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The complexity of the genus *Arthrospira:* A review
La complejidad del género *Arthrospira:* Una revisión

E. Jiménez-Muñoz [a], J. Delgadillo-Díaz [a], X. Gómez-Quijada [a,b], P. A. López-Pérez [a], A. N.-Peón [a,c]

C. Jardínez-Vera [a,b,*]

[a] *Escuela Superior de Apan, Universidad Autónoma del Estado de Hidalgo, Carretera Apan-Calpulalpan, Km.8., Chimalpa Tlalayote s/n, 43900, Colonia Chimalpa, Apan, Hgo. México.*
[b]*Laboratorio de Modelado y Simulación Computacional en Nanomedicina, Escuela Superior de Apan, Universidad Autónoma del Estado de Hidalgo, Carretera Apan-Calpulalpan, Km.8., Chimalpa Tlalayote s/n, 43900, Colonia Chimalpa, Apan, Hgo. México.*
[c]*Sociedad Española de Beneficencia, Av. Juárez # 908, Colonia la Villita, CP. 42060, Pachuca, Hgo. México.*

Abstract

The genus *Arthrospira* includes the distinctive blue-green microalgae known as spirulina, which has a spiral morphology and a unique chemical composition, making it an intriguing candidate for research in therapeutic applications. Spirulina (SP) is rich in a variety of important metabolites, including exopolysaccharides, mucopolysaccharides, γ (gamma)-linolenic acid (GLA), provitamin A, B12, E, and various minerals, which may contribute to its reported antioxidant, anti-inflammatory, anticoagulant, antiviral, and neuroprotective properties, as well as its potential applications in the treatment of different types of cancer. The objectives of this review are to visualize the extensive health benefits that *Arthrospira* can provide, as well as its negative effects due to consumption. Additionally, it describes the optimal conditions for cultivation, reproduction, and treatments for future applications.

Keywords: Arthrospira, microalgae, cancer, metabolites, culture and nutrients.

Resumen

El género *Arthrospira* incluye a la distintiva microalga verde azulada conocida como espirulina, que tiene una morfología espiral y una composición química única, colocándola como pieza interesante para investigaciones en aplicaciones terapéuticas. La espirulina es rica en una variedad de metabolitos importantes, incluyendo exopolisacáridos, mucopolisacáridos, ácido gamma-linolénico (GLA), provitamina A, B12, E y varios minerales, los cuales pueden contribuir a sus propiedades antioxidantes, antiinflamatorias, anticoagulantes, antivirales y neuroprotectoras reportadas, así como, a sus posibles aplicaciones en el tratamiento de diferentes tipos de cáncer. En esta revisión se tienen como objetivos visualizar los amplios beneficios que *Arthrospira* puede proporcionar a la salud, así como, sus efectos negativos por consumo. También, describe las condiciones óptimas para su cultivo, reproducción y los tratamientos para futuras aplicaciones.

Palabras Clave: Arthrospira, microalga, cáncer, metabolitos, cultivo y nutrientes.

1. Introduction

In recent years, microalgae have gained importance; due to their wide biotechnological and commercial application, such as in nitrogen production for biofertilizers (Moreno, F., 2016; Hernández *et al*., 2019; Albuja *et al*., 2011), formulation of biostimulants for the improvement of nutritional efficiency, tolerance to abiotic stress or abiotic stress quality (Arahou, F., *et al*., 2023; Godlewska *et al*., 2019), bioremediation of contaminated environments (Cepoi, L., and Zinicovscaia, I. 2020; Chaumont, D., 1993), production of secondary metabolites for food or the elaboration of some drugs, cosmetics, paints, textile products, etc (Dhandayuthapani, K., *et al*., 2021; Ponce, E., 2013; Naranjo *et al*., 2010; De Philippis, 1998; Villalba-Alderete., 2018).

Due to their morphological, structural and physiological diversity, microalgae are distributed in freshwater, saltwater and terrestrial habitats (Elmore and Boorman, 2013; Saber, A. A., *et al*., 2022). Within their taxonomy, there are several genera, among which are *Ammassolinea, Arthrospira, Leptolyngbya, Limnospira, Geitlerinema, Pseudophormidium, Planktothrix, Pseudanabaena, Clostridium, Chromatium*, among others (Pineda *et al*., 2011; Hauer and Komárek, 2020). The genus *Arthrospira* from the

*Autor para la correspondencia: aldo_jardinez@uaeh.edu.mx
Correo electrónico: edith_jimenez@uaeh.edu.mx (Edith Jiménez-Muñoz), Alberto_navarrete@uaeh.edu.mx (Alberto N. Peón), aldo_jardinez@uaeh.edu.mx (Christiaan Jardínez-Vera), pablo_lopez@uaeh.edu.mx (Pablo Antonio López-Pérez), (Jazmín Delgadillo-Díaz), go366601@uaeh.edu.mx (Ximena Gómez-Quijada)

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kingdom Eubacteria, domain Bacteria, family *Microcoleaceae*, order *Oscillatoriales*, phylum and class *Cyanobacteria* (Komárek *et al*., 2014; Hauer and Komárek, 2020) deserves special attention due to its nutraceutical properties (Miranda *et al*., 1998; Gutiérrez *et al*., 2015).

Arthrospira maxima, or spirulina, is a filamentous, undifferentiated, blue-green cyanobacterium whose cylindrical cells are 3 to 12 µm wide and 5-7 µm long. Its filaments or trichomes are spiral-shaped (open helix), measuring 7 to 9 µm wide by 100- 200 µm long (Ramírez and Olvera, 2006; Sili *et al*., 2013), as shown in Figure 1.

The inclination and diameter of the helix are 0-80 µm and 15-60 µm, respectively (Sili *et al*., 2013); both characteristics vary according to the environmental and growth conditions of the microalga (Tomaselli, L., 2002).

Figure 1: Morphological aspect of a trichome of *Arthrospira maxima*.

and enveloped by a capsule or sheath. These cells are also separated by septa visible under the microscope (Sanchez *et al*., 2003; Vonshak and Tomaselli, 2000). It can reproduce in water bodies with high carbonate and bicarbonate content, at pH between 8.5 and 11.5 and temperatures between 15 and 35 °C (Habib *et al*., 2008).

The life cycle of *Arthrospira maxima* begins with the fragmentation of the trichomes into smaller multicellular units called hormogonium; subsequently, there will be an enlargement and longitudinal elongation of the cells so that *Arthrospira* takes its typical helical shape, see Figure 2a. Finally, the mature trichome will divide; this takes place because all the cells that compose the filament can reproduce by transverse binary fission, that is, through the formation of cell necridia (area where there will be cell death) as indicated by the arrow in Figure 2b (Hernández, F., 2016; Richmond, A., 2017; Vonshak and Tomaselli, 2000).

The importance of spirulina lies in its nutritional richness from its macronutrients and micronutrients, some of which are essential for humans (Ramirez and Olvera, 2006; Anupamaa and Ravindra, Assuncao *et al*., 2019; P., 2000; Miranda *et al*., 1998; Belay *et al*., 1993).

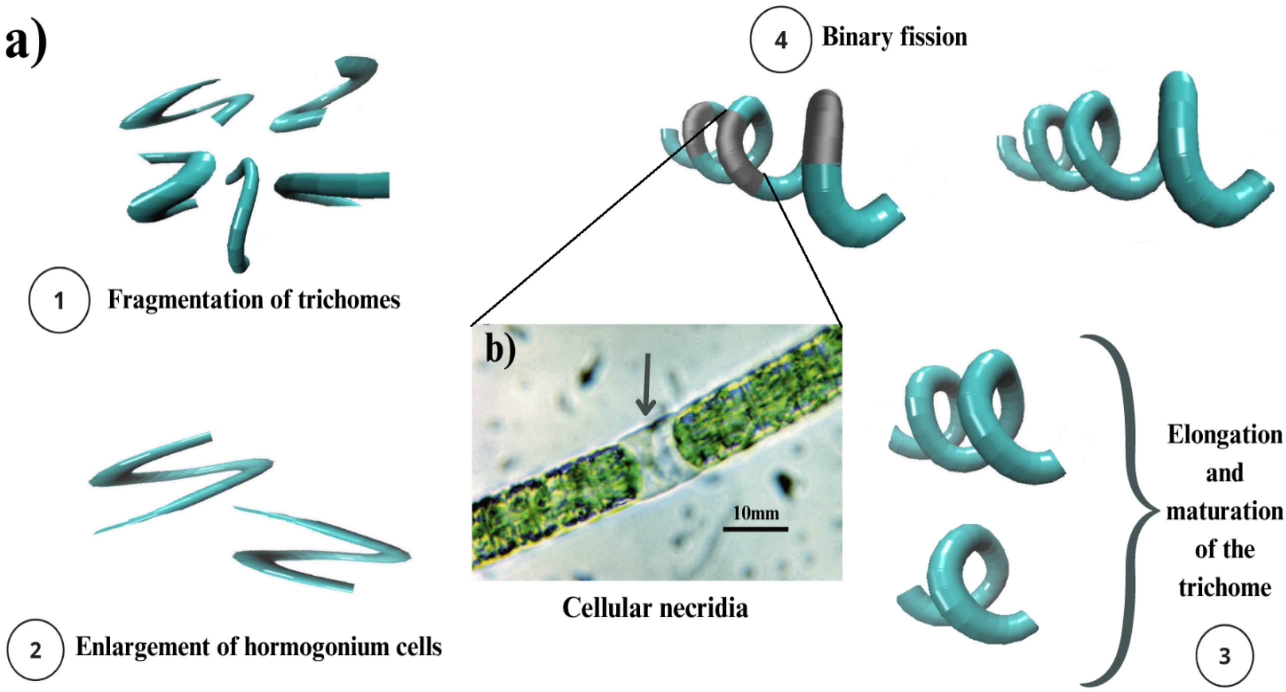

Figure 2: a) Life cycle of *Arthrospira sp*. b) Formation of cell necridia. Source: Sili *et al*., 2013.

Table 1: Biochemical composition of *Arthrospira maxima*

Molecules	Content (% dry weight)	Principal compounds
Proteins	50-70%	Leucine, valine, isoleucine, lysine, phenylalanine, methionine, tryptophan, tyrosine, glutamic acid, aspartic acid and cysteine.
Carbohydrates	15-20%	Glycerol, glucose, rhamnose, fucose, ribose, xylose, mannose, galactose and D-glucosamine.
Fatty acids	3-6.5%	Myristic, palmitic, palmitoleic, γ-linolenic acid (GLA) and oleic acids.
Minerals	7%	Potassium, sodium, phosphorus, calcium, magnesium, iron, manganese, zinc, copper and chromium.
Pigments	6%	Chlorophyll a, carotenoids, β-carotene, echinenone, β-cryptoxanthin, 3'-hydroxyethoxyquinenone, zeaxanthin, diatoxanthin, canthaxanthin, myxoxanthophyll, oscillaxanthin and phycocyanin.
Vitamins	< 1 %	Provitamin A, thiamin B1, riboflavin B2, niacin B3, Vitamin B6, cobalamin B12, Vitamin E, Vitamin K, folic acid, pantothenic acid and biotin.

Each *Arthrospira* cell has a plasma membrane surrounded by a gram-negative cell wall, with pores around the trichome

2. Methodology

The search and collection of information on *Arthrospira* consisted of the compilation of scientific articles extracted from the PUBMED database, which is a bibliographic database developed by the National Center for Biotechnology Information (NCBI) of the National Library of Medicine (NLM) of the United States.

3. Metabolites obtained from *Arthrospira* for pharmaceutical use

In recent years, there have been several investigations that have attributed pharmacological properties to spirulina, such as antiviral, anticancer, antioxidant, among others; the reason for its properties is due to specific components that act as active principles (Sandoval, D., 2017; Daki, S., *et al*., 2022; Dewi, I. C., *et al*., 2018; El-Sheekh, M., and Abomohra, A. E. F., 2020; Ramirez and Olvera, 2006; Chamorro *et al*., 2002; Sandoval, D., 2017; Singab, A. N., *et al*., 2018; Singh, S., *et al*., 2020). Some of these are being mentioned below:

3.1. *Exopolysaccharides (EPS)*

A series of compounds, such as pods, capsules or mucilage, are expelled in the stationary phase of spirulina culture; because the polysaccharides are suspended in the culture medium, they can be recovered by centrifugation, precipitation and dialysis methods (Mata, J., 2006; Ramírez and Olvera, 2006). Ca-Spirulan (Ca-SP) is the most prominent exopolysaccharide of *Arthrospira* (Chamorro *et al*., 2002), as it has the following applications:

- Antiviral: It inhibits, in vitro and ex vivo, the replication of the following viruses: *Herpes simplex* virus type 1 (HSV-1), human immunodeficiency virus (HIV-1), human cytomegalovirus, measles, mumps, and influenza virus, since it affects the events that occur during the first two hours of the viral cycle, which correspond to adsorption and penetration, without affecting the subsequent stages of biosynthesis (Carbone, D. A., *et al*., 2021; Chamorro *et al*., 2002; Hayashi *et al*., 2009).

- Anticancer: In an experiment conducted by Mishima *et al*. (1998), inhibition of lung tumour colonization of B-16-BL6 cells was observed in spontaneous lung metastasis; the treatment consisted of injections of 100 μg of Ca-SP in mice.

- Anticoagulant: It is well known that thrombin is a blood enzyme involved in the clotting process, while heparin is a natural anticoagulant substance. Ca-SP has been shown to potentiate (10,000 times) the anti-thrombin activity of heparin since Ca-SP effectively induces the formation of a thrombin-HC II complex in plasma (Chamorro *et al*., 2002; Hayakawa *et al*., 1996).

3.2 *Mucopolysaccharides (MPS)*

The cell wall of spirulina is composed of mucopolysaccharides, MPS are complex sugars intertwined with amino acids, simple sugars and proteins; these are 100% digestible, unlike the cell wall of other algae (such as *Chlorella*), To the above, it can be added that the proteins in this cyanobacterium are easily and quickly digested and metabolized, helping treat malnutrition (Sandoval, D., 2017; Villalba, C., 2018). If spirulina is compared with to other protein sources, it has higher levels than fish meat (15- 20%), egg (12%), cereals (8-14%) and whole milk (3%) (Sandoval, D., 2017). Phycocyanins (FC).

Phycocyanins are soluble proteins that predominate in blue-green algae with 8.72% (78.51 ± 0.778 mg/L) concerning dry mass (Romero *et al*., 2017).

3.2.1 Biological effects presented by phycocyanins:

- Antioxidant: Phycocyanins can scavenge different radicals such as OH and RO at an IC_{50} = 0.91 mg/mL and 76 μg/mL, respectively. IC_{50} equals the concentration at which a drug can inhibit a particular biological process by 50% (Romay *et al*., 1998).

- Anti-inflammatory: It has been demonstrated the anti-inflammatory effect of phycocyanin's at doses of 100 and 200 mg/kg, administered orally to mice, reducing the inflammation of the extremities produced by glucose oxidase (Romay *et al*., 1998), also reducing the activity of myeloperoxidase and inhibiting inflammatory cell infiltration and colon damage (Gonzalez *et al*., 1999).

- Antihepatotoxic: It prevents fatty liver and protecting against hepatotoxicity produced by carbon tetrachloride and pulegone (El-Bialy, *et al*., 2019; Torres *et al*., 1998).

- Immunostimulant: Phycocyanin increases lymphocytic activity (Chamorro *et al*., 2002).

Phycocyanin is also used in immunoassays since it forms stable conjugates with antibodies and presents unique physical and spectroscopic properties, being highly fluorescent components useful for diagnostics and biomedical research (Kronick, M., 1986; Glazer, A., 1994).

3.3 γ -linolenic acid (GLA)

γ -linolenic acid (GLA) is an essential, unsaturated fatty acid that reduces serum cholesterol levels in humans by 4.5% and significantly reduces body weight by 1.4 ± 0.4 kg after four weeks (Henrikson, R., 1994; Sánchez *et al*., 2003), in addition, there were no changes in clinical parameters (blood pressure) or biochemical variables (hematocrit, haemoglobin, white blood cells, sedimentation rate), which represents an alternative in the management of cardiovascular diseases and weight control (Ramirez and Olvera, 2006).

3.4 Provitamin A (β-carotene)

Carotenoids are natural lipid-soluble pigments that collect light during photosynthesis (Nwoba, E. G., *et al*., 2020). They are also photoprotective substances that inhibit the propagation of reactive oxygen species, preventing their harmful action at the cellular level (Mínguez *et al*., 2005; Piñero *et al*., 2001).

The β-carotene is found between 700- 1,700 mg per kg of dried microalgae, which represents 80% of the carotenoids in spirulina (Ramirez and Olvera, 2006; Rodriguez and Triana, 2006). It is a very popular additive and is non-toxic. Therefore, it is used as a food colourant (Ramírez and Olvera, 2006).

Other biological functions performed by β carotene is to increase the immune response in animals and humans (Villalba, C., 2018); experiments with extracts rich in β-carotene from two algae, *Arthrospira* and *Dunaliella*, have demonstrated its anticarcinogenic effect inhibiting 20% of the carcinogenesis caused in the oral cavity of rodents (Schwartz and Shklar, 1987; Schwartz *et al*., 1988), β-carotene also inhibits by 46.2% the frequency of micronuclei induced by maleic hydrazide in meiotic cells of herbaceous plants (Chamorro *et al*., 2002).

3.5 Vitamin B12

Vitamin B12 is difficult to obtain in a vegetarian diet since it is not contained in any common vegetable. Therefore, spirulina is recommended to obtain it (Rodriguez and Triana, 2006). Vitamin B12 is necessary for normal functioning of nervous tissue, helping to maintain the myelin sheath that surrounds neuronal axons (Ponce, E., 2013). When Vitamin B12 deficiency exists, polyneuropathic and neuropsychiatric disorders may appear (Sánchez *et al*., 2003).

3.6 Vitamin E

Approximately 50 to 190 mg of Vitamin E are found per kilogram of dry spirulina; this content is comparable to wheat germ. Vitamin E groups different compounds, including tocopherols and tocotrienols (Belay, A., 2002; Rodríguez and Triana, 2006). Some of its functions are mentioned below:

- Antioxidant: Vitamin E is a natural antioxidant that reacts with free radicals soluble in membrane lipids, inhibiting lipid peroxidation by 35%.

- Immune system: plays a vital role in maintaining a healthy immune system, especially during oxidative stress and chronic viral diseases. It induces the proliferation of defence cells and increases the cellular response to damage or infection (Belay, A., 2002).

3.7 Minerals

Arthrospira provides many minerals, such as calcium, iron, manganese, magnesium, zinc, germanium and copper (Cardenas, *et al*., 2010; Furmaniak, M. A., *et al*., 2017). These minerals are easily absorbed by the organism and have the most efficacy in our body. Iron is the most important, since it is absorbed 60% more than ferrous sulfate and other supplements necessary for the treatment of hypoferric anaemia (Sanchez *et al*., 2003; Chamorro *et al*., 2002; Kapoor and Mehta, 1998).

4. Adverse effects

Although the consumption of spirulina may have significant health benefits, there have been reports of adverse effects in patients who have been on an *Arthrospira* supplement.

Some mild effects can range from headaches, muscle aches, facial flushing, sweating, and difficulty concentrating, to skin reactions and liver damage in people who have reported taking 1g (per day) of spirulina (Iwasa *et al*., 2002). In addition, supplementation with these algae is believed to increase the concentration of calcium in the human body, but there are no concrete studies to confirm this (Marles *et al*., 2011).

A 17-year-old young man started taking 300 mg capsules as a dietary supplement, with symptoms of anaphylaxis such as tingling of the lips, urticaria on the arms, angioedema of the face and pruritic exanthema; it is mentioned that a possible cause of this reaction could be the patient's history of a history of asthma, allergic rhinitis, apathetic dermatitis and food pollen syndrome before taking the tablets (Le *et al*., 2014). Two cases of patients with outbreaks of pemphigus vulgaris and a severe case of dermatomyositis were also reported (Lee *et al*., 2004).

An 82-year-old woman was reported to have blisters on the trunk and extremities, presumably caused by ingestion of *Arthrospira plantensis* one year prior to the onset of symptoms. However, no lesions were noted after discontinuation (Kraigher *et al*., 2007). Likewise, a 28-year-old man ingested 3g (per day) tablets of a Hawaiian spirulina (*A. plantensis*) supplement for one month, causing rhabdomyolysis (rupture of muscle tissue), which resulted in chest weakness and myalgia (Mazokopakis *et al*., 2008).

Herbal supplements can cause these ailments in people who are genetically predisposed to these types of disorders or who have a history of mild or severe illnesses prior to their consumption (Lee *et al*., 2004).

The recommended dosage as a supplement is one to 10g (per day). The members of the DSI-EC (Dietary Supplements Information Expert Committee) have analysed this; despite the presentation of some cases of adverse effects, the DSI-EC indicates that the consumption of *Arthrospira* does not represent a serious health risk (Marles *et al*., 2011).

5. *Arthrospira* growth and cultivation conditions

5.1 Growth rate

The growth rate of spirulina follows the typical pattern of many other microorganisms that undergo simple cell division. Therefore, the following equation describes the specific growth rate (μ):

$$\mu = \frac{\left(\ln ln\, x_2 - \ln ln\, x_1\right)}{\left(t_2 - t_1\right)} \tag{1}$$

Where x_1 and x_2 are biomass concentrations at time intervals t_1 and t_2. The simple equation that combines the specific growth rate (μ) and the doubling time (d.t.) or generation time (g) of a culture is:

$$g = \frac{\ln ln\, 2}{\mu} = \frac{0.693}{\mu} = d.t \tag{2}$$

These equations are valid for batch or discontinuous cultures logarithmic or exponential growth phase (Vonshak, A., 1997).

In a batch culture of *Arthrospira sp*., the following growth phases occur, as shown in Figure 3:

- Adaptation phase (1-4 days): In this phase, *Arthrospira sp*. adapts to the conditions established in the culture medium; the growth rate is low but increases progressively (Licett *et al*., 2014).

- Exponential growth phase (14-16 days): the culture of *Arthrospira sp*. already adapted to the conditions, accelerates its cell division rate, and the biomass concentration becomes exponential (Licett *et al*., 2014).

- Stationary phase (24 days): Growth continues until there is nutrient or light limitation; it is then when the growth curve reaches equilibrium between maximum biomass concentration and biomass loss (Romero *et al*., 2017).

- Death phase: In this phase, the resources available in the culture medium are exhausted; therefore, the cells of *Arthrospira sp*. die, releasing organic matter (Rodríguez and Triana, 2006).

It is worth mentioning that *Arthrospira sp.* should always be maintained in an exponential growth phase to obtain better results in the establishment and production of the same (Hernández, F., 2016).

5.2 Physical and chemical parameters

The metabolites synthesized by spirulina, as well as the rest of its chemical composition, are influenced by physical and chemical factors that interact with the culture medium (Romero *et al,* 2018); obtain better results within the production of *Arthrospira,* the culture conditions should resemble the natural environment of cyanobacteria (Sandoval, D., 2017). Therefore, attention should be to the following parameters:

- Radiation: UV radiation causes damage to cyanobacteria, such as DNA degradation and inhibition of proteins, enzymes and pigments involved in photosynthesis (Hernández, F., 2016; Huarachi *et al*., 2015), particularly in spirulina, filament breakage and photoinhibition has been reported (Wu *et al*., 2005).

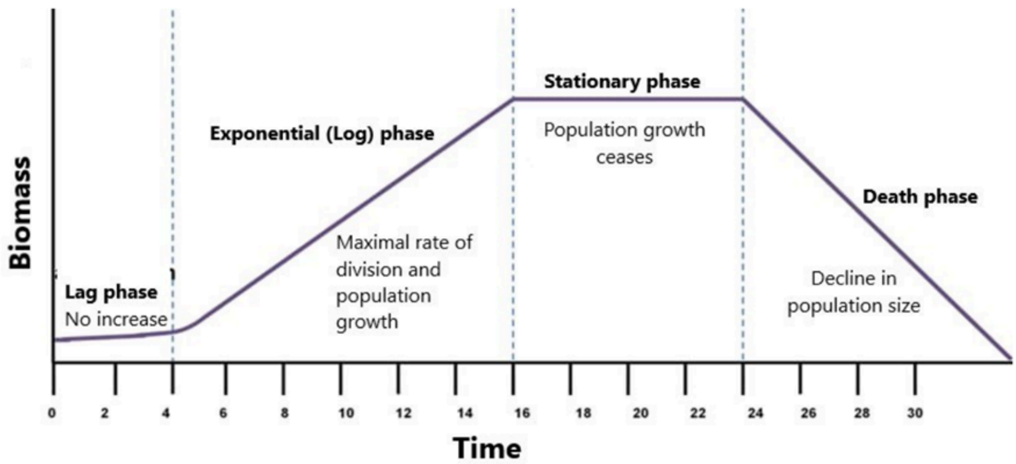

Figure 3: Growth curve of *Arthrospira.*

UV radiation also induces morphological changes in the shape, size and orientation of the *Arthrospira* spiral (Huarachi *et al*., 2015); these changes occur at different scales:

Short time (days): Trichome length decreases (breakage of filaments into small pieces).

Long time (years to decades): The filament compresses, resulting in self-shading and thus less photoinhibition; this adaptation generates an advantage in outdoor Spirulina cultivation (Wu *et al*., 2005).

- Photoperiod: Photoperiod is an essential factor, as it directly influences spirulina´s life cycles and metabolic activities (Bhat, O., *et al*., 2023; Vásquez *et al*., 2017). The growth of the alga is in the light (photosynthesis), but this does not mean that illumination performed 24 hours a day; on the contrary, if the photoperiod is long, spirulina is not able to withstand it, as the filaments destroyed by photolysis (Vásquez *et al*., 2017; Cárdenas *et al*., 2010); moreover, during periods of darkness, chemical reactions such as protein synthesis and respiration take place inside spirulina (Cárdenas *et al*., 2010). Therefore, they maintain a photoperiod with 12 hrs of light and 12 hrs of darkness with a light intensity between 2,000 and 5,000 lux, being these the adequate conditions to promote the photosynthetic process of this microalga (Villalba, C., 2018; Rodríguez and Triana, 2006).

- Temperature: The growth rate of spirulina is influenced by temperature (Park, J., *et al*., 2022); during the dark phase of photosynthesis, the respiration rate increases exponentially with the temperature. Maintaining a high temperature during this phase causes an increase in respiration rate and, therefore, biomass loss (Sandoval, D., 2017). The optimal range for developing *Arthrospira maxima* ranges from 15 to 35°C (Habib *et al*., 2008). Low temperatures about to the previous range do not kill the microalgae (Béchet, Q., *et al*., 2017); however, they can cause a decrease in growth (Romo, R., 2002).

- Agitation: Agitation is a significant factor in avoiding cell adhesion, allowing the homogeneous distribution of cells and nutrients within the culture, and improve the distribution of light to the cells. Thanks to agitation, the O_2 produced by the culture and the contribution of CO_2 for the realization of photosynthesis are eliminated (Hernández and Labbé, 2014; Sandoval, D., 2017).

Most systems used for microalgae cultivation implement aeration through centrifugal pumps or compressors as they provide less cell damage to microalgae (Romo, R., 2002; Sandoval, D., 2017), since if the agitation is excessive, it can damage the trichomes and reduce them in size, which will hinder their harvest (Sandoval, D., 2017). Is recommended that spirulina cultures maintain constant agitation with aeration of 0.025 vvm (volume of air per volume of medium per minute) (Villalba, C., 2018).

In other culture systems, such as circular tanks, agitation is performed by paddles and propellers rotating across the entire surface of the culture medium; this type of agitation is little used due to its high construction cost, high energy consumption and higher risk of cell damage (Hernández and Labbé, 2014).

- pH: The pH of the culture medium is influenced by several factors such as algal productivity, respiration, alkalinity and ionic composition of the culture medium (AlFadhly, N. K., *et al*., 2022; Hernández and Labbé, 2014); for the growth of *Arthrospira*, it is necessary to have alkaline waters whose hydrogen potentials (pH) have values between 8.5-11.5 (Torres and Correa, 2008; Habib *et al*., 2008).

The photosynthetic rate increases with alkaline pH; therefore, a decrease in pH causes reduction in algal growth (Sandoval, D., 2017). It is worth mentioning that maintaining pH at a high level also helps to control undesirable flocculation caused by excess production of exopolysaccharides (EPS) or their slow biodegradation (Cárdenas *et al*., 2010).

- Dissolved oxygen: Dissolved Oxygen (DO) is the amount of gaseous oxygen dissolved in water (Kazbar, A., *et al*., 2019). The concentration of this element result from the oxygen that enters the system (culture medium) and is consumed; this variable, like pH, is dependent on other variables associated with the crop. The intense photosynthesis carried out by microalgae during the day can saturate the oxygen input up to concentrations above 200 or 300% saturation, which decreases photosynthetic activity, affecting algae productivity; studies have determined that there is an approximate reduction of 17% in productivity (Hernández and Labbé, 2014).

- Nutrients: Nutrients are chemical compounds formed by molecules tightly bound to each other, necessary for the metabolism of microalgae. Some of the essential nutrients are oxygen (O), carbon (C), nitrogen (N), water (H_2O) and minerals such as phosphorus (P), magnesium (Mg), iron (Fe) and zinc (Zn), these nutrients supplied in a controlled manner and various forms (preferably in a soluble form), through the culture medium (Sandoval, D., 2017; Cárdenas *et al*., 2010).

Zarrouk medium: Zarrouk medium was the first synthetic medium formulated for the culture of *Arthrospira maxima* (Zarrouk, C., 1996) and frequently used during the isolation process (Rodriguez and Triana, 2006). Due to its international use, it is considered a standard medium for this species, industrial-scale production with this medium results in a high marketing price (Sandoval, D., 2017). The composition of a Zarrouk medium is shown in Table 2.

Table 2: Composition of Zarrouk medium for one liter of solution.
Source: (Sandoval, D., 2017; Camacho, A., 2016; Torres et al., 2008; Raoof et al., 2006)

Substance	Concentration (g/L)	Function
$NaHCO_3$	16.8	Carbon sources and regulates alkaline conditions in the crop.
Disodium EDTA	0.08	Chelating agent.
$NaNO_3$	2.5	Source of nitrogen, necessary for the formation of nucleic acids, proteins and other cellular components such as phycocyanin.
K_2SO_4	1	Source of sulfur and potassium necessary for the constitution of essential amino acids, proteins, enzymes, vitamins and sulfolipids, which help the algae to grow.
$NaCl$	1	Osmotic regulation and growth indicator (reduction in NaCl reflects a reduction in growth).
$MgSO_4 * 7H_2O$	0.2	Source of magnesium, vital for photosynthesis and catalase formation.
$CaCl_2$	0.04	Source of calcium, necessary for catalyzing enzymatic reactions and cell membrane activity.
$FeSO_4 * 7H_2O$	0.1	Source of sulfur, a constituent of essential amino acids, Vitamins and sulfolipids.
K_2HPO_4	0.5	Source of phosphorus and potassium, maintains high production rates, participates in intracellular energy transfer, synthesis of nucleic acids, proteins and cell division reactions.
H_3BO_3	2.86 E^{-06}	Buffering agent for pH regulation.
$MnCl_2 * 4H_2O$	1.81 E^{-06}	Increases enzymatic activity.
$CuSO_4 * 5H_2O$	2.22 E^{-07}	Aids algae growth.
MoO_3	1.50 E^{-08}	It acts in oxidation-reduction reactions.

6. Conclusion

Arthrospira offers many advantages, including its high nutritional value, low toxicity, availability of nutrients, rapid production of metabolites, low nutritional requirements for growth and adaptability to different habitats (freshwater, saltwater and terrestrial ecosystems).

Due to its increasing consumption in the population´s diet, expectation about this cyanobacterium have been increasing. Many bibliographic sources consider that more than the information on spirulina is needed to assign it a therapeutic role. However, many studies show that the metabolites, offer pharmacological properties and may constitute an alternative for treating some ailments.

It is worth mentioning that more clinical studies are needed to determine the effects of its metabolites, as a whole and in the long term; it would also be convenient to carry out research that involves increasing the concentration of the metabolites of interest to enhance their pharmacological effects.

References

Albuja, R. F., Araujo, P. A. y López A. C. (2011). Obtención de un biofertilizante a partir del residuo ultra fino de *Spirulina platensis*, mediante degradación anaerobia [Boletín técnico]. Repositorio Institucional de la Universidad de las Fuerzas Armadas ESPE. https://repositorio.espe.edu.ec/bitstream/21000/5015/2/T-ESPE-033046-A.pdf

AlFadhly, N. K., Alhelfi, N., Altemimi, A. B., Verma, D. K., and Cacciola, F. (2022). Tendencies affecting the growth and cultivation of genus Spirulina: An investigative review on current trends. Plants, 11(22), 3063.

Arahou, F., Lijassi, I., Wahby, A., Rhazi, L., Arahou, M., and Wahby, I. (2023). Spirulina-based biostimulants for sustainable agriculture: Yield improvement and market trends. BioEnergy Research, 16(3), 1401-1416.

Anupamaa and Ravindra, P. (2000). Value-added food: Single cell protein. Biotechnology Advances, 18(6), 459-479. DOI:10.1016/s0734-9750(00)00045-8

Assuncao, M. F., Batista, A. P., Amaral, R., and Santos, L. M. (2019). Microalgae for Human Nutrition: Perspectives for the Future. In Handbook of Algal Technologies and Phytochemicals (pp. 161-176). CRC Press.

Béchet, Q., Laviale, M., Arsapin, N., Bonnefond, H., and Bernard, O. (2017). Modeling the impact of high temperatures on microalgal viability and photosynthetic activity. Biotechnology for Biofuels, 10, 1-11.

Belay, A., Ota, Y., Miyakawa, K. and Shimamatsu H. (1993). Current knowledge on potential health benefits of Spirulina. Journal of Applied Phycology, volumen 5, 235–241. DOI: 10.1007/BF00004024

Belay, A. (2002). The Potential Application of Spirulina (Arthrospira) as a Nutritional and Therapeutic Supplement in Health ManagementThe potential application of Spirulina (Arthrospira) as a nutritional and therapeutic supplement in health management. Journal of the American Nutraceutical Association, 5, 27-48.

Bhat, O., Unpaprom, Y., and Ramaraj, R. (2023). Effect of photoperiod and white LED on biomass growth and protein production by Spirulina. Molecular Biotechnology, 1-9.

Camacho-Morales, A. S. (2016). Aislamiento y preservación Arthrospira (Spirulina) nativa de Jalisco [tesis de maestría, Instituto Tecnológico y de Estudios Superiores de Occidente]. Repositorio Institucional del ITESO https://rei.iteso.mx/bitstream/handle/11117/3547/RPAP%20Sof%C3%ADa%20Camacho%20Subido.pdf?sequence=2

Carbone, D. A., Pellone, P., Lubritto, C., and Ciniglia, C. (2021). Evaluation of microalgae antiviral activity and their bioactive compounds. Antibiotics, 10(6), 746.

Cárdenas-Nieto, J. D., Díaz-Bacca, M. F. y Vizcaíno-Wagner, M. (2010). Industrialización del alga Spirulina. ReCiTeIA ed. Cali: Universidad del Valle, 10(1), 1-41. https://www.researchgate.net/publication/259601864_Industrializacion_del_Alga _Spirulina

Chamorro, G., Salazar, M., Gomes de Lima Araujo, K., Pereira dos Santos, C., Ceballos, G. y Fabila-Castillo, L. (2002). Actualización en la farmacología de *Spirulina* (*Arthrospira*), un alimento no convencional. Archivos Latinoamericanos de Nutrición, 232-240. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S000406222002000300002

Chaumont, D. (1993). Biotechnology of algal biomass production: a review of systems for outdoor mass culture. Journal of Applied Phycology, 593–604. DOI: 10.1007/BF02184638

Cepoi, L., and Zinicovscaia, I. (2020). Spirulina platensis as a model object for the environment bioremediation studies. In Handbook of Algal science, technology and medicine (pp. 629-640). Academic Press.

Daki, S., Parmar, S., and Shrivastav, A. (2022). Nutraceutical and therapeutical potential of Spirulina. In Algae and Aquatic Macrophytes in Cities (pp. 349-360). Elsevier

Dhandayuthapani, K., Malathy, S., Mulla, S. I., and Gupta, S. K. (2021). An insight into the potential application of microalgae in pharmaceutical and nutraceutical production. Algae: Multifarious Applications for a Sustainable World, 135-179.

De Philippis, R., Margheri, M. C., Materassi, R. and Vincenzini, M. (1998). Potential of unicellular cyanobacteria from saline environments as exopolysaccharide producers. Applied and Environmental Microbiology, 64(3), 1130-2. DOI: 10.1128/AEM.64.3.1130-1132.1998

Dewi, I. C., Falaise, C., Hellio, C., Bourgougnon, N., and Mouget, J. L. (2018). Anticancer, antiviral, antibacterial, and antifungal properties in microalgae. In Microalgae in health and disease prevention (pp. 235-261). Academic Press.

El-Bialy, B. E., El-Boraey, N. G., Hamouda, R. A., and Abdel-Daim, M. M. (2019). Comparative protective effects of Spirulina and Spirulina supplemented with thiamine against subacute carbon tetrachloride toxicity in rats. Biomedical and Pharmacology Journal, 12(2), 511-525.

Elmore, S. A. and Boorman, G. A. (2013). Environmental Toxicologic Pathology and Human Health. En Haschek and Rousseaux's Handbook of Toxicologic Pathology (Haschek, W. M., Rousseaux, C. G. and Wallig, M. A., eds., 3.ª ed., vol. 2, 1029-1049). Academic Press. DOI:10.1016/C2010-1-67850-9

El-Sheekh, M., and Abomohra, A. E. F. (2020). The therapeutic potential of spirulina to combat COVID-19 infection. Egyptian Journal of Botany, 60(3), 605-609.

Furmaniak, M. A., Misztak, A. E., Franczuk, M. D., Wilmotte, A., Waleron, M., and Waleron, K. F. (2017). Edible cyanobacterial genus Arthrospira: Actual state of the art in cultivation methods, genetics, and application in medicine. Frontiers in Microbiology, 8, 2541.

Glazer, A. (1994). Phycobiliproteins A Family of Valuable, Widely Used Fluorophores. Journal of Applied Phycology, 6(2), 105- 112. DOI: 10.1007/BF02186064

Godlewska, K., Michalak, I., Pacyga, P., Baśladyńska, S. and Chojnacka, K. (2019). Potential applications of cyanobacteria: Spirulina platensis filtrates and homogenates in agriculture. World Journal of Microbiology and Biotechnology, 35(6). DOI: 10.1007/s11274-019-2653-6

González, R., Rodríguez, S., Romay, C., Ancheta, O., González, A., Armesto, J. Remirez, D. and Merino, N. (1999). Anti-inflammatory activity of phycocyanin extract in aceticinduced colitis in rats. Pharmacological Research, 39(1), 55-59. DOI:10.1006/phrs.1998.0409

Gutiérrez-Salmeán, G., Fabila-Castillo, L. and Chamorro-Cevallos, G. (2015). Nutritional and toxicological aspects of Spirulina (Arthrospira). Nutrición Hospitalaria, 32(1), 34-40. DOI:10.3305/nh.2015.32.1.9001

Habib, M. A. B., Parvin, M., Huntington T. C. and Hasan, M. R. (2008). A review on culture, production and use of Spirulina as food for humans and feed for domestic animals and fish. FAO Fisheries and Aquaculture Circular No.1034. Rome, 1-22 páginas. http://www.fao.org/3/a-i0424e.pdf

Hauer, T. y Komárek, J. (2020). CyanoDB (version 2.0) [base de datos]. - On-line database of cyanobacterial genera. - World-wide electronic publication, Univ. of South Bohemia & Inst. of Botany AS CR. http://www.cyanodb.cz.

Hayashi, K., Hayashi, T. and Kojima, I. (2009). A Natural Sulfated Polysaccharide, Calcium Spirulan, Isolated from Spirulina platensis: In Vitro and ex Vivo Evaluation of Anti-Herpes Simplex Virus and Anti-Human Immunodeficiency Virus Activities. AIDS Research and Human Retroviruses, 12(15). DOI:10.1089/aid.1996.12.1463

Hayakawa, Y., Hayashi, T., Hayashi, K., Hayashi, T., Ozawa, T., Niiya, K and Sakuragawa, N. (1996). Heparin cofactor II-dependent antithrombin activity of calcium spirulan. Blood Coagulation & Fibrinolysis, 7(5), 554-560. DOI:10.1097/00001721- 199607000-00007

Henrikson, R. (1994) Microalga Spirulina: Superalimento del futuro. Ediciones Urano, S.A.

Hernández-Pérez, A. and Labbé, J. I. (2014). Microalgas, cultivo y beneficios. Revista de Biología Marina y Oceanografía, 49(2), 157-173. DOI: 10.4067/S0718-19572014000200001

Hernández-Uribe, F. (2016). Efecto de la deficiencia de nitrógeno y la radiacón UV en la actividad fotosintética y en los compuesstos antioxidantes de las cianobacterias Spirulina (Arthrospira) maxima y Phormidium persicinum [tesis de maestría, Centro de Investigaciones Biológicas del Noroeste, S.C.]. Repositorio del Centro de Investigaciones Biológicas del Noroeste. http://dspace.cibnor.mx:8080/bitstream/handle/123456789/496/hernandez_f.pdf?sequence=1&isAllowed=y

Hernández-Reyes, B. M., Rodríguez-Palacio, M.C., Castilla-Hernández P., Sánchez-Robles, J., Vela-Correa, G. y Schettino-Bermúdez, B. (2019). Uso potencial de cianobacterias como biofertilizante para el cultivo de maíz azul en la Ciudad de México. Revista Latinoamericana de Biotecnología Ambiental y Algal, 10 (1), 13-27.

Huarachi-Olivera, R., Yapo-Pari, Ú., DueñasGonza, A., Condori-Huamanga, J., Pacheco-Salazar, D.G. y Soto-Flores, J. (2015). Cultivo de Arthrospira platensis (Spirulina) en fotobiorreactor tubular doblemente curvado a condiciones ambientales en el sur del Perú. Revista Colombiana de Biotecnología, 17(1), 142-149. DOI:10.15446/rev.colomb.biote.v17n1.50679

Iwasa, M., Yamamoto, M., Tanaka, Y., Kaito, M., and Adachi, Y. (2002). Spirulina-Associated hepatotoxicity. The American Journal Of Gastroenterology, 97(12), 3212-3213. DOI: 10.1111/j.1572-0241.2002.07145.x

Kazbar, A., Cogne, G., Urbain, B., Marec, H., Le-Gouic, B., Tallec, J., .and Pruvost, J. (2019). Effect of dissolved oxygen concentration on microalgal culture in photobioreactors. Algal Research, 39, 101432.

Kapoor, R. and Mehta, U. (1998). Supplementary effect of Spirulina on hematological status of rats during pregnancy and lactation. Plant Foods for Human Nutrition, 52, 315–324. DOI:10.1023/A:1008027408919.

Komárek, J., Kaštovský, J., Mareš, J., Johansen, J.R. (2014): Taxonomic classification of cyanoprokaryotes (cyanobacterial genera) 2014, using a polyphasic approach. Preslia, volume 86, 295–335. Consultado el 13 de abril de 2020. http://www.preslia.cz/P144Komarek.pdf

Kraigher, O., Wohl, Y., Gat, A., and Brenner, S. (2007). A mixed immunoblistering disorder exhibiting features of bullous pemphigoid and pemphigus foliaceus associated with Spirulina algae intake. International Journal Of Dermatology, 47(1), 61-63. DOI: 10.1111/j.1365-4632.2007. 03388.x

Kronick, M. N. (1986). The use of phycobiliproteins as fluorescent labels in immunoassay. Journal of Immunological Methods, 92(1), 1-13. DOI:10.1016/0022- 1759(86)90496-5

Lee, A. N., and Werth, V. P. (2004). Activation of Autoimmunity Following Use of Immunostimulatory Herbal Supplements. Archives Of Dermatology, 140(6). DOI: 10.1001/archderm.140.6.723

Le, T., Knulst, A. C., and Röckmann, H. (2014). Anaphylaxis to Spirulina confirmed by skin prick test with ingredients of Spirulina tablets. Food And Chemical Toxicology, 74, 309-310. DOI: 10.1016/j.fct.2014.10.024

Licett, B., Guevara, M., Lemus, N., Freites, L., Romero, L., Lodeiros, C. and Arredondo, B. (2014). Crecimiento y composición bioquímica de Arthrospira platensis (division Cyanophyta) cultivada a diferentes salinidades y fuentes de nitrógeno. Boletín del Instituto Oceanográfico de Venezuela,53(1),3-13. https://cibnor.repositorioinstitucional.mx/jspui/handle/1001/1268

Marles, R. J., Barrett, M., Barnes, J., Chavez, M. L., Gardiner, P., Ko, R., Mahady, G. B., Dog, T. L., Sarma, N. D., Giancaspro, G. I., Sharaf, M. H. M., and Griffiths, J. C. (2011). United States Pharmacopeia Safety Evaluation of Spirulina. Critical Reviews In Food Science And Nutrition, 51(7), 593-604. DOI: 10.1080/10408391003721719

Mata-Gómez, J. A. (2006). Caracterización de los exopolisacáridos producidos por microorganismos halófilos pertenecientes a los géneros Halomonas, Alteromonas, Idiomarina, Palleronia y Salipiger [tesis de doctorado, Universidad de Granada]. Semantic Scholar https://pdfs.semanticscholar.org/2a7f/f327d9bfc3c8ab342d77d5f9de8921b32ddc.pdf?ga=2.102246600.832486348.15870608301919408055.1565391181

Mazokopakis, E. E., Karefilakis, C. M., Tsartsalis, A. N., Milkas, A., and Ganotakis, E. S. (2008). Acute rhabdomyolysis caused by Spirulina (Arthrospira platensis). Phytomedicine, 15(6-7), 525-527. DOI: 10.1016/j.phymed.2008.03.003

Mínguez-Mosquera, M. I., Pérez-Gálvez, A. y Hornero-Méndez, D. (2005). Pigmentos carotenoides en frutas y vegetales; mucho más que simples "colorantes" naturales, 2-7. Repositorio institucional del Consejo Superior de Investigaciones Científicas https://digital.csic.es/bitstream/10261/57 54/1/IG_AGROCSIC_4.pdf

Miranda, M. M., Cintra, R.G., Barros, S. B., and Mancini-Filho, J. (1998). Antioxidant activity of the microalga Spirulina maxima. Brazilian Journal of Medical and Biological Research, 31(8), 1075-1079. DOI:10.1590/S0100- 879X1998000800007

Mishima, T., Murata, J., Toyoshima, M., Fujii, H., Nakajima, M., Hayashi, T., Kato, T. and Saiki, I. (1998). Inhibition of tumor invasion and metastasis by calcium spirulan (Ca-SP), a novel sulfated polysaccharide derived from a blue-green alga, Spirulina platensis. Clinical & Experimental Metastasis, 16(6), 541– 550. DOI:10.1023/a:1006594318633.

Moreno-García, F. E. (2016). Obtención de un biofertilizante a partir del cultivo de Spirulina platensis en aguas residuales domésticas provenientes del campamento de la estación de bombeo de crudo Rubiales [tesis de maestría, Universidad de Manizales]. Repositório Institucional Universidad de Manizales.
http://ridum.umanizales.edu.co:8080/xml ui/handle/6789/3059

Naranjo, L., Rojas, D., González, H., Parra, R., Narro, J., Sena-D'Anna, L. y Sosa, D. (2010). Arthrospira platensis como biofactoría de metabolitos secundarios de interés farmacológico: el ácido pipecólico. Revista Latinoamericana de Biotecnología ambiental y algal, 1(1), 64-90.
https://www.researchgate.net/publication/268224097_Arthrospira_platensis_como_biofactoria_de_metabolitos_secundarios_de_interes_farmacologico_el_acido_ pipecolico

Nwoba, E. G., Ogbonna, C., Ishika, T., and Vadiveloo, A. (2020). Microalgal Pigments: A Source of Natural Food Colors. 10.1007/978-981-15-0169-2_3.

Park, J., Lee, H., Dinh, T. B., Choi, S., De Saeger, J., Depuydt, S., .and Han, T. (2022). Potencial comercial de la cianobacteria Arthrospira maxima: rasgos fisiológicos y bioquímicos y purificación de ficocianina. Biología, 11(5), 628.

Pineda-Mendoza, R., Martínez-Jerónimo, F., Garduño-Solórzano, G. y Olvera-Ramírez, R. (2011). Caracterización morfológica y molecular de cianobacterias filamentosas aisladas de florecimientos de tres lagos urbanos eutróficos de la ciudad de México. Polibotánica no. 31. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-27682011000100003

Piñero-Estrada, J. E., Bermejo-Bescós, P. and Villar del Fresno, A. M. (2001). Antioxidant activity of different fractions of *Spirulina* platensis protean extract Il. Il Farmaco, 56(5-7), 497-500. DOI:10.1016/S0014-827X(01)01084-9

Ponce-López, E. (2013). Superalimento para un mundo en crisis: *Spirulina* a bajo costo. IDESIA, 31(1), 135-139. DOI: 10.4067/S0718-34292013000100016

Ramírez-Moreno, L. and Olvera-Ramírez, R. (2006). Uso tradicional y actual de *Spirulina* sp. (*Arthrospira* sp.). Interciencia, 31(9), 657-663. https://www.redalyc.org/pdf/339/339120 09.pdf

Raoof, B., B.D.Kaushik, B. D. and Prasanna, R. (2006). Formulation of a low-cost medium for mass production of *Spirulina*. Biomass and Bioenergy, 30(6), 537-542. DOI: 10.1016/j.biombioe.2005. 09.006

Richmond, A. (2017). Microalgae of economic potential. In Handbook of Microalgal Mass Culture (1986) (pp. 199-244). CRC press.

Rodríguez-Cuesta, A. R. and Triana-Serrano, F. C. (2006). Evaluación del pH en el cultivo de Spirulina spp.(=Arthrospira) bajo condiciones de laboratorio [tesis de licenciatura, Pontificia Universidad Javeriana]. Repositorio de Pontificia Universidad Javeriana. https://repository.javeriana.edu.co/bitstream/handle/10554/8281/tesis261.pdf?sequence=1&isAllowed=y

Romay, C., Armesto, J., Remirez, D., González, R., Ledon, N. and García, I. (1998) Antioxidant and anti-inflammatory properties of C-phycocyaninfrom blue-green algae. Inflammation Research, 47, 36-41. DOI: 10.1007/s000110050256

Romero-Maza, L., Guevara, M., Gómez, B., Arredondo-Vega, B., Cortez, R. and Licef, B. (2017). Producción de pigmentos procedentes de Arthrospira maxima cultivada en fotobiorreactores. Revista Colombiana de Biotecnología, 19(1), 108-114. DOI: 10.15446/rev.colomb.biote.v19n1.59671

Romero-Maza, L., Guevara, M. y Bernal, J. F. (2018). Crecimiento y pigmentos de Spirulina subsalsa cultivada a diferentes salinidades y concentraciones de nitrógeno. Revista Mutis, 8(2), 25-36. DOI: 10.21789/22561498.1402

Romo-Piñera, R. P. (2002). Manual para el cultivo de microalgas [tesis de licenciatura, Universidad Autónoma de Baja California Sur]. Biblioteca Central UABCS. http://biblio.uabcs.mx/tesis/TE1366.pdf

Saber, A. A., El-Refaey, A. A., Saber, H., Singh, P., van Vuuren, S. J., and Cantonati, M. (2022). Cyanoprokaryotes and algae: classification and habitats. In Handbook of Algal Biofuels (pp. 1-38). Elsevier.

Sánchez, M., Bernal-Castillo, J., Rozo, C. and Rodríguez, I. (2003). Spirulina (Arthrospira): An edible microorganism. A review. Universitas Scientiarum, 8(1), 7-24. https://revistas.javeriana.edu.co/index.php/scientarium/article/view/4842/0

Sandoval-Simbaña, D. C. (2017). Evaluación del crecimiento de espirulina (Arthrospira platensis) mediante alternativas de fertilización orgánica e inorgánica y su masificación en condiciones de campo en la Hda. El Prado [tesis de licenciatura, Universidad de las Fuerzas Armadas]. Repositorio Institucional de la Universidad de las Fuerzas Armadas ESPE. http://repositorio.espe.edu.ec/handle/21000/14508

Schwartz, J. and Shklar, G. (1987). Regression of experimental hamster cancer by beta caroteno and algae extracts. Journal of Oral and Maxillofacial Surgery, 45(6), 510-515. DOI:10.1016/S0278-2391(87)80011-3

Schwartz, J., Shklar, G., Reid, S. and Trickler, D. (1988). Prevention of experimental oral cancer by extracts of Spirulina-Dunaliella algae. Nutrition and Cancer, 11(2), 127-134. DOI:10.1080/01635588809513979

Singab, A. N., Ibrahim, N., Elsayed, A. E. K., El-Senousy, W., Aly, H., Abd Elsamiae, A., and Matloub, A. A. (2018). Antiviral, cytotoxic, antioxidant and anti-cholinesterase activities of polysaccharides isolated from microalgae Spirulina platensis, Scenedesmus obliquus and Dunaliella salina. Archives of Pharmaceutical Sciences Ain Shams University, 2(2), 121-137.

Singh, S., Dwivedi, V., Sanyal, D., and Dasgupta, S. (2020). Therapeutic and nutritional potential of Spirulina in combating COVID-19 infection. AIJR Preprints, 49(1), 2-8.

Sili, C., Torzillo, G. and Vonshak, A. (2013). Arthrospira (Spirulina). En Whitton, B. A. (Ed.). Ecology of Cyanobacteria II: Their Diversity in Space and Time (pp. 677-705) Springer, Dordrecht. DOI: 10.1007/978-94-007-3855-3

Tomaselli, L. (2002). Morphology, Ultrastructure and Taxonomy of Arthrospira (Spirulina) maxima and Arthrospira (Spirulina) platensis. En Spirulina platensis (Arthrospira): Physiology, Cell-biology and Biotechnology (Vonshak, A, ed.). Taylor & Francis e-Library.

Torres-Durán, P. V., Miranda-Zamora, R., Paredes-Carbajal, M. C., Mascher, D., Díaz-Zagoya, J. C. and Juárez-Oropeza, M. A. (1998). Spirulina maxima prevents induction of fatty liver by carbon tetrachloride in the rat. Biochemistry and Molecular Biology International, 44(4), 787-793. DOI: 10.1080/15216549800201832

Torres-Urango, B. D. and Correa-Trujillo, D. (2008). Diseño conceptual de un proceso de cultivo y obtención de Cyanobacteria Arthrospira platensis [tesis de licenciatura, Universidad EAFIT], Repositorio Institucional Universidad EAFIT. https://repository.eafit.edu.co/items/18f622b6-2484-44ea-ad2d-6f3c911ecea0

Vásquez-Villalobos, V., Vergaray, D., Méndez, J., Barrios, I., Baquedano, R., Caldas, C., Cruz, J., Gamboa, J. and Rivera, I. (2017). Efecto de la intensidad de diodos electroluminosos y fotoperiodo en la optimización de la producción de biomasa de Spirulina (Arthrospira). Scientia Agropecuaria, 8(1), 43-55. DOI: 10.17268/sci.agropecu. 2017.01.04

Villalba-Alderete, C. I. (2018). Bioprospección de Arthrospira platensis nativa del chaco Paraguayo como propuesta alternativa para fines alimentarios [tesis de maestría, Universidad Nacional de Itapúa]. CONACYT.https://www.conacyt.gov.py/sites/default/files/tesis_claravillalba.pdf

Vonshak, A. (1997). *Spirulina:* Growth, Physiology and Biochemistry. En Vonshak, A. (1997). *Spirulina Platensis* (*Arthrospira*): Physiology, Cell-Biology and Biotechnology (pp. 43-65). Taylor & Francis e-Library.

Vonshak, A. and Tomaselli, L. (2000). Arthrospira (Spirulina): Systematics and Ecophysiology. En The Ecology of Cyanobacteria. Kluwer Academic Publishers. 505-522.

Wu, H., Gao, K., Villafañe, V. E., Watanabe, T. and Helbling, E. W. (2005). Effects of Solar UV Radiation on Morphology and Photosynthesis of Filamentous Cyanobacterium Arthrospira platensis. Applied and Environmental Microbiology, 71(9), 5004-5013. DOI: 10.1128/AEM.71.9.5004- 5013.2005

Zarrouk, C. (1966). Contribution to the study of a Cyanophyceae influence of various physical and chemical factors on growth and phototsynthesis Spirulina maxima. Setch. and Gardner, Geithner [tesis de doctorado, University of Paris], 74 página. https://scielo.conicyt.cl/scielo.php?script=sci_nlinks&ref=5001899&pid=S0718560X2012000300023000026&n