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MINI-REVIEW

(Bio)Technological aspects of microalgae pigments for cosmetics

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Abstract
Photosynthetic microorganisms convert carbon dioxide and solar radiation into interesting bioactive compounds not yet entirely explored. Several species of microalgae are known to be rich in colored high-valuable components that, although remarkable, are poorly explored as natural sources of pigments for cosmetics. Pigments associated to photosynthetic activity include chlorophyll, β-carotene, astaxanthin, xanthophylls, and phycobiliproteins, many of which have shown high potential as cosmetic actives due to their antioxidant, immune-enhancing, and anti-inflammatory properties. In the last decade, concern with a young and beautiful appearance has emerged, encouraging many consumers to use anti-aging cosmetics daily. As a result, the cosmetic market has been growing and evolving rapidly to meet consumer expectations. However, due to regular use and the sensitive nature of facial skin, local adverse reactions may often occur, such as irritation, sensitization, or photoreactions, and safety evaluation is mandatory prior to marketing. It is, therefore, understandable that new actives from natural sources, such as microalgae, are perceived as attractive alternatives for consumers who seek ingredients without allergenic potential. Thus, the cosmetic industry has recently started to explore the inclusion of compounds extracted from microalgae and cyanobacteria in innovative formulations. Herein, we revised nontraditional microalgae species for pigment production with cosmetic applications, indicating those that could also be considered potential ingredients for innovative cosmetics.

Key points
• *Extraction methods for pigments from photosynthetic microorganisms were compiled.*
• *Innovative cosmeceuticals could be developed with natural pigments.*
• *Safety features of such natural pigments were also described.*

Keywords Cyanobacteria · Cosmeceuticals · Microalgae · Pigment extraction · Safety

Introduction

Microalgae are fast-growing species formed by one or multiple simple cells that are able to live in extreme environmental conditions (e.g., temperature variations, oxygen absence, increased salt concentration, photo-oxidation, osmotic pressure, and high ultraviolet (UV) radiation). Their productivity exceeds that of high vascular plants, since they have shown less seasonal variation and easier extraction processes of useful compounds, producing abundant raw materials. They can be artificially cultivated in batch, fed-batch, or continuous systems. In such processes, the culture conditions could be modulated to obtain autotrophic, heterotrophic, or mixotrophic growth according to biomass applications (Safafar et al. 2015; Chen et al. 2017; Hu et al. 2018). Thus, different closed systems for microalgae production have been developed to be

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applied at industrial scale. Such closed systems, known as photobioreactors, have been designed to ensure high microalgae quality with high productivities for different industrial applications (Bresaola et al. 2019; Avila-León et al. 2020). One of the fastest growing applications in biorefineries is pigment production (Ruiz et al. 2016; Khanra et al. 2018; Cezare-Gomes et al. 2019). Therefore, microalgae species are sources of biofuels, feed additives, food, and other compounds; they could be used in wastewater treatment as well as nutraceuticals and potential pharmaceuticals (Caporgno et al. 2015; Wang et al. 2015; Hamed 2016; Zhang et al. 2020).

Different microalgae compounds have been studied for their biological activities, such as anti-mutagenic, anti-allergic, antiviral, immune-enhancing, anticancer, lipid-lowering, as well as hepato-protective (De Jesus Raposo et al. 2013a; De Jesus Raposo et al. 2013b; Koller et al. 2014; Sathasivam and Ki 2018). Moreover, the presence of a high amount of pigments is conducive to enhance their antioxidant activities (De Jesus Raposo et al. 2013a; Safafar et al. 2015; Wang et al. 2015).

Free radicals, such as superoxide anions ($O_2\cdot-$) or hydroxyl radicals (·HO), have high oxidizing potency that can cause irreversible injury to human tissues, cell membranes, and genetic material. Thus, deleterious effects such as wrinkles, spots, and other aging signs are evident in skin (Lorencini et al. 2014). As it is well known, personal care products containing microalgae extracts have developed to claim antioxidant and anti-aging properties. Hence, this mini-review briefly reports cosmetic and cosmeceutical potential applications of biopigments obtained from microalgae and cyanobacteria biomasses.

Microalgae in cosmetics and cosmeceuticals

One of the most accepted definitions of cosmetics is "articles intended to be rubbed, poured, sprinkled or sprayed on, introduced into, or otherwise applied to the human body or any part for cleansing, beautifying, promoting attractiveness, or altering the appearance" (Brandt 2011). Therefore, cosmetics are not designed to disturb human structure and function, controversially to drugs/medicines. On the other hand, cosmeceuticals are a mid-step between cosmetics and drugs, not globally harmonized, and sometimes called as over-the-counter products (OTC) in the USA or quasi-drugs in Japan. The nomenclature is controversial and lies mainly on the concentration of active ingredients, *stratum corneum* penetration, mechanism of action elucidation, and clinical trials to validate claims (Wanjari and Waghmare 2015). Herein, the terms "cosmetics" and "cosmeceuticals" will be addressed as one single class in this publication.

Microalgae use in cosmetics/cosmeceuticals is an interesting strategy to fill the increment in searching of new natural ingredients from environmentally sustainable biomass, since they have high productivity and easy extraction under controlled conditions (Wang et al. 2015). Thus, new extraction and purification methods have been tested to explore its potential in cosmetics, since the whole microalgae biomass is difficult to incorporate in cosmetic formulations.

Scientific research about the biological activities of microalgae extracts or their compounds enhance the development of several cosmetic products containing microalgae, such as rheology modifiers, like some described polysaccharides (Delattre et al. 2016; Mourelle et al. 2017). Other molecules may induce biochemical mechanisms on the skin: biopeptides to collagen stimulation (Apone et al. 2019), as well as astaxanthin and its esters with high antioxidant properties to inhibit hyperpigmentation from tyrosinase (Rao et al. 2013). Therefore, those molecules may be available in some commercial cosmetic formulations, including anti-aging and regenerating creams, emollients, sunscreens, and hair care products (Ariede et al. 2017, 2020; Couteau and Coiffard 2018; Zhang et al. 2020). However, only a few products are commercialized worldwide. Thus, biopigments extracted from microalgae biomass are good alternatives with potential for new market due to the fast-growing ability and the high pigment content with a vast variability of colors without or minimum risk of skin allergenic effects (Begum et al. 2016; Saini et al. 2020; Zhang et al. 2020).

Microalgae as a source of pigments for cosmetic applications

Table 1 summarizes microalgae pigment application in cosmetics available on the market. Natural pigments derived from the microalgae photosynthetic system are responsible for biomass color. Photosynthetic pigments are chemical substances divided into three groups: carotenoids, chlorophylls, and phycobiliproteins. Thus, autotrophic organisms, such as plants, algae, and cyanobacteria, use them to capture solar energy to be transformed into chemical energy by photosynthesis (Varela et al. 2015). Considering microalgae production, as it is largely reported in specialized literature, controlled environmental conditions during cultivation could enhance the production of lipids, proteins, and pigments (Koller et al. 2014; Hamed 2016; Bresaola et al. 2019; Avila-León et al. 2020). Extraction and application of microalgae compounds for cosmetics are related to the most traditional species in literature, such as *Dunaliella, Chlorella, Haematococcus*, and *Arthrospira* (Ariede et al. 2017; Mourelle et al. 2017; Zhang et al. 2020). Among the different pharmacological activities demonstrated for some microalgae compounds, pigments from microalgae could be applied in cosmetics, as

Table 1 Cosmetic products on the market with pigments from microalgae.

Cosmetic	Cyanobacteria/microalgae	Pigment	Potential activity	Suppliers
Pepha®-Ctive	*Dunaliella salina*	β-Carotene	Antioxidant, stimulates cell proliferation	Pentapharm Ltd. (Switzerland) (DSM 2020)
Dermochlorella D®	*Chlorella vulgaris*	Carotenoids	Photoprotection against UV light and oxidative damage, enhances collagen synthesis	Codif Recherche and Nature (France) (CODIF 2020)
OceaRides™	*Odontella* spp.	NI	Stimulates elastin synthesis	Daniel Jouvance (France) (Daniel Jouvance 2019)
AstaPure®	*Haematococcus pluvialis*	Astaxanthin	Antioxidant properties	Algatech (Israel) (ALGATECH 2020)
FucoVital™	*Phaeodactylum tricornutum*	Fucoxanthin	Antioxidant properties	Algatech (Israel) (ALGATECH 2020)
Megassane®	*Phaeodactylum tricornutum*	NI	Cell protection from UV, prevention of photo-aging and age-spots	Soliance (French) (GIVAUDAN 2020)
Linablue®	*Arthrospira* spp.	Phycocyanin	Eye shadow	Dainippon Ink and Chemicals Inc. (Japan) (DIC 2020)

NI, no avaliable information

recently reported (Mourelle et al. 2017; Couteau and Coiffard 2018).

Table 2 shows the novel discoveries in pigment production. It is remarkable that not only environmental conditions for microalgae cultivation but also extraction methods induce a strong influence on the final pigment concentration on biomass. Consequently, these aspects are the most important keys in choosing species to obtain compounds for new innovative cosmeceuticals.

Carotenoids

Isoprenoid molecules, named carotenoids, are the main pigments (yellow to red) in vegetables, flowers, fruits, and even insects, birds, and marine species. They are classified into xanthophylls and carotenes. Microalgal eukaryotes contain such pigments as crucial constituents to absorb light energy in photosynthetic reactions as well as photoprotective defenses against high light stress. Carotenoids are currently used as natural color enhancers or to add healthy claims into food, cosmetics, and even pharmaceutical products (Ryu et al. 2015). Thus, carotenoids have been largely explored due to their health benefits (Sathasivam et al. 2017).

Among microalgae, *Dunaliella* sp. and *Haematococcus* sp. are largely studied for carotene production. Many studies focused on changes of light and nitrogen regimes to enhance carotenes and xhantophylls biosynthesis. For instance, high light intensities could induce high β-carotene and astaxanthin production in *Dunaliella salina* and *Haematococcus pluvialis*, respectively (Koller et al. 2014; Safafar et al. 2015; Hamed 2016). Carotenoids, one of the most important microalgae pigments from *Dunaliella* sp., are considered safe natural dyes and have been used for different applications in food and cosmetics industries due to their coloring (Novoveská et al. 2019).

The biological activities of carotenoids in the skin are associated to their provitamin A function, as well as the property of photoprotection against UV radiation, as physical quenching. Hence, the direct absorption of UV light is the mechanism of action to prevent sun damage to the skin. Some clinical studies demonstrated that premature skin aging could be controlled by using carotenoids as nutricosmetic ingredients (Yeager and Lim 2019).

Xanthophylls are oxygenated molecules, e.g., astaxanthin, lutein, canthaxanthin, zeaxanthin, and fucoxanthin (Fig. 1). Among xanthophyll industrial production, astaxanthin showed the most promising market (Panis and Carreon 2016; Zhang et al. 2020). However, fucoxanthin production of some microalgae species was recently evaluated by means of salinity effects on pigment production (Ishika et al. 2017). Recently, three groups of volunteers/subjects were treated with lutein and zeaxanthin: the first group received both molecules in oral and topical applications; the second one received the association topically; and the third one only received oral supplementation. The results revealed that all treatments showed significant enhancement of skin elasticity with cutaneous hydration more pronounced in the combined treatment than in the isolated ones. The synergistic effect of oral and topical treatments also provided the highest degree of antioxidant protection (Palombo et al. 2007).

Regarding the most of carotenoids, their maximum wavelength absorption ranges are in the visible region.

Table 2 Pigment composition examples in recent studies of photosynthetic microorganisms

Cyanobacteria/microalgae	Pigment	Pigment concentration	Extraction method	Reference
Chlorella vulgaris	Lutein	5.4 mg g^{-1}	Ethanol followed by alkaline pH extraction of proteins	Kulkarni and Nikolov (2018)
	Total chlorophyll	15.4 mg g^{-1}		
Coelastrella sp. M-60	β-Carotene	0.16 mg g^{-1}	Ground in mortar and pestle using chloroform: methanol (2:1) along with silica	Karpagam et al. (2018)
	Astaxanthin	12.6 mg g^{-1}		
	Zeaxanthin	0.7 mg g^{-1}		
	Lutein	0.52 mg g^{-1}		
Pavlova lutheri CCAP 931/6	Total carotenoid	51.1–76.4%	Ground in mortar and a small quantity of sand in the presence of cold 90% aqueous acetone	Guihéneuf and Stengel (2017)
	Total chlorophyll	23.6-48.9%		
Porphyridium purpureum PLY#539	Chlorophyll-a	108–1134 mg g^{-1}	Grinding in cold 90% aqueous acetone. Overnight extraction at 4 °C	Guihéneuf and Stengel (2015)
	Zeaxanthin	63–269 mg g^{-1}		
	β-Carotene	37–338 mg g^{-1}		
Chaetoceros muelleri CS176	Fucoxanthin	2.92 mg g^{-1}	Liquid nitrogen followed by absolute ice-cold acetone (100%) solvent and supernatant separated by centrifugation	Ishika et al. (2017)
Chrysotila carterae CCMP647	Fucoxanthin	1.04 mg g^{-1}		
Pheodactylum tricornutum CS-29/7	Fucoxanthin	1.87 mg g^{-1}		
Tisochrysis lutea CS-177/7	Fucoxanthin	2.05 mg g^{-1}		
Amphora sp. MUR258	Fucoxanthin	1.21 mg g^{-1}		
Navicula sp. MUR259	Fucoxanthin	1.49 mg g^{-1}		
Parietochloris incisa P127	β-Carotene	30–59.5%	Dimethyl sulfoxide (DMSO) for 5 min at 70 °C with 5 mL per *ca*. 3.5 mg DW	Solovchenko et al. (2013)
	Lutein	18–55%		
	Neoxanthin	2–4%		
	Violaxanthin	1–3%		
	Antheraxanthin	1–3%		
	Zeaxanthin	5–12%		
Arthrospira platensis	Allophycocyanin	6.34 mg g^{-1}	Ultrasonic bath at 25 °C and at a frequency of 25 kHz	Rodrigues et al. (2018)
	Phycocyanin	5.95 mg g^{-1}		
	Phycoerythrin	2.62 mg g^{-1}		
Scenedesmus sp. KGU-Y002	Astaxanthin	0.04–1.51 mg g^{-1}	Dichloromethane/methanol (25:75, v/v)	Aburai et al. (2013)
	Adonixanthin	0.11–1.35 mg g^{-1}		
	Lutein/zeaxanthin	0.60–1.26 mg g^{-1}		
	Canthaxanthin	0.37–1.66 mg g^{-1}		
	Violaxanthin	0.0 mg g^{-1}		
	β-Carotene	0.08–0.13 mg g^{-1}		
	Total chlorophyll	4.11–3.51 mg g^{-1}		
Scenedesmus sp. KGU-0002	Astaxanthin	2.02–2.63 mg g^{-1}		Aburai et al. (2013)
	Adonixanthin	0.02–3.49 mg g^{-1}		
	Lutein/zeaxanthin	1.22–3.42 mg g^{-1}		
	Canthaxanthin	1.01–2.09 mg g^{-1}		
	Violaxanthin	0.0 mg g^{-1}		
	β-Carotene	0.12–0.71 mg g^{-1}		
	Total chlorophyll	5.88–7.34 mg g^{-1}		
Coelastrella sp. KGU-H001	Astaxanthin	0.01–0.99 mg g^{-1}		Aburai et al. (2013)
	Adonixanthin	0.37–0.4 mg g^{-1}		
	Lutein/zeaxanthin	0.49–0.95 mg g^{-1}		
	Canthaxanthin	0.42–0.44 mg g^{-1}		
	Violaxanthin	0.0 mg g^{-1}		

Table 2 (continued)

Cyanobacteria/microalgae	Pigment	Pigment concentration	Extraction method	Reference
	β-Carotene	0.12–0.27 mg g^{-1}		
	Total chlorophyll	2.91–6.82 mg g^{-1}		
Vischeria Helvetica KGU-Y001	Astaxanthin Adonixanthin	0.03–1.56 mg g^{-1} 0.0 mg g^{-1}		Aburai et al. (2013)
	Lutein/zeaxanthin	0.22–0.73 mg g^{-1}		
	Canthaxanthin	0.41 mg g^{-1}		
	Violaxanthin	0.39–0.83 mg g^{-1}		
	β-Carotene	2.52–6.93 mg g^{-1}		
	Total chlorophyll	7.17–9.89 mg g^{-1}		
Scenedesmus quadricauda CPCC-158	Chlorophyll Total carotenoids	210.6 ng $cell^{-1}$ 178 ng $cell^{-1}$	Placed on ice, centrifuged, resuspended in 99.8% methanol	Kozlova et al. (2018)
Geitlerinema sp. H8DM	Phycocyanin	0.156–0.188 mg mL^{-1}	Sonicated for homogenization of mat in 20 mM potassium phosphate buffer (KPB) (pH 7.2) on ice	Patel et al. (2018)
Arthrospira platensis	Chlorophyll β-Carotene	21.35 μg mL^{-1} 5.45 μg mL^{-1}	Soaked in 10 mL of methanol (100%) and ground with the aid of a glass rod	Lima et al. (2018)
	Phycocyanin	167.98 μg mL^{-1}		

Phytoene and phytofluene are the exceptions, which absorb wavelengths covering the UVB and UVA regions as a response of their 3 and 5 conjugated double bonds, respectively. Accordingly to their versatility, many cosmetic effects of carotenoids have been studied (Stahl and Sies 2012). However, the real application for optimum skin health is under discussion, with recent application in patents (Table 3).

Chlorophylls

Chlorophyll is easily extracted from microalgae biomass. Thus, it can be used in food, pharmaceutic, and cosmetic industries thanks to its high green pigmentation. Particularly, chlorophyll from *Chlorophyta* species is also used as dyeing, as well as in products with anti-inflammatory properties. Moreover, some detailed studies are recently compiled in some reviews (Ariede et al. 2017; Levasseur et al. 2020; Yarkent et al. 2020). For instance, it exhibits the ability to mask odors in deodorants, toothpastes, and other hygienic products (Mourelle et al. 2017).

Phycobiliproteins

Phycobiliproteins are formed by phycobilins bounded to water-soluble proteins. For instance, phycocyanin is a blue pigment from cyanobacteria while phycoerythrin is from red algae (D'Alessandro and Antoniosi Filho 2016). As it is known, phycocyanin has been studied due to its antioxidant and anti-inflammatory activities, as well as immune enhancer. Moreover, another important point is its stability that turns phycocyanin into a valuable ingredient in cosmetic formulations, like lipsticks, eyeliners, eye shadow powders, and perfumes (Sekar and Chandramohan 2008), and it has already been approved as food colorant (Table 2).

Toxicological aspects (safety) of microalgae pigments

In the last decades, many studies have been published about the chemical composition and functional ingredients of several species of microalgae. Nevertheless, the potential toxicity of some species should also be considered. Recently, there has been an emphasis on the adverse effects of algae on fisheries, aquaculture, and freshwater resources (Rhodes and Wood 2014). Algal cells have developed different strategies to defend and adapt to their environment, which in some cases include the production of metabolites, including some with biological activities and also toxins, known as phycotoxins (Rhodes and Wood 2014; Caruana and Amzil 2018).

Nonetheless, of the thousands of microalgae species that exist, only around 200 are considered to have harmful effects, and just about 100 species have the capacity to produce toxins (Hallegraeff 2014; Caruana and Amzil 2018). The main toxic microalgae include dinoflagellates

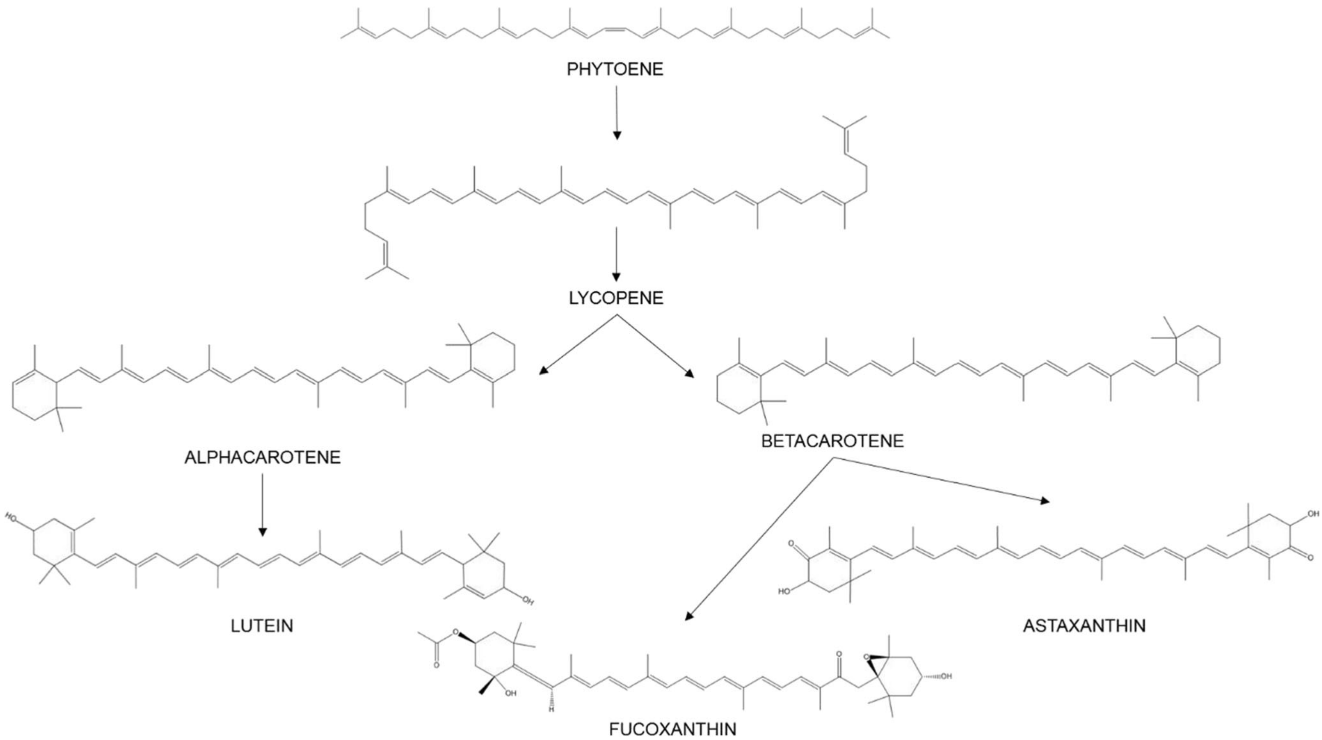

Fig. 1 Main carotenoids and summarized carotenogenesis

(e.g., planktonic and benthic genus) and diatoms (e.g., planktonic genus). In humans, phycotoxins can lead to different harmful effects, including gastrointestinal, skin, and neurological problems, and they are even lethal in some cases (Hallegraeff 2014; Caruana and Amzil 2018). Furthermore, microalgae and its extracts can also contain heavy metals, inorganic arsenic, or cyanotoxins (Rzymski et al. 2015; Scoglio 2018). In addition, standard guidelines provided by international regulatory organizations (e.g., Food and Drug Administration (FDA)) could be a valuable tool to guarantee the quality and safety of microalgae-derived compounds (Buono et al. 2014). Moreover, the use of proper extraction techniques may be a valuable strategy to obtain pigments or other components from microalgae avoiding the presence of harmful residues of phycotoxins or other toxics. Thus, microalgae from aquaculture, which has a more controlled environment, can avoid some toxicological risks of contamination and bioaccumulation when compared with those from natural sources. Nevertheless, industry should implement monitoring systems to detect the presence of harmful algal species, phycotoxins, and other toxic compounds throughout the manufacturing process. In the last years, important advances have been achieved towards the development of more specific, sensitive, and rapid methodologies that allow the identification of the different microalgae species and toxins (Penna and Galluzzi 2014).

In addition to this, legislations and regulatory aspects about the commercialization of carotenoids from microalgae biomass are recently described for food and cosmetic products in the USA, Japan, China, and Europe (Novoveská et al. 2019). Thus, astaxanthin, β-carotene, and chloprophyll derived from some microalgae species are regulated and approved by the FDA due to their nontoxic and noncarcinogenic properties (Begum et al. 2016). Moreover, astaxanthin from *Haematococcus pluvialis* has been approved as a color additive in Europe, the USA, and Japan. Thus, it is approved for direct human consumption and has been recognized as safe by the FDA using "generally recognized as safe (GRAS)" status (Davinelli et al. 2018).

Potential use of microalgae pigments in cosmetics

The increased use of algae in the cosmetic industry is due to the fact that some algae have promising properties, like antioxidant and collagen production stimulant (anti-aging) (Ariede et al. 2017). Also, the incorporation of safe microalgae compounds in cosmeceuticals adds organic value to these products.

Considering that the incorporation of microalgae extracts and compounds into cosmeceuticals is kept as an industrial secret, this section presents some tendencies about pigments from microalgae in cosmetics (Table 3). Cosmetic Ingredient Database (CosIng) offers more than 120 examples of ingredients derived from microalgae (European Commission 2020). Most of them are related to extracts or polysaccharide compositions; however, there is no evidence of pigments isolated from microalgae biomass in

Table 3 Recent patents using microalgae pigments for cosmeceuticals

Microalgae	Pigment	Extraction method	Potential activity uses in cosmetics	Patent
Haematococcus sp.	Astaxanthin	Supercritical CO_2 extraction	Sunscreen products, anti-aging products, skin hydration	WO2018/062427 (Tominaga et al. 2018)
Phaeodactylum tricornutum	Fucoxanthin	Ethanol extraction and/or SCF-CO_2 extraction	In liquid form for cosmetic preparation	US2018/0078521 (Grundman et al. 2018)
Haematococcus pluvialis	Astaxanthin Zeaxanthin Lutein	Supercritical CO_2 extraction	Skin hydration, anti-wrinkle, ceratolytics, peeling and mask via creams, gels, lotions or oils, moisturizing creams, sunscreens	US2018/0042978 (Minatelli and Hill 2018)
NI	Neoxanthin Fucoxanthin Isofuncoxanthinol Lutein	NI	Anti-aging products, skin-care creams, facial makeup	WO2017/178456 (Ruiz Canovas et al. 2017)
Haematococcus spp. *Chlamydomonas* spp. *Chloromonas* spp. *Dunaliella* spp. *Chlamydocapsa* spp.	Astaxanthin Lutein Lycopene Zeaxanthin Cantaxanthin Carotene Phytofluene Phytoene	NI	Colorant in cosmetic ingredients	US2018/002711 (Schurr and Kuehnle 2018)
Haematococcus spp. *Chlamydomonas* spp. *Chloromonas* spp. *Dunaliella* spp. *Chlamydocapsa* spp.	Astaxanthin	Drying, grinding, lysing, or extracting the cell	Pigment for cosmetic formulations	WO2018/06068 (Schurr and Keuhnle 2016)

NI, no available information

such important reference. Finally, regarding safety aspects, it is essential to select nontoxic microalgal species and analyze each toxicological profile before industrial applications. Hence, nontoxic microalgae and cyanobacteria could be a valuable source of biopigments and other bioactive compounds with potential health-promoting properties, as well as cosmeceutical properties for novel products with high quality assurance.

Conclusions and perspectives

We briefly summarize the cosmeceutical applications of pigments derived from microalgae biomass. Currently, there are researches conducted for the enhancement of knowledge on the application of active ingredients in cosmeceuticals claiming antioxidant, anti-inflammatory, and antipollution activities (Velasco et al. 2018), with further skin collagen production stimulant, among others. Thus, the biopigments described among this study were safe, highly efficient, and with low environmental impact. Several compounds found in microalgae species have these potential characteristics, with emphasis on the pigments that are already part of the formulation of some cosmetics and personal products, claiming organic value. Otherwise, production of these biopigments may be considered relatively expensive, with a consequent increment in costs of final raw materials. In addition to this, microalgae cultivation is linked to high demand of water, although water recycling in "red stage" production could decrease water footprint (Panis and Carreon 2016). However, it is important to recognize that the rapid growth with simple medium composition of most microalgae strains could be cited as the best advantage to produce their pigments in large scale. Furthermore, the increase in pigment production by microalgae and cyanobacterial species with a significant reduction in costs is a very attractive field for industries to use these biopigments in personal care products. Thus, one of the most promising ways to make this challenge possible is to obtain detailed information on DNA sequencing, for instance, to provide valuable information on metabolic pathways for metabolic and genetic engineering for the enhancement of biopigment production (Saini et al. 2020). Therefore, these aspects reflect the importance of the growing interest for the discovery of new applications for microalgae pigments. Despite the complications of stablishing extraction methods environmentally safer, there is still a need for further investigations to evaluate safety, efficacy, and real potential alternatives of using microalgae pigments in the cosmetic industry.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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