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USE OF MICROALGAE AND POTENTIAL NANOTECHNOLOGICAL APPLICATION: A REVIEW[1]

USO DAS MICROALGAS E POTENCIAL APLICAÇÃO NANOTECNOLÓGICA: UMA REVISÃO

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ABSTRACT

Microalgae are eukaryotic and unicellular microorganisms of simple structure, colonial that need for their growth and reproduction, light, water, carbon dioxide and inorganic nutrients. Demonstrate commercial interest due to a biomass rich in bioactive substances, such as pigments, lipids, polyunsaturated fatty acids, carbohydrates, proteins, and vitamins. Among these substances, Chlorella microalgae oil contains lipids with a wide range of interesting properties. In this context, the present review aims to demonstrate the potential and applications of microalgae, mainly of the Chlorella species, as well as the methods and conditions of cultivation, the chemical composition, and its relationship with nanotechnology. The data for this review were obtained from a search in the main databases such as Scielo, Scopus and Science Direct, without restriction to the period of publication, using following descriptors: microalgae, Chlorella, biomass, oil, application, nanotechnology and their combinations. These microorganisms, as they are easy to cultivate and rapidly proliferate, are gaining ground in the area of new technologies involving species of the Chlorella type, which has several applications, including in the nutraceutical and cosmetics area, guaranteeing products with quality, efficacy and biodegradable assets.

Keywords: Biomass, Chlorella, Cosmetics, Microalgae, Nanotechnology.

RESUMO

As microalgas são microrganismos eucariontes e unicelulares de estrutura simples, coloniais e que necessitam, para seu crescimento e reprodução, luz, água, dióxido de carbono e nutrientes inorgânicos. Demostram interesse comercial em função de uma biomassa rica em substâncias bioativas, como pigmentos, lipídios, ácidos graxos poli-insaturados, carboidratos, proteínas e vitaminas. Dentre estas substâncias o óleo da microalga do tipo Chlorella contém lipídios com uma ampla gama de propriedades interessantes. Neste contexto, a presente revisão tem por objetivo demonstrar as potencialidades e aplicações das microalgas, principalmente da espécie Chlorella, bem como os métodos e condições de cultivo, a composição química e sua relação

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com a nanotecnologia. Os dados para esta revisão foram obtidos a partir de uma pesquisa nas principais bases de dados como Scielo, Scopus e Science Direct, sem restrição ao período de publicação, utilizando os seguintes descritores: microalgas, Chlorella, biomassa, óleo, aplicação, nanotecnologia e suas combinações. Estes microrganismos por serem de fácil cultivo e rápida proliferação estão ganhando espaço na área de novas tecnologias envolvendo as espécies do tipo Chlorella, a qual possui diversas aplicações, inclusive na área nutracêutica e de cosméticos, garantindo produtos com ativos de qualidade, eficácia e biodegradáveis.

Palavras-chave: *Biomassa, Chlorella, Cosméticos, Microalga, Nanotecnology.*

INTRODUCTION

Microalgae are photosynthetic single-celled microorganisms that form colonies or filaments and belong to various divisions of algae such as Chlorophyta, Charophyta, or also called green algae, in which chlorophyll is one of its main pigments, the species *Haematococcus, Chlorella, Dunaliella, Graesiella, Scenedesmus* are some examples of this type of algae (TAN *et al*., 2020). These single-celled microorganisms can be found in different habitats, both in seawater and fresh water (RANDRIANARISON; ASHRAF, 2017).They are also considered as raw material for food, feed, fuel, fertilizers, chemicals, and other value-added products, as they have a rapid growth rate and valuable intracellular components (JING-HAN *et al*., 2018).

Microalgae can convert solar energy and carbon dioxide into high levels of secondary lipids and carotenoids in their biomass. These microorganisms are emerging as a factory of important and economical cells to produce commercial products, such as carotenoids (BOROWITZKA, 2013) and fatty acids (MENDES *et al*., 2008). These microalgae exhibit great biomass production compared to terrestrial plants in relation to the surface area needed to grow them, demonstrating that they represent a lower cost per production (CHIU *et al*., 2015; BEKIROUGULLARI *et al*., 2018). They also have advantages over other crops, such as high growth rate, short growth period and low land use (SANYANO *et al*., 2013).

Microalgae have long been explored, being sources of colloids used as thickeners, gelling agents, and stabilizers in the food industry, both human and animal. Due to its chemical composition, its applicability includes from aquaculture, wastewater treatment (JING-HAN *et al*., 2018), energy production (BIANCHINI *et al*., 2006; YANG *et al*., 2018) to cosmetics (SPOLAORE *et al*., 2006; LEE *et al*., 2018). Furthermore, microalgae also stand out for their biotechnological potential, for the identification of substances extracted by these algae (SPOLAORE *et al*., 2006; BIANCHINI *et al*., 2006; CARDOZO *et al*., 2007; BECKER, 2007).

The literature describes that microalgae perform very well in several areas where they are applied, with concentrations of valuable compounds found in their dry biomass, which is generated in laboratory experiments (CUELLAR-BERMUDEZ *et al*., 2014). These compounds have a high commercial value, since the biomass of microalgae contains: polyunsaturated fatty acids, carotenoids

(CHEN; LIU, 2018), phycobilins, polysaccharides, vitamins, steroids (LEVASSEUR *et al.*, 2020) and other bioactive compounds, such as antioxidants and cholesterol, for example (YAÑEZ, 2006; BIANCHINI *et al.*, 2006; CARDOZO *et al.*, 2007; BECKER, 2007), which arouse great interest in the production of natural products, both in food and in cosmetics (MILLEDGE, 2011).

Based on the above, this review aims to highlight the use of microalgae in general, but also in particular *Chlorella*, in various scientific researches, both on a laboratory and industrial scale, as well as describing their various applications, cultivation conditions, biochemical composition and their relationship with nanotechnology.

METHODOLOGY

To carry out this review, a bibliographic search was performed on the materials of the scientific literature, featuring a bibliographic review (GIL, 2002).

The scientific materials found were analyzed in four stages of reading: exploratory, selective, analytical and finally interpretive (GIL, 2002).

The research was carried out in the main electronic databases, such as Scielo, Science Direct, Scopus, Google Scholar, with the following keywords: “MICROALGAS”, “*CHLORELLA*”, “BIOMASSA”, “OIL”, “APPLICATION”, “NANOTECHNOLOGY”, “COSMETICS” and their combinations, in Portuguese and English, without restriction of the publication period.

DEVELOPMENT

Microalgae

Microalgae are called single-celled aquatic microorganisms that are found both in fresh water and in marine systems (DANESHVAR *et al.*, 2018), capable of photosynthesis (SHUBA; KIFLE, 2018) and are found in many shapes and sizes , which range from three to ten micrometers (VU *et al.*, 2018). Its growth can occur as individual cells or associated in chains, as well as in small colonies (POSTMA *et al.*, 2016), play an important role in aquatic ecosystems due to their photosynthetic capacity (MALCATA *et al.*, 2018).

There are a variety of microalgae species evaluated, but still considered restricted, compared to the 40,000 that had their names published (GUIRY, 2012). Researchers have focused on those that showed high protein content (‘t LAM *et al.*, 2018), ability to produce carotenoids and fatty acids (PERIN *et al.*, 2019) and several other high-value products (‘t LAM *et al.*, 2018).

With a short life cycle (which may vary from hours to days), a high rate of nutrient absorption (LEHMUSKERO *et al.*, 2018) and a capacity for growth in both fresh and marine waters

(DANESHVAR *et al*., 2018), microalgae allow researchers to screen a variety of species in miniaturized systems, thereby reducing development costs and intensifying the process. Such characteristics, associated with its high photosynthetic efficiency and the possibility of cultivation in mixotrophic or heterotrophic modes, are its main advantages compared to other organisms that perform photosynthesis (MORALES-SÁNCHEZ *et al*., 2017).

The cultivation of microalgae can be based on a variety of methods, from strictly controlled methods that can be photobioreactors, closed systems, as well as those in open systems that are more susceptible to environmental conditions (CONTRERAS-FLORES *et al*., 2003; TREDICI, 2004; POSTEN, 2009).

Some species of microalgae used as inputs in skin and hair care products, including extracts of *Spirulina*, *Chlorella*, *Dunaliella* and *Nanochloropsis*. More specifically, carotenoids such as astaxanthin, β-carotene and lutein can be included as part of topical cosmetic products to protect against hyperpigmentation or damage induced by ultraviolet rays (WANG *et al*., 2015; MOURELLE *et al*., 2017).

Dunaliella and *Chlorella* species do not produce toxic substances and are classified as safe food and some of the main species for animal and human consumption (WALKER *et al*., 2005). Thus, microalgae can be applied in nutritional and biomedical areas and are associated with therapeutic properties such as antioxidants, anti-inflammatory, anti-tumor, anti-obesity (PENG *et al*., 2011; GAMMONE; D'ORAZIO, 2015), immunostimulants and antivirals (YAAKOB *et al*., 2014).

Cultivation methods and conditions

Microalgae can be grown in both open and closed systems. Open systems are the simplest and have a low installation cost, they can be ponds, without any mechanical apparatus and these systems are generally made of materials such as sand, brick, cement, fiberglass and high density polyethylene (HDPE) or polyvinyl chloride (PVC) (CHISTI, 2007; BRENNAN; OWENDE, 2010).

Among closed systems, photobioreactors stand out as the main system for cultivating microalgae on a large scale (BJERK, 2012). Photobioreactor is a transparent reactor made of glass or plastic, and can have several geometries (BITOG *et al*., 2011; TAMBURIC *et al*., 2011), the tubular being the most conventional, with the layout planned in order to minimize the exposure of biomass to light. The main characteristic is the control of almost all biotic and abiotic parameters of microalgae cultivation such as pH, temperature, agitation and aeration speed, nutrition, light intensity, which influence other factors (VOLOSHIN *et al*., 2016).

The development and growth of microalgae depends on the interaction between some factors, such as: biological, chemical, and physical, in which, biological factors are associated with the metabolic rates of the species under cultivation (RICHMOND, 2004).

Chemical factors such as nutrient availability, salinity and pH are the parameters that most interfere with the development of microalgae. For optimal growth and development of microalgae, additions of macronutrients (C, N, O, H, Ca, Mg, S and K), micronutrients (Mn, Mo, Fe, Co, Cu, Zn, Se and B), in addition to vitamins or specific substances that some species need (OSHE *et al.*, 2007; OLIVEIRA, 2009). Carbon is considered the most important macronutrient, however, nitrogen and phosphorus are the limiting nutrients for the cultivation of microalgae (OSHE *et al.*, 2007), potentiating the production of biomass and lipids in different concentrations of these nutrients (MATOUKE *et al.*, 2018).

In studies carried out with microalgae cultivation by Kumar and collaborators (2018), the authors demonstrated that the C/N ratio is an indicator of bioconversion reactions. In this research they discovered a C/N ratio of 6.3 in a microalgae biomass concentration of 5 g/L. They were also evaluated under other conditions, and the C/N ratio ranged from 5.9 to 6.1, these values being like those found in the scientific literature with cultivation of *Arthrospira platensis* algae biomass. In general, the biomass of microalgae tends to have a high protein content instead of carbohydrates and the C/N ratio is partially lower than the biomass of macroalgae, with the maximum carbohydrate content being associated with biomass. For *Chlorella sp.* , studies have shown values of 44.5% C, 6.2% H, 9.6% N and a C/N ratio of 4.63%, these values being higher than those found in terrestrial plants (THANGALAZHY-GOPAKUMAR *et al.*, 2012).

Through experiments, it was found that the *Chlorella* strain can accumulate significant amounts of lipids under a condition of high salinity stress, but in return causes a limitation in the biomass production of this microalgae (KAKARLA *et al.*, 2018).

In relation to pH, the control of this parameter is essential for the cultivation of microalgae, as it directly affects the availability of various chemical elements, influencing the absorption of nutrients from the culture medium by microalgal cells. It should be noted that different species of algae exhibit different levels of tolerance to the pH of the culture medium, affecting their growth rate, but the most common pH range for microalgae can vary from 6 to 8 (ZHU, 2015; RAI; GUPTA, 2017).

Parameters such as light and temperature are physical factors that also affect the development and growth of microalgae. Many microalgae species are photoautotrophic, that is, they can convert sunlight into energy and use the inorganic carbon necessary for building biomass through photosynthesis (DERNER *et al.*, 2006; OHSE *et al.*, 2007). Therefore, the intensity of light plays an extremely important role in the development of microalgae, the control of luminosity is directly linked to the carbon that will be fixed, influencing the growth rate of the crops (FONTOURA *et al.*, 2017). In a study by Sang-Il *et al.* (2019), it was found that when evaluating different growing conditions such as the intensity of LED lights (blue, red and white), in the cultivation of microalgae different yields of β-carotene were obtained.

Temperature is another parameter that must be observed, and should be monitored in small-scale crops grown in air-conditioned rooms, but for crops grown outdoors there are variations between day and night cycles, in addition to seasonal differences, causing difficulty in the reproducibility of the animals. growth results for the same species, even under apparently equivalent growing conditions (LOURENÇO, 2006). The temperature for cultivating microalgae can vary in a range between 28 and 35 ˚C (PARK *et al.*, 2011).

Militão and collaborators (2019) conducted a study with the objective of evaluating the development of three types of microalgae species in unialgal and mixed crops, at different temperatures, 20, 30 and 40 ˚C, on a laboratory scale in order to analyze the biomass and the biochemical composition. The results showed that at 40 ˚C there was no cell growth of the cultivated strains, at 30 ˚C, obtained cell density of 13.6×10^6 cell. mL^{-1} and biomass of 55 g. L^{-1} in one of the species in the unialgal culture. High protein concentrations (672.6 mg. g^{-1}) were also observed in the unialgal cultures of two of the three cultivated species, at a temperature of 20 ˚C and of carbohydrates (6.17 mg. g^{-1}) only in unialgal culture of one species in 30 ˚C.

Composition of microalgae

From microalgae, natural bioactive compounds can be extracted (XU *et al.*, 2009) such as pigments, lipids, polyunsaturated fatty acids, carbohydrates, proteins, and vitamins (GONG; BASSI, 2016).

Microalgae are able to produce more lipids than any other conventional crop, in addition, numerous other species can produce large amounts of essential fatty acids (EFA), especially omega-3 (ω-3) and 6 (ω-6), which they are the two most abundant fatty acids, as well as α-linolenic acid (ALA, C18: 3 ω-3) and linoleic acid (Al, C18: 2 ω-6) (HO *et al.*, 2014; BELLOU *et al.*, 2016), both precursors in the human body for long-chain polyunsaturated fatty acids (≥ C20) (PUFA) (RINCÓN-CERVERA *et al.*, 2016).

Chen *et al.* (2011) highlight that the lipid content of microalgae is not the only factor that determines their oil production capacity, according to these authors, the lipid content and biomass production need to be considered simultaneously. Therefore, the lipid productivity that represents the combined effect of these two factors mentioned is the most appropriate performance index to indicate the productive capacity of lipids by a microalgae.

In general, microalgae present on average 27% of the dry cell weight in oil, a percentage that can double or even triple when grown under stress conditions (photo-oxidative or lack of specific nutrients) (BASOVA, 2005).

The microalgae have their oil composed mainly of a mixture of unsaturated fatty acids, although saturated fatty acids are also present, but in a smaller amount (BJERK, 2012). According to Arceo (2012), in some species, polyunsaturated fatty acids can reach between 25% and 60% of total lipids.

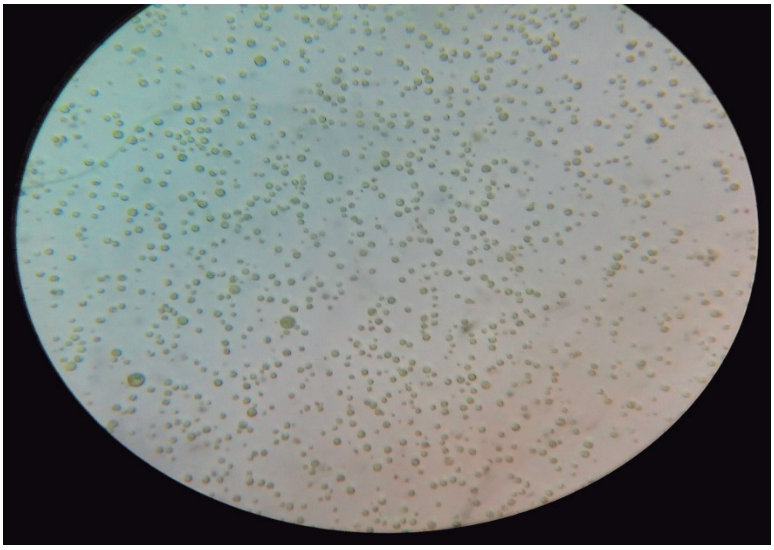
The oil extracted from the microalgae has aroused great interest in both the academic and industrial fields, since biodiesel can also be produced from this oil, due to the high capacity that some species of microalgae have to store lipids in their cells, and there may not be competition with food, with high biomass productivity per hectare of cultivation and also a high CO_2 absorption (DEMIRBAS; DEMIRBAS, 2011; MOAZAMI *et al*., 2011).

Chlorella microalgae can produce in every 100 g of dry biomass, vitamin A (30.77 mg), vitamin C (10.4 mg), vitamin B1 (1.7 mg), vitamin B2 (4.3 mg) , vitamin B3 (28.3 mg), vitamin B5 (1.1 mg), vitamin B6 (1.4 mg), vitamin B9 (94 µg), vitamin B12 (0.1 µg) and vitamin E (1.5 mg) (ANDRADE *et al*., 2018).

Chlorella sp.

Chlorella is a species of green alga from a single cell, which belongs to the phylum *Chlorophyta*, this microalga has a spherical shape, approximately 5 to 10 micrometers in diameter without flagella (figure 1). It has the photosynthetic pigments green chlorophyll in its chloroplast (ILLMAN *et al*., 2000). Through photosynthesis, this microalga multiplies rapidly, requiring carbon dioxide, water, and sunlight to reproduce (GONÇALVES *et al*., 2013). It also has a lot of resistance to contamination, in addition to fast growth and easy cultivation (HUNTLEY; REDALJE, 2007).

Figure 1 - Microscopic 40X objective image of the microalgae *Chlorella homosferae*



Source: Author's construction.

The microalgae *Chlorella* started to be commercialized in 1961, when it was mass produced by the company Nihon *Chlorella* in the premises of the Institute of Research of Microalgae of Japan, also known as Instituto *Chlorella*, which was constituted in 1957 for the development of microalgae, in particular *Chlorella* (RICHMOND, 2004).

Due to specific characteristics, *Chlorella sp.* it becomes the group of microalgae that is most researched by the scientific community, with high nutritional value in terms of natural antioxidants (MATSUKAMA *et al*., 2000) and lipid production (ZHU *et al*., 2014). With a high content of bio-active compounds contained in *Chlorella*, it makes it an attractive source as a nutritional food and product for human health with a global production exceeding 2000 metric tons/year (RAMARAJ *et al.*, 2016). Table 1 below shows the main applications of *Chlorella*.

Table 1 - Main applications of *Chlorella* microalgae**.**

Application	Reference
Coloring food, medicine, cosmetics; Functional additives for baby foods	Basu *et al.*, 2001; Del Campo *et al.*, 2001; Shi *et al.*, 2002.
Coloring of chicken skin and egg yolks. Fish and poultry pigments	Bhosale; Bernstein, 2005; Abe *et al.*, 2007; Gong; Bassi, 2016.
Strong antioxidant and anticancer activity	Schubert *et al.*, 2006; Ferruzzi; Bakeslee, 2007; Koo *et al.*, 2012; Kim *et al.*, 2017.
Food supplement; Aquaculture food	Brenan; Owende, 2010.

Source: Author's construction

In studies presented by González (2010), *Chlorella sp.* it proved to be a microalgae that is easy to grow and that adapts to various conditions, with rapid growth and that is hardly contaminated by other types of microalgae. This microalgae is also the most popular for its varied applications, such as biofuel, healthy foods, cosmetics, and bioremediation (HSIEH *et al.*, 2012).

The use of *Chlorella* extracts shows many beneficial properties such as cholesterol reduction, antioxidant, antibacterial and anti-tumor activities (MEDINA-JARITZ *et al.*, 2013; RYU *et al.*, 2014; REYNA-MARTINEZ *et al.*, 2018). *Chlorella sp.* it is also highly efficient due to its easy adaptation to laboratory conditions and represents an ideal biological system for several research areas (ORTEGA *et al.*, 2004; REDÓN *et al.*, 2013).

Chlorella sp. for presenting specific characteristics it is one of the most researched and scientifically studied microalgae. Among its characteristics, it stands out for its high nutritional value in terms of natural antioxidants (MATSUKAWA *et al.*, 2000) and lipid production (ZHU *et al.*, 2014).

According to the scientific literature, many *Chlorella* species have a potential to produce oil, reaching a lipid accumulation of 2% to 63% on a dry basis. For example, the species *Chlorella protothecoides* is an important raw material for producing biodiesel due to its high lipid content, which varies from 14.6% to 57.8% on a dry basis (MATA *et al.*, 2010).

Batista and collaborators (2018) conducted a study to evaluate the production of ethyl biodiesel from microalgae oil of the *Chlorella* type. vegetable oils. They also observed that the values of acidity, water content, flash and pour points were better values than other traditional biodiesels, evidencing in this study that lipids derived from microalgae are a viable alternative source of raw material to produce biofuels.

Nanotechnology, nanocosmetics and microalgae

Nanotechnology is seen by the European Commission as one of its six "main enabling technologies" which contributes to sustainable competitiveness and growth in many fields of industrial application (EC, 2012). The new chemical and or physical properties that nanotechnology confers to nanoscale particles provide useful functions that are being explored very quickly in the sectors of medicine, biotechnology, electronics, materials science and energy, among others (OBSERVATORYNANO FP7, 2011).

The nanoscale refers to structures smaller than 1,000 nm in size, because on this scale the properties of materials differ in relation to the physical, chemical, and biological properties of a macro scale (ROSSI-BERGMANN, 2008; DIMER *et al.*, 2013).

For cosmetic companies, it is not new that nanotechnology is the way of the future and, therefore, considered the rising technology available. Nanoscale versions of components are used by cosmetic manufacturers to better provide ultraviolet protection, greater penetration into the skin, color and finish quality, prolonged effects, among others (LAW 360, 2011). The use of nanoscale materials for cosmetics is given by the fact that nanoparticles have new properties that differentiate the properties of larger particles. Among the new properties, there are: color, transparency, solubility and chemical reactivity, making nanomaterials more attractive for the cosmetics and personal care industries (FRIENDS OF THE EARTH REPORT, 2006). Therefore, the most synthesized nanomaterials in this area are polymeric nanoparticles, described as colloidal suspensions with diameters smaller than 1 μm and which are divided into nanocapsules (NC) and nanospheres (NS), acting as nanocarriers with vesicular and matrix structures (MORA-HUERTAS *et al.*, 2010).

In addition to influencing skin penetration/permeation behavior, nanocarriers can protect the substance from premature chemical degradation, improving its apparent solubility, greater stability, less toxicity and protection of the encapsulated substance, among others (OURIQUE *et al.*, 2011).

The concept of beauty assets from natural origin is expanding, and its manufacturers seek to promote sustainability through the incorporation of local approaches and developments in biotechnology (ABIHPEC, 2019).

The Personal Hygiene, Perfumery and Cosmetics (HPPC) segment has undergone extremely significant changes. Concepts such as sustainability, personalization, social value, technology, and transparency become decisive when choosing a product. And this is the new consumer profile (ABIHPEC, 2019).

The relationship of the consumer market with brands and products is changing. In its 2018 Beauty and Personal Care Trends survey, Mintel Global explained that selling a great product will no longer be enough, it will be necessary to adapt to the new market and your marketing campaigns must be aware of this reality. Some research points in this direction: 37% of UK consumers take into account whether or not a product is tested on animals; 56% of Americans stop buying products from a brand or a store if they think they are unethical and finally, 29% of Brazilians prefer to buy products from companies with sustainable practices. Thus, the consumer is increasingly demanding regarding the products he uses, seeking not only quality products, but also ensuring sustainability and good practices throughout the production segment (ABIHPEC, 2020).

According to the Brazilian Association of the Personal Hygiene, Perfumery and Cosmetics Industry (ABIHPEC), Brazil is the fourth country in the market for personal hygiene, perfumery and cosmetics items (HPPC), and the third country in new product launches in this field. Therefore, investing in innovation has been very strategic so that companies can meet the growing demand, since they have competence to contribute to overcome technological challenges with solutions in nanotechnology, biotechnology, advanced materials and information technologies, which ensure a more economical and sustainable production process (ABIHPEC, 2020).

The Innovation Award for the Personal Hygiene, Perfumery and Cosmetics Industry (ITEHPEC) launched at In-cosmetics Brazil in 2015, aimed to recognize companies that manufacture cosmetic components that have contributed to the increase in the competitiveness of the Brazilian HPPC industry, through implementation of innovative projects. The BASF company that transforms chemistry for a sustainable future, received the gold category award for biotechnology used in obtaining the first surfactant derived from microalgae oil in the world, developed in partnership with Solazyme (BRAZIL BEAUTY NEWS, 2015).

The scientific community, based on several studies showing that microalgae have a high antioxidant action, found that microalgae extracts or their bioactive compounds offer great potential to be new bio-based products, such as cosmetics, pharmaceuticals and nutraceuticals, as well as bioplastics and biopolymers (WANG *et al.* 2015; ARIEDE *et al.*, 2017; KHANRA *et al.*, 2018).

Among the assets that are extracted from microalgae with potential use in cosmetics are polysaccharides, which are used as gelling and thickening agents in various cosmetic formulations, mainly for hydration, in which the microalgae of the genus Chlorella is the most used (JAIN *et al.*, 2005). Especially β-1,3-glucan polysaccharides are good collectors of free radicals and active immunostimulators, making them excellent candidates for use in skin cosmetics, mainly preventing external aging (SPOLAORE *et al.*, 2006; KOLLER *et al.*, 2014. The microalgae of the genus *Chlorella* and *skeletonema* diatom, as well as *Porphyridium* and *Nostoc flegeliforme* are the species richest in β-glucans (HAMED, 2016).

Due to their diversity and physiology, microalgae have versatility in the designed processes, occupying a special position in nanobiotechnology, in addition to having the resources of other types of microorganisms, they also offer additional advantages. Therefore, this field should evolve soon, since microalgae offer different forms of exploration in the biosynthesis of nanomaterials, on a molecular or cellular scale (DAHOUMANE *et al.*, 2016).

Studies have shown that microalgae-derived compounds can be used as the main active ingredient in cosmetics and still have beneficial properties such as an excipient, stabilizer, dye or even thickening agents (RYU *et al.*, 2015; LEVASSEUR *et al.*, 2020).

CONCLUSION

Microalgae because they are photosynthetic and easy-to-grow single-cell microorganisms, they produce from their oil substances such as fatty acids, carbohydrates, proteins, vitamins, carotenoids and even pigments that offer various benefits and can be applied in various areas such as pharmaceutical, cosmetics, nutritional, environmental, ensuring advantages that make all the difference in the applied areas.

Chlorella has been the most researched and scientifically studied microalgae in recent years, which stands out for its beneficial properties such as natural antioxidants, antibacterial and anti-tumors, among others, with promising results for the designated purpose. Thus, Chlorella arouses interest mainly in the cosmetics industry, as it is an alternative source of important assets, in order, to obtain products with higher quality and efficiency combined with nanotechnology and thus guaranteeing the development of new biotechnologies. Therefore, microalgae have been explored for their potential and bioavailability, making the cosmetic industry more attractive not only for quality and efficacy products, but also ensuring biodegradable actives in their formulations, as this branch of the industry has been seeking to expand its final products with a green appeal, thus ensuring social sustainability.

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