contains proteins (up to 60-70% dry weight), essential amino acids, polyunsaturated fatty acids, vitamins (B-complex, vitamin E), minerals (iron, calcium, magnesium), and bioactive substances such phycocyanin, carotenoids, and polysaccharides (Calella et al., 2022). Spirulina's biochemical makeup makes it a popular dietary supplement and a sustainable protein source with great digestion and nutritional value (Ramírez-Rodrigues et al., 2021). Spirulina has numerous pharmacological properties, including antioxidant, anti-inflammatory, immunomodulatory, antiviral, anticancer, antidiabetic, and lipid-lowering effects (Citi et al., 2024; Prete et al., 2024; Rahma et al., 2025; Spínola et al., 2024). Spirulina's qualities make it a potential natural product for the prevention and treatment of chronic illnesses and metabolic disorders.

Spirulina has been used as a food source since the 16th century, and it is currently widely grown and used in food, feed, nutraceuticals, medicines, and cosmetics (Gabr et al., 2020; Prabha et al., 2022). Spirulina supplementation has been shown to improve immune response, reduce lipid peroxidation, improve growth performance, and have antimicrobial properties against several pathogenic bacteria and fungi, including Candida and Aspergillus species (Abdel-Moneim et al., 2022; Metekia& Ulusoy, 2023; Ghamry et al., 2023).

Despite extensive research on Spirulina, challenges remain, including the need for standardised products, detailed dose-response studies, bioavailability analysis of bioactive compounds, and more randomised clinical trials to confirm its therapeutic efficacy (Fellyp Avelino Diniz et al., 2023; Spínola et al., 2024). Recent studies have also focused on Spirulina in functional meals, nanotechnology-based medicine delivery, gut microbiome regulation, and sustainable food production systems (Chang & Liu, 2024). As a result, Spirulina has become an important functional food, nutraceutical, and therapeutic agent in current biomedical and biotechnological research.The primary goal of this study is to conduct a full analysis of Spirulina platensis' nutritional content, bioactive chemicals, and pharmacological activity, as well as to assess its potential as a sustainable superfood in human health and illness management. This review will summarise recent studies on Spirulina's antioxidant, anti-inflammatory, immunomodulatory, antibacterial, anticancer, antidiabetic, and lipid-lowering characteristics, as well as the mechanisms of action.

The review will also look at Spirulina's uses in functional meals, nutraceuticals, medicines, and cosmetics. Furthermore, this review focuses on new and emerging research fields such as Spirulina in gut microbiota modification, nano-formulations for drug administration, bioavailability of Spirulina bioactive chemicals, and its potential as an alternative protein source for sustainable nutrition.

Furthermore, the study intends to highlight existing research needs, such as the need for Spirulina product standardisation, clinical trials to determine therapeutic dose, and in-depth investigations on the structure-activity connections of Spirulina bioactive chemicals. Finally, this study suggests future research avenues for the development of Spirulina-based functional foods and therapeutics.To review and summarise the nutritional, medicinal, and therapeutic importance of Spirulina and to evaluate its role as a sustainable superfood for human health and disease management.

## 2. Nutritional Composition of *Spirulina platensis*

*Spirulina platensis* is a filamentous, photosynthetic cyanobacterium widely used as a dietary supplement due to its exceptional nutritional composition and therapeutic importance. It is considered a functional food and nutraceutical because it contains high-quality proteins, carbohydrates, essential fatty acids, vitamins, minerals, pigments, and bioactive compounds that contribute to human health. Due to its high nutrient content and ease of digestion, Spirulina has been recommended by several health organisations as a supplementary food to combat malnutrition and improve overall health (Calella et al., 2022; Gabr et al., 2020).

**Protein:** Protein is the major component of Spirulina, comprising approximately 60–70% of its dry weight, significantly higher than in many conventional protein sources, such as soybean (35%), eggs (13%), and milk (3.5%). Spirulina protein contains all essential amino acids, including leucine, isoleucine, valine, lysine, methionine, threonine, phenylalanine, and tryptophan, making it a complete protein source. Additionally, Spirulina protein is highly digestible because it lacks a cellulose cell wall, allowing easy absorption in the human body. Protein is essential for muscle development, tissue repair, enzyme and hormone synthesis, and immune system regulation. Because of this high protein content, Spirulina is used in the treatment of protein-energy malnutrition and is considered an alternative protein source for vegetarians and vegans (Ramírez-Rodrigues et al., 2021; Calella et al., 2022).

**Carbohydrates:** Spirulina contains about 15–20% carbohydrates, mainly in the form of polysaccharides such as rhamnose, glucose, mannose, and glycogen. These carbohydrates serve as an energy source and help maintain metabolic activities. Spirulina polysaccharides also play a role in improving gut health by promoting beneficial gut bacteria and enhancing immune response. Some Spirulina polysaccharides have been reported to exhibit immunomodulatory and antiviral properties (Gentscheva et al., 2023).

**Lipids and Essential Fatty Acids:** Spirulina contains approximately 5–7% lipids, including essential fatty acids such as gamma-linolenic acid (GLA), linoleic acid, oleic acid, palmitic acid, and stearic acid. Among these, gamma-linolenic acid (GLA) is particularly important because it helps reduce inflammation, regulate cholesterol levels, support cardiovascular health, and maintain hormonal balance. Essential fatty acids also play a crucial role in maintaining the structural integrity of cell membranes and proper functioning of the nervous system (Citi et al., 2024).

**Vitamins:** Spirulina is a rich source of vitamins, particularly B-complex vitamins such as thiamine (B1), riboflavin (B2), niacin (B3), pyridoxine (B6), folic acid, and vitamin B12, as well as vitamin E and provitamin A (beta-carotene). These vitamins are essential for energy metabolism, nervous system function, red blood cell formation, DNA synthesis, and antioxidant protection. Beta-carotene present in Spirulina acts as a precursor for vitamin A and helps maintain eye health and immune function (Calella et al., 2022; Gabr et al., 2020).

**Minerals:** Spirulina is rich in essential minerals such as iron, calcium, magnesium, potassium, zinc, phosphorus, and selenium. Iron present in Spirulina is highly bioavailable and plays an important role in haemoglobin formation and the prevention of anaemia. Calcium and phosphorus are important for bone and teeth development. Magnesium acts as a cofactor for many enzymatic reactions and supports muscle and nerve function. Potassium helps maintain electrolyte balance and regulate blood pressure, while zinc supports immune function, wound healing, and enzyme activity (Ramírez-Rodrigues et al., 2021).

**Pigments and Bioactive Compounds:** Spirulina contains several important pigments such as phycocyanin, chlorophyll, and carotenoids. Phycocyanin is the major blue pigment of Spirulina and has strong antioxidant, anti-

inflammatory, hepatoprotective, and anticancer properties. Chlorophyll helps in detoxification by removing toxins and heavy metals from the body and supports blood purification. Carotenoids such as beta-carotene act as antioxidants and help in preventing oxidative stress, eye diseases, and immune disorders (Gentscheva et al., 2023; Citi et al., 2024).

**Polysaccharides:** Spirulina contains sulfated polysaccharides such as calcium spirulan, which enhance immune system function by stimulating macrophages, lymphocytes, and antibody production. These polysaccharides also exhibit antiviral, antibacterial, and anti-inflammatory activities and may help in preventing viral infections and chronic diseases (Gentscheva et al., 2023).

**Dietary Fiber:** Spirulina contains a small amount of dietary fibre that helps improve digestion, promotes gut health, and helps regulate blood sugar levels. Fibre also supports the growth of beneficial intestinal bacteria and improves nutrient absorption. (Table-1).

**Table-1 Nutritional Composition of *Spirulina platensis* with Uses and References**

| Nutrient | Composition (Approx.) | Uses / Functions in Human Health | References |
|---|---|---|---|
| Protein | 60–70% | Body building, enzyme synthesis, tissue repair, muscle growth | Calella et al., 2022; Ramírez-Rodrigues et al., 2021 |
| Carbohydrates | 15–20% | Energy source | Gabr et al., 2020 |
| Lipids | 5–7% | Energy, cell membrane structure | Gabr et al., 2020 |
| Essential Fatty Acids (GLA) | 1–2% | Reduces cholesterol, anti-inflammatory | Citi et al., 2024 |
| Vitamins (B1, B2, B3, B6, B12, E) | Small amounts | Metabolism, nerve function, immunity | Calella et al., 2022 |
| Iron | 28–50 mg/100 g | Hemoglobin formation, prevents anemia | Ramírez-Rodrigues et al., 2021 |
| Calcium | 120–150 mg/100 g | Bone and teeth formation | Calella et al., 2022 |
| Magnesium | 180–200 mg/100 g | Enzyme activation, muscle and nerve function | Calella et al., 2022 |
| Potassium | 1300–1500 mg/100 g | Maintains blood pressure, heart function | Gabr et al., 2020 |
| Phycocyanin | 10–15% | Antioxidant, anti-inflammatory, anticancer | Citi et al., 2024 |
| Chlorophyll | 1% | Detoxification, blood purification | Gentscheva et al., 2023 |
| Carotenoids | 0.5–1% | Eye health, antioxidant | Calella et al., 2022 |
| Polysaccharides | 15–20% | Immune booster | Gentscheva et al., 2023 |
| Dietary Fiber | 3–5% | Improves digestion | Ramírez-Rodrigues et al., 2021 |

## 3. Medicinal Properties:

*Spirulina platensis* is well known for its medicinal properties due to the presence of various bioactive compounds such as phycocyanin, carotenoids, phenolic compounds, vitamins, minerals, gamma-linolenic acid, and sulfated polysaccharides. These compounds are responsible for several pharmacological activities, including antioxidant, anti-inflammatory, immune-boosting, antidiabetic, and anticancer properties. Because of these therapeutic effects, Spirulina is widely used as a nutraceutical and functional food in the prevention and management of chronic diseases (Wu et al., 2016; Calella et al., 2022).

**3.1 Antioxidant Activity:** Spirulina exhibits strong antioxidant activity mainly due to the presence of phycocyanin, beta-carotene, vitamin E, and phenolic compounds. These bioactive compounds neutralise free radicals and reactive oxygen species (ROS), thereby reducing oxidative stress, lipid peroxidation, DNA damage, and cell aging. Phycocyanin is considered one of the most powerful natural antioxidants found in Spirulina and plays an important role in protecting cells from oxidative damage and degenerative diseases such as diabetes, cancer, and cardiovascular diseases (Gentscheva et al., 2023; Wu et al., 2016).

**3.2 Anti-inflammatory Activity:** Spirulina shows significant anti-inflammatory activity due to phycocyanin, gamma-linolenic acid (GLA), and polysaccharides. Phycocyanin inhibits cyclooxygenase-2 (COX-2), an enzyme responsible for the synthesis of inflammatory prostaglandins. Gamma-linolenic acid helps in the production of anti-inflammatory prostaglandins and reduces inflammation in tissues. Spirulina supplementation has been reported to reduce inflammatory markers and is useful in inflammatory diseases such as arthritis, cardiovascular diseases, and inflammatory bowel disease (Citi et al., 2024; Wu et al., 2016).

### 3.3: Immune Boosting Property

Spirulina enhances the immune system by stimulating immune cells such as macrophages, T-lymphocytes, B-lymphocytes, and natural killer (NK) cells. Spirulina polysaccharides, particularly calcium spirulan, stimulate antibody production and cytokine activity, thereby improving the body's defense mechanism against infections and viral diseases. Spirulina also enhances the production of interferons and interleukins which play a key role in immune regulation (Gentscheva et al., 2023).

### 3.4 Anti-diabetic Property

Spirulina has shown significant antidiabetic activity by reducing blood glucose levels, improving insulin sensitivity, and reducing oxidative stress in diabetic patients. Spirulina supplementation helps reduce fasting blood glucose, HbA1c levels, cholesterol, and triglycerides. It also improves pancreatic beta-cell function and enhances insulin secretion. The antidiabetic effect of Spirulina is mainly due to phycocyanin, antioxidants, and essential fatty acids (Calella et al., 2022; Wu et al., 2016).

### 3.5 Anti-cancer Potential

Spirulina exhibits anticancer potential due to bioactive compounds such as phycocyanin, beta-carotene, selenium, and polysaccharides. These compounds help in preventing cancer by inhibiting tumor cell proliferation, inducing apoptosis (programmed cell death), preventing DNA damage, and enhancing immune response against tumor cells. Several studies reported that Spirulina supplementation reduced the risk of oral cancer, liver cancer, and colon cancer due to its antioxidant and immunomodulatory effects (Belay, 2002; Wu et al., 2016).(Table-2).

**Table 2:Medicinal Properties of *Spirulina platensis* and Mechanism**

| Medicinal Property | Active Compounds | Mechanism | Health Benefits |
|---|---|---|---|
| Antioxidant | Phycocyanin, Beta-carotene, Vitamin E | Neutralises ROS and free radicals | Prevents oxidative stress and aging |
| Anti-inflammatory | Phycocyanin, GLA | Inhibits COX-2 and inflammatory mediators | Reduces inflammation |
| Immune boosting | Polysaccharides, Calcium spirulan | Activates macrophages, NK cells, antibodies | Improves immunity |
| Anti-diabetic | Phycocyanin, Antioxidants | Improves insulin sensitivity | Controls blood glucose |
| Anti-cancer | Phycocyanin, Beta-carotene | Induces apoptosis and inhibits tumour growth | Prevents cancer |

# 4. Therapeutic Applications

*Spirulina platensis* has gained significant attention as a therapeutic agent due to its rich nutritional profile and diverse pharmacological properties. It is widely used in the prevention and management of several health conditions such as malnutrition, anemia, diabetes, cardiovascular diseases, and allergies. The presence of proteins, iron, essential fatty acids, vitamins, minerals, and bioactive compounds like phycocyanin and polysaccharides contributes to its therapeutic efficacy.

## 4.1 Malnutrition

Spirulina is highly effective in combating protein-energy malnutrition due to its high protein content (60–70%) and balanced amino acid profile. It provides essential nutrients required for growth and development, especially in children and undernourished populations. Spirulina supplementation improves body weight, nutritional status, and immune function. It is widely recommended by international organizations as a supplementary food in malnourished individuals (Ramírez-Rodrigues, Estrada-Beristain, Metri-Ojeda, Perez-Alva, and Baez-Gonzalez, 2021; Gabr, El-Sayed, and Hikal, 2020).

## 4.2 Anemia

Spirulina is an excellent source of highly bioavailable iron, along with vitamins such as B12 and folic acid, which are essential for red blood cell formation. Regular consumption of Spirulina helps increase haemoglobin levels and improves iron status in anemic patients. It is particularly beneficial for pregnant women, children, and individuals with iron deficiency anaemia (Calella, Cerullo, Di Dio, Liguori, and Di Onofrio, 2022).

## 4.3 Diabetes

Spirulina is effective in the management of diabetes mellitus by lowering blood glucose levels and improving insulin sensitivity. It reduces oxidative stress and improves lipid profiles by decreasing cholesterol and triglyceride levels. Spirulina also enhances pancreatic beta-cell function and helps in better glucose utilization. These effects are mainly due to phycocyanin, antioxidants, and essential fatty acids present in Spirulina (Citi, Martelli, Testai, Marino, and Calderone, 2024; Wu, Liu, Miron, Klímová, Wan, and Kuča, 2016).

### 4.4 Cardiovascular Diseases

Spirulina plays an important role in maintaining cardiovascular health. It helps reduce low-density lipoprotein (LDL) cholesterol and triglycerides while increasing high-density lipoprotein (HDL) cholesterol. It also helps in lowering blood pressure and improving blood circulation. The antioxidant and anti-inflammatory properties of Spirulina prevent oxidative damage to blood vessels and reduce the risk of atherosclerosis and heart diseases (Gentscheva, Yancheva, Dzhambazov, and Ivanova, 2023; Citi, Martelli, Testai, Marino, and Calderone, 2024).

### 4.5 Allergy Management

Spirulina is effective in managing allergic conditions such as allergic rhinitis. It reduces symptoms like sneezing, nasal congestion, itching, and runny nose. Spirulina inhibits the release of histamine from mast cells and reduces inflammatory responses. It also enhances immune regulation, thereby reducing hypersensitivity reactions (Wu, Liu, Miron, Klímová, Wan, and Kuča, 2016).( Table-3).

**Table-3: Therapeutic Applications of *Spirulina platensis***

| Condition | Active Components | Mechanism of Action | Therapeutic Effect |
|---|---|---|---|
| Malnutrition | Proteins, Vitamins, Minerals | Provides essential nutrients and improves immunity | Improves growth and nutritional status |
| Anemia | Iron, Vitamin B12, Folic acid | Enhances haemoglobin synthesis | Increases RBC count and haemoglobin |
| Diabetes | Phycocyanin, Antioxidants | Improves insulin sensitivity and reduces glucose levels | Controls blood sugar |
| Cardiovascular diseases | GLA, Antioxidants | Reduces cholesterol and oxidative stress | Protects heart and blood vessels |
| Allergy management | Polysaccharides, Phycocyanin | Inhibits histamine release | Reduces allergy symptoms |

## 5. Industrial Applications

Spirulina platensis has gained considerable industrial importance due to its high nutritional value, bioactive compounds, and ease of cultivation. It is widely used in various industries such as the food industry, pharmaceutical industry, cosmetics, agriculture as a biofertilizer, and in biofuel production. Its fast growth rate, high biomass yield, and ability to grow in alkaline conditions make it suitable for large-scale industrial production.

### 5.1 Food Industry

In the food industry, Spirulina is used as a nutritional supplement and functional food ingredient due to its high protein content, vitamins, minerals, essential fatty acids, and antioxidants. It is commonly used in the preparation of health supplements, protein powders, tablets, capsules, energy bars, biscuits, beverages, and baby food formulations. Spirulina is also used as a natural food colorant because of the presence of the blue pigment phycocyanin. Due to its high nutritional value, Spirulina is used

to combat malnutrition and is included in health food products worldwide (Ramírez-Rodrigues et al., 2021; Gabr et al., 2020).

### 5.2 Pharmaceutical Industry

Spirulina is widely used in the pharmaceutical industry due to its bioactive compounds such as phycocyanin, polysaccharides, gamma-linolenic acid, vitamins, and antioxidants. These compounds possess antioxidant, anti-inflammatory, antiviral, antibacterial, antidiabetic, and anticancer properties. Spirulina is used in the preparation of nutraceuticals, therapeutic supplements, immune boosters, and antioxidant formulations. Phycocyanin extracted from Spirulina is used in drug formulations due to its pharmacological activities (Citi et al., 2024; Wu et al., 2016).

### 5.3 Cosmetics Industry

Spirulina is used in the cosmetics industry due to its antioxidant, anti-aging, and skin-nourishing properties. Spirulina extracts are used in face creams, anti-aging creams, face masks, shampoos, and skin care products. The presence of vitamins, minerals, and antioxidants helps in improving skin elasticity, reducing wrinkles, preventing skin aging, and promoting hair growth. Spirulina also protects the skin from oxidative damage caused by UV radiation and pollution (Gentscheva et al., 2023).

### 5.4 Biofertilizer

Spirulina is used as a biofertilizer in agriculture because it improves soil fertility and plant growth. Being a cyanobacterium, it has the ability to fix atmospheric nitrogen and increase soil nutrient content. Spirulina also releases growth-promoting substances such as auxins, gibberellins, and vitamins that enhance seed germination, root development, and crop yield. It is used in organic farming as an eco-friendly alternative to chemical fertilizers (Gabr et al., 2020).

### 5.5 Biofuel

Spirulina is considered a potential source for biofuel production due to its high lipid content and rapid biomass production. The lipids present in Spirulina can be converted into biodiesel through transesterification. Spirulina biomass can also be used for the production of bioethanol, biogas, and hydrogen fuel. Due to its high photosynthetic efficiency and ability to grow in non-arable land, Spirulina is considered a promising renewable energy source (Citi et al., 2024). (Table-4).

**Table-4: Industrial Applications of *Spirulina platensis***

| Industry | Spirulina Product | Application | Benefit |
|---|---|---|---|
| Food Industry | Protein powder, tablets | Nutritional supplement | Combats malnutrition |
| Pharmaceutical | Phycocyanin extract | Drug and nutraceutical preparation | Treats chronic diseases |
| Cosmetics | Spirulina extract | Creams, shampoos | Anti-aging and skin protection |
| Biofertilizer | Spirulina biomass | Soil fertility improvement | Increases crop yield |
| Biofuel | Spirulina lipids | Biodiesel production | Renewable energy source |

## 6. Dosage and Safety of *Spirulina platensis*

*Spirulina platensis* is generally considered safe for human consumption and has been widely used as a dietary supplement. However, proper dosage, safety considerations, and precautions are important for its effective and safe use.

### 6.1 Recommended Dosage

The recommended dosage of Spirulina varies depending on age, health condition, and purpose of use. In general, the commonly recommended dosage for adults ranges between **1–5 g per day**, while some clinical studies have used doses up to **10 g per day** without significant side effects. For malnutrition and anemia, 2–3 g per day is commonly recommended, while for diabetes and cholesterol management, 3–5 g per day is often used. Spirulina is usually available in powder, tablet, or capsule form and can be consumed with water, juice, or food (Wu et al., 2016; Calella et al., 2022).

Children are usually given lower doses, typically **0.5–1 g per day**, depending on age and nutritional status. Spirulina supplementation should be taken regularly for several weeks to observe significant health benefits.

### 6.2 Toxicity

Spirulina is generally non-toxic and safe when consumed in recommended amounts. However, toxicity may occur if Spirulina is contaminated with heavy metals (lead, mercury, arsenic), harmful bacteria, or microcystins produced by other cyanobacteria during cultivation. Consumption of contaminated Spirulina may cause nausea, vomiting, liver damage, weakness, and allergic reactions. Therefore, Spirulina should be obtained from certified and quality-controlled sources.

High doses of Spirulina may cause minor side effects such as headache, sweating, insomnia, stomach upset, and skin rashes in some individuals. However, these effects are rare and usually mild (Belay, 2002; Wu et al., 2016).

### 6.3 Precautions

Some individuals should take precautions before consuming Spirulina:

- People with **autoimmune diseases** (such as rheumatoid arthritis, lupus, multiple sclerosis) should consult a doctor because Spirulina stimulates the immune system.
- People with **phenylketonuria (PKU)** should avoid Spirulina because it contains phenylalanine.
- People taking **anticoagulant drugs** should use Spirulina cautiously because it contains vitamin K, which may affect blood clotting.
- Pregnant and breastfeeding women should consult a doctor before taking Spirulina supplements.
- Spirulina should always be taken in recommended doses and from safe, contamination-free sources. (Table-5).

**Table-5: Dosage and Safety of Spirulina**

| Parameter | Details |
|---|---|
| Recommended dosage | 1–5 g/day (adults) |
| Children dosage | 0.5–1 g/day |
| High dose used in studies | Up to 10 g/day |
| Common side effects | Headache, nausea, stomach upset |
| Toxicity cause | Contamination with heavy metals or microcystins |
| Precautions | Autoimmune diseases, PKU, pregnancy, anticoagulant drugs |

# 7. Future Prospects of *Spirulina platensis*

## 7.1 Spirulina in Biotechnology

*Spirulina platensis* has significant potential in the field of biotechnology due to its rapid growth rate, high protein content, and ability to produce valuable bioactive compounds. Modern biotechnological approaches such as genetic engineering, metabolic engineering, and tissue culture techniques are being applied to improve Spirulina strains for higher production of proteins, pigments (phycocyanin), vitamins, and essential fatty acids. Spirulina is also being explored for recombinant protein production, where genetically modified Spirulina can be used to produce vaccines, antibodies, and therapeutic proteins. In addition, Spirulina is being studied for wastewater treatment and bioremediation because it can absorb heavy metals and remove excess nutrients from polluted water (Ciferri, 1983; Wu et al., 2016; Gentscheva et al., 2023).

## 7.2 Spirulina in Drug Development

Spirulina platensis is gaining importance in pharmaceutical research due to its bioactive compounds such as phycocyanin, polysaccharides, phenolic compounds, and gamma-linolenic acid. These compounds have shown antioxidant, anti-inflammatory, antiviral, antibacterial, antidiabetic, and anticancer activities. Researchers are focusing on isolating and purifying Spirulina bioactive compounds for the development of new drugs, especially for the treatment of cancer, diabetes, viral infections, and immune-related diseases. Phycocyanin is being studied as a potential natural drug due to its ability to inhibit tumor growth, reduce oxidative stress, and suppress inflammation. Spirulina-derived compounds are also being investigated for use in nanomedicine and targeted drug delivery systems (Citi et al., 2024; Wu et al., 2016).

## 7.3 Spirulina in Space Nutrition

*Spirulina platensis* is considered an ideal food source for space missions due to its high nutritional value, oxygen-producing ability, and carbon dioxide utilization. Space agencies are studying Spirulina as a part of life-support systems for astronauts because it can produce oxygen through photosynthesis while providing food rich in protein, vitamins, and minerals. Spirulina can be grown in controlled environments with minimal resources, making it suitable for long-duration space missions and space colonization programs. It is also being studied as a sustainable food source for future missions to the Moon and Mars (Gershwin and Belay, 2008).

# 7. Conclusion

*Spirulina platensis* is a highly nutritious cyanobacterium with significant health benefits and wide industrial applications. It contains high-quality proteins, essential fatty acids, vitamins, minerals, pigments, and bioactive compounds that contribute to its antioxidant, anti-inflammatory, immunomodulatory, antidiabetic, cardio-protective, and anticancer properties. Due to these medicinal properties, Spirulina is widely used in the treatment and prevention of various diseases such as malnutrition, anemia, diabetes, cardiovascular diseases, and allergies.

In addition to its therapeutic importance, Spirulina has wide industrial applications in the food industry, pharmaceutical industry, cosmetics, biofertilizer production, and biofuel production. Its fast growth rate, high biomass production, and ability to grow in extreme environmental conditions make it suitable for large-scale cultivation and commercial production.

Furthermore, future research on Spirulina in biotechnology, drug development, and space nutrition shows that it has enormous potential as a sustainable food source, therapeutic agent, and industrial microorganism. With increasing demand for natural products, nutraceuticals, and sustainable resources, *Spirulina platensis* will play an important role in improving human health, food security, and environmental sustainability.

Overall, *Spirulina platensis* can be considered a "superfood" and a promising natural resource for future medicine, nutrition, and biotechnology. However, more clinical studies and large

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