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# Review on Biomass Production and Application of Spirulina

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## Abstract

*Spirulina are free floating gram negative bacteria which carry out photosynthesis. They are oxygenic, filamentous, photolithoautotroph, unbranched and multicellular blue-green algae with symbiotic bacteria that fix atmospheric nitrogen by the process of nitrogen fixation from air. Spirulina is commercially produced around the world and used as food and feed supplement in the human dietary and aquaculture industries, respectively. Spirulina is nutritionally rich in protein and has got worldwide attention to solve malnutrition problems. Moreover, it becomes more popular based on its best applicability on the utilization mechanism of carbon dioxide as in photosynthesis. The growth and productivity of spirulina are mainly dependent on temperature, light source, salinity, growth media, pH, size of inoculum, agitation and carbon dioxide. Spirulina have different applications in bio-fertilizer production, food industry, animal forage supplement, greasepaints, pharmaceutical industry, and energy making industry, waste water treatment and carbon dioxide alleviation. Therefore, this paper reviews how to increase the biomass productivity of Spirulina.*

**Keywords**: *Spirulin; Zarrouk's medium; biomass productivity; Protein content.*

# 1. Introduction

Spirulina is one of the most important microscopic and filamentous cyanobacterium (blue-green algae) which are commonly found in fresh water, salt water and brackish water. It is produced mainly from *Arthrospira platensis* and *Arthrospira maxima.* Due to its nutritional and health importance, spirulina plays a vital in human food supplement [34]. Spirulina contains about 50–70 % protein, carbohydrates, essential fatty acids, and various types of vitamins, especially vitamin B12, carotenoids, minerals (iron and zinc) and almost all essential amino acids [2; 3; 4].

In aquaculture sector, spirulina is becoming one of the most popular health food items and used as a supplementary diet in nutrient deficient feedstuffs [12]. Due to the above mentioned and other nutritional importance, spirulina has got global attention through large scale production systems. Spirulina replicates within a short period of time and this makes them to increase productivity [24]. However, growth and biomass production of Spirulina is highly dependent on temperature, nutrients, pH, nutrients and light sources. However, biomass production of spirulina can be increased when these environmental factors are adjusted based on their growth requirement [15].

Thus, various biotechnological researches and innovations were undertaken to investigate low cost and alternative methods of cultivation without reducing biomass productivity [38]. Based on different research works, spirulina biomass has been increased using saltwater supplemented with various sources of nitrogen, phosphorus and carbon [29; 5; 15]. Therefore, the aim of this review is to evaluate the current knowledge on the biomass production of spirulina and point out its broad application.

# 2. Historical Background of Spirulina

Spirulina is one of the earliest photosynthesizing organism deriving around 3.5 billion years ago which has been well-known its capability to use carbon dioxide in saltwater as a nutrient source for their reproduction. Spirulina grows mostly in strong light, under high temperatures and extremely alkaline conditions. In the $16^{th}$ century, when the Spanish invaders conquered Mexico, outbreaks of infectious disease were occurred. Hence, to tackle thus incidences, Mexicans living in the Valley of Mexico found a “new food” from the lake and making a blue-green cake from it. After so many experimental findings, it has been proved as cyanobacteria or spirulina [15]. It has been projected by NASA and the European space agency as one of the major foods to be consumed when scientists stay for long period of time in space. Since, it is extremely rich with different types of food nutrients and does not take significant energy to form circulatory systems [34].

# 3. Morphological and ecological characteristics of Spirulina

*Spirulina* are multicellular blue-green microalgae characterized by coiled cylindrical filaments. Spirulina species have three different forms such as spiral, straight and wavy [1].

Moreover, they also have several important cell components and inclusions such as stratified cell wall, DNA region, thylakoids, ribosomes, gas vacuoles, carboxysomes, phosphate granules and cylindrical bodies [7]. However,

morphology of Spirulina species is affected by various environmental factors such as temperature, pH, salt, light and nutrient availability [40].

Based on their ecological preferences, spirulina species are commonly originated in tropical and subtropical regions of the world. Moreover, spirulina can survive in alkalophilic, halophilic, thermophilic and extremophilic conditions [25]**.** Therefore, such environmental conditions enable them to grow with less possibility of contamination by other microorganisms and contribute for maintenance of monoalgal cultures in large scale production using outdoor ponds [28]. Although spirulina can grow in precarious conditions, anthropogenic activities and naturally occurring environmental changes may affect the spreading of Spirulina and allowing the growth of other microorganisms [6].

# 4. Environmental and nutritional factors affecting the growth of Spirulina

Biomass production of Spirulina is mainly affected by temperature, pH and light. Light is an essential environmental factor needed by Spirulina throughout the growth phases. Altering the color of the light intensity by covering the fluorescent bulbs can influence the yield of chemical compositions and products of Spirulina [33]. In addition, Spirulina growth rate also depends on different temperature ranges. Most of Spirulina species optimally grow in the range of 30-35°C. When the growth temperature is above 35°C, the color of Spirulina become changed or decolorized; because temperature affects the metabolic activities of Spirulina [22]. Furthermore, Spirulina is mostly found in natural alkaline lakes having pH value between 8.0-10.0 [21].

In addition to water and light, most microalgae require major nutrients such as carbon, nitrogen and phosphorus [16]. For their optimal growth, microalgae also need various micronutrients; such as, potassium, magnesium, sulfur, calcium and iron [26].

In order to perform photosynthesis and biomass production, most microalgae uses carbonates and bicarbonates as source of carbon [20]. Nitrogen and phosphorus can contribute for the highest production of Spirulina. However, among the two major nutrients, nitrogen plays the major role in the production of by producing amino acids, nucleotides, chlorophylls and phycobilins [16]. Phosphorous can also contribute for the production of chlorophyll a and protein content of spirulina. Furthermore, phosphorus has an important role in the metabolism process of ATP, DNA, RNA and phospholipids [27].

In addition to macronutrients, other trace elements such as magnesium, iron and sulfur are required for Spirulina growth and biosynthesis of different compounds. Sulfur is one of the most important micronutrients used for the production of nitrogenase enzyme and CoA, it can also be required for the biosynthesis of some amino acids like cysteine and methionine. Magnesium is also required mainly for the biosynthesis of chlorophyll. In addition, Iron is a cofactor for many enzymes such as, ferredoxins, catalases, glutamate synthetases, nitrogenases, nitrates and nitrite reductases [14; 23].

# 5. Applications of Spirulina

### *5.1. Human Food and Animal Feed*

Spirulina is becoming a well-known food for human in the worldwide. It is rich in various nutritional compositions such as proteins, vitamins, amino acids, fatty acids, minerals and pigments [1; 10]. In addition, nutritional components of Spirulina play great role in promoting healthy body functions of consumers and thus reduce the risk of disease by enhancing the immune system [18]. Due to its high sensorial properties and non-toxicity, spirulina is

considered as safe for human consumption or food supplement. Consequently, many African countries directly collected spirulina from natural water bodies, dried and eaten as a cake form [12]. In addition to this, Spirulina has also a potential feed resource to many agriculturally important animal species such as chickens, pigs, cattle, ruminants, sheep and rabbits. The reports of [17] indicated that around 50% of the current world production of Spirulina is widely used as feed supplement to poultry and different animals.

### *5.2. Aquaculture*

In aquaculture sectors, Spirulina is commonly used as a supplementary feed mainly for fish larvae and juveniles of both zooplankton and fish [12]. Furthermore, due to their probiotic nature, Spirulina has the abilities to promote the growth and stimulate the fish immune system [19]. During all their growth stages, many aquatic organisms consumes Spirulina as live feeds such as molluscs, crustaceans and some fish species [36]. Therefore, it is possible to replace 50 percent fishmeal by Spirulina meal, because Spirulina is a cheaper feed ingredient than others of animal origin. Feeding on Spirulina is very important to increase the survival rate of high value fish species [11].

### *5.3. Spirulina in Cosmetics and food colorant Industry*

Spirulina plays a significant role in cosmetics industry as thickening agents, water-binding agents and antioxidants [30]. The extracts mainly found in face, skin and hair care products and sun protection creams [37]. In addition, spirulina extracts can be used to produce cream for the treatment of animal's wounds. Spirulina produces different types of substances such as chlorophyll a, beta carotene and other pigment substances. These substances are very important in food colorant industry. In addition, Spirulina is rich with natural phycocyanin and hence it is used as a natural food colorant in different food industries [13].

### *5.4. Environment and Agriculture*

Spirulina is the most important microalgae in bioremediation systems to keep the environment from pollutants, hazardous substances and organic contaminants. It has a great role in wastewater treatment process as heavy metal remover for treating water contaminated with metals such as copper and cadmium [35]. Spirulina can also survive in highly alkaline and other extreme environmental conditions where contaminants do not grow, demonstrating its significant roles from environmental application point of view. Due to its high nitrogen and phosphorous content, Spirulina can be used as a source of biofertilizer and thus it is ideal for the growth and development of agricultural plants and for soil conditioning. In general, blue-green algae have the possibilities to replace chemical fertilizers and rebuilding the structure of depleted soils [12]. Therefore, spirulina is very important to replace chemical fertilizer in agricultural sectors [39].

### *5.5. Biofuels*

Compared to other crops, Spirulina is considered as good sources of biofuel production. Due to its high protein content and prompt biomass production, spirulina is preferred by different researchers, entrepreneurs and the general public [30]. Moreover, extraction of oil from spirulina is estimated to be greater than 80% (on dry weight basis) and average annual biodiesel yield of 98.4 $m^3$ per hectare [31]. Biofuel production from microalgae genera including spirulina has the capacity to reduce CO, hydrocarbons and other particulate matter emissions [32]. From the economic point of view, biofuel production from spirulina is profitable since it can grow easily using wastes or seawater.

### *5.6. Spirulina in Pharmaceutical Industries*

Spirulina play great role in the pharmaceutical industry. It has mostly bioactive compound containing carbohydrates, organic acids, amino acids and peptides, vitamins, growth substances, antibiotics, enzymes and toxic compounds of pharmaceutical importance [10]. Spirulina produces different bioactive metabolites (primary and secondary metabolites) such as antifungal, antibacterial, antiviral, antibiotic, anticancerous, antidiabetic, antianaemic and antileucopenic effects [1]). Extract of spirulina can prevent the penetration and replication of various types of enveloped viruses, including the Herpes Simplex Virus Type-1 (HSV-1), human cytomegalovirus, measles virus, mumps virus, influenza A virus and HIV- 1 replication in human T-cell lines, peripheral blood mononuclear cells (PBMC), and Langerhans cells [9]. Furthermore, extracts obtained from spirulina has therapeutic properties, such as the ability to prevent the incidence of cancers, decrease blood cholesterol levels, stimulate the immunological system, reduce the nephrotoxicity of pharmaceuticals and toxic metals and provide protection against the harmful effect of radiation [8].

## 6. Conclusion

Nowadays, malnutrition is becoming a major worldwide problem. Although governments, food and agricultural organization (FAO), non-governmental organizations (NGO's), world food program (WFP) and others have maximum efforts to provide sufficient food for those having low income individuals, people are still suffered from malnutrition. Thus, to improve the nutritional status of children, particularly under the age of 6 years, pregnant and lactating women, there is a need to supply nutrient rich foods to reduce nutrition insecurity throughout the world. Hence, in order to complement foods with sufficient amounts of macro and micro- nutrients, spirulina could be essential microalgae for nutritionally insecure populations since it contains high levels of essential macro and micronutrients. In addition to this, spirulina plays an essential role in waste water treatment, pharmaceutical industries, cosmetic industry, aquaculture and food colorant industry. However, spirulina is highly affected by major environmental factors and hence biomass production of spirulina has to be boosted by maintaining major growth conditions.

## Declarations

## Conflicts of Interest

The authors declare that there are no conflicts of interest. Therefore, the authors approved to publish this review article.

## Data availability

Data will available on request.

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