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Review article

Revealing the potential of cyanobacteria in cosmetics and cosmeceuticals — A new bioactive approach

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ABSTRACT

The growing concern over appearance, health and aging has driven the exploration for cosmetics based on natural sources. Alongside with plants, algae and eukaryotic microalgae, cyanobacteria have been explored for the isolation of compounds with potential application in the cosmetic and cosmeceutical field. The long evolutionary history of cyanobacteria and exposure to environmental stress conditions seems to be the basis for the production of compounds with protective roles against external factors, such as desiccation, UV radiation and salinity. The production of exopolysaccharides, UV-protectors such as mycrosporine like amino acids and scytonemin, and antioxidant and anti-inflammatory compounds, by a wide range of cyanobacteria genera, coupled with a growing demand for natural origin products, places these organisms in the investigation line linked to cosmetics. The low nutritional requirements for large scale culture and the possibility to increase compounds production by manipulating culture conditions, also highlights the importance of these organisms as an alternative and a promising source for cosmetics based on nature. In this review, a general overview of the state of the art regarding the potential of cyanobacteria for the cosmetic and cosmeceutical industry is provided, emphasizing the main properties required in skin care formulations.

1. General introduction

The skin major functions include the protection against desiccation, UV-radiation and the maintenance of the body homeostasis, in variables, such as temperature and osmolarity [1]. In addition, the skin is an organ of social communication, self-esteem and exteriorization of health. Although aesthetic appearance has always been a subject of great importance, the life expectancy and the concern over skin health and aging has undergone a considerable increase, resulting in a significant demand for skin care products.

The importance of a healthy skin drives the development of topical products designed to protect against exogenous and endogenous injurious agents. Most of these products are regulated as cosmetics [2,3] and cover a great variety of product categories, such as skin creams, UV-protectors, anti-aging and hypoallergenic products [4]. Currently, besides the cosmetic term, cosmeceutical terminology has also been introduced, which is referred to as a cosmetic product with active ingredients that exerts a pharmaceutical therapeutic benefit, such as anti-inflammatory [5]. Since cosmetic and cosmeceutical products are part of everyone's daily life, a variety of choice options and higher efficacy is always expected by the consumer [6]. Also, in the last decades a great concern for safer skin care products has been raised, not only due to human health concerns but also due to environmental issues. The detection of pharmaceuticals and personal care products (PPCPs), such as cosmetics, in environmental ecosystems has become a worldwide matter [7]. Studies have clearly shown that the elimination of PPCPs in municipal Sewage Treatment Plants (STP) is often incomplete [7] and several negative impacts were ascribed to ecosystems and organisms [8–10].

As a result of the harmful effects attributed to use of synthetic compounds, cosmetic research has increasingly focused investigation on natural compounds. Although cosmetics based on natural sources have always been used, in particular those based on plants [11], macroalgae and eukaryotic microalgae [12], the use of natural extracts in

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low demand for culture requirements both in terms of nutrition and space, and the possibility to increase the production of compounds by manipulating culture conditions. Effectively, cyanobacteria growth requires only basic nutrients, and cultivation is not dependent on arable land, which decreases environmental impacts and allows for wider cropping location points [19]. Also cyanobacteria can be cultured under continuous cultivation, which also ensures smaller cultivation areas and is considered the most feasible system for large scale production, both in terms biomass rates, product quality and costs associated with investments, such as for operation and harvesting (reviewed by [114]). The possibility to increase the compounds production is based on the evident influence of culture conditions, namely in variables such as UV radiation and salinity. For MAAs and SCY, it was found that the production of these photoprotectors is highly dependent on these same variables. In a *Lyngbya* sp. culture, an exposition for 72 h to 320 nm UVA and 295 nm UVB radiation, significantly increased the synthesis of MAAs and SCY [66]. Also, the growth of the filamentous strain *Scytonema* sp. R77DM under UV-radiation stress, resulted in a 2- to 3-fold increase in SCY biosynthesis [85]. Related to salinity, it has been reported that cyanobacteria inhabiting hypersaline environments accumulate large concentrations of MAAs, that are released from the cells when placed in medium with lower salinity [115]. For EPS, factors such as salt stress, irradiance, light cycle and temperature, were also found to influence production (reviwed by [75,114]). Under high salt concentrations of 500 mmol L^{-1} NaCl, for example, a significant increase in total carbohydrates and EPS content was described for a *Microcoleus vaginatus* cyanobacterium isolated from desert algal crusts [76] and cultured under laboratory conditions. This increase ranged 363% and 161% of unstressed cells respectively for total carbohydrates and EPS, and was followed by a decrease to original levels when the culture was transferred to non-saline medium, which suggests an involvement of EPS in the enhancing salt tolerance. For polyphenolics and flavonoids, the accumulation of the natural antioxidants gallic, caffeic, chlorogenic and ferulic acids and vanillic, rutin and quercetine, was also stimulated in several cyanobacteria species by exposure to salt stress conditions [116]. These later authors demonstrated also that the increase in total phenol, flavonoids and carotenoid content under different salt conditions was positively correlated with the antioxidant activity of the cyanobacteria extracts, emphasizing the role of salinity in the production and activity of the compounds. Low rates of UV-B radiation have been also considered an efficient technology for the production of photosynthetic pigments and polyphenolics. In a study involving *Nostoc muscorum*, *Phormidium foveolarum*, and *Arthrospira platensis* strains, an increase in biomass production, total phenolic content, photosynthetic pigments (*e.g.* chlorophyll *a*, carotenoids, and phycobiliproteins) and nonenzymatic antioxidants (*e.g.* proline, ascorbate, cysteine) was obtained at an UV-B rate of 0.045 $W \cdot m^{-2}$ when compared to an UV-B rate of 0.23, and 0.45 $W \cdot m^{-2}$ [117]. Also, in this study, an increase of 97.9%, 86.11% and 77.08% in the antioxidant activity of *A. platensis, P. foveolarum* and *N. muscorum*, respectively, was obtained at the lower UV- B rate, highlining the role of radiation in the production and activity of the compounds.

The evidences described above, although only based on laboratory scale studies, are suggestive of the potential that the manipulation of the culture conditions can bring to the increment of the production of compounds and, combined with the sustainable biomass production, reveal cyanobacteria as a strategy to efficiently produce natural compounds for natural skin care products.

4. Conclusion

The increased concern with skin health, particularly regarding appearance and aging is reflected in a higher demand for new cosmetic products, mainly of natural origin, with less side effects and environmentally friendly. The effective mechanisms of cyanobacteria against dissection, radiation and oxidative stress, through the production of specific compounds, makes this group of organisms promising in the cosmetic/cosmeceutical industry. In this sense cyanobacteria, may be used as an efficient biotechnology to produce natural ingredients, such as EPS, UV filters, and antioxidants for skin care products. Along with the potentialities required for cosmetic formulations, cyanobacteria offer facilities in terms of culture for biomass and compounds production, which can make the production more cost-effective. The studies presented in this review reflect the work that has been invested in the application of cyanobacteria in cosmetics and emphasize the biotechnological potential of these organisms as an economically and sustainable base for the cosmetic industry.

Conflicts of interest

The authors declare no conflict of interest.

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Statement of informed consent, human/animal rights

No conflicts, informed consent, human or animal rights applicable.

Author contributions

Rosário Martins and Vitor Vasconcelos were involved in planning and supervising the work. Janaína Morone and Anna Alfeus were involved in collecting and organizing the data. All authors were involved in the analysis of the collected data and in the writing of the manuscript.

Authors agreement to authorship and submission of the manuscript for peer review

All authors have seen and approved the manuscript as submitted.

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