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Review

Exploring the potential of using algae in cosmetics

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HIGHLIGHTS

- Algae extract combats skin aging, de-pigmentation and anti-microorganism.
- Algae can be functional antioxidants, alginates, polysaccharides and carotenoids.
- Algae extract contributes skin health and beauty in practical cosmetic uses.

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ABSTRACT

The applications of microalgae in cosmetic products have recently received more attention in the treatment of skin problems, such as aging, tanning and pigment disorders. There are also potential uses in the areas of anti-aging, skin-whitening, and pigmentation reduction products. While algae species have already been used in some cosmetic formulations, such as moisturizing and thickening agents, algae remain largely untapped as an asset in this industry due to an apparent lack of utility as a primary active ingredient. This review article focuses on integrating studies on algae pertinent to skin health and beauty, with the purpose of identifying serviceable algae functions in practical cosmetic uses.

1. Introduction

1.1. Composition and function of the skin

As the biggest organ in the human body, the skin has an important role in many physical functions (Wang et al., 2013a,b). Skin is composed of the epidermis, dermis and hypodermis. Generally speaking, the epidermis is subdivided into five separate strata: basal, spinous, granular, lucid, and corneum, as shown in Fig. S1 (supplementary materials). In the epidermis, the predominant keratinocyte cells repair skin damage, while melanocytes contain melanin, thus determining skin color and protecting the skin from UV light (Brenner and Hearing, 2007). Langerhans cells, a type of dendritic cell, provide a degree of immunity (Wollenberg et al., 1996), as they take up microbial antigens in the skin and transform microbial antigens into antigen presenting cells by interacting with T cells. Sebaceous glands produce an oily substance known as sebum that lubricates the skin, although the occlusion and infection of these can trigger acne (Zouboulis, 2004). Receptors in the skin detect various environmental stimuli and respond accordingly, with mechanoreceptors detecting sensations and thermoreceptors detecting heat. These receptors can cause sweat glands to produce sweat, thus maintaining temperature homeostasis as well as getting rid of waste (Denda et al., 2007). Insulation is also provided in the subcutaneous layer of the skin, where fat is stored. Skin absorbs not only oxygen and water, but also certain drugs, such as topical steroids. In addition, skin is rich in 7-dehydrocholesterol, and when it is exposed to UV light this substance is converted into vitamin D (cholecalciferol), which is otherwise obtained by dietary means, such as by ingesting dairy products (Chen et al., 2007).

The stratum corneum (SC) on top of the skin is an important barrier to passive water diffusion from the skin, preventing dehydration and thus enabling humans to live in air (Cartlidge, 2000).

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It is also a barrier to certain irritations to the skin. For example, the immune function of the skin prevents damage from UV light by the use of pigmentation (Wickett and Visscher, 2006). Under the epidermis is the dermis, which is mainly composed of connective tissues, including blood vessels sweat glands, nerves, fibroblasts, collagen and elastin. Collagen and elastin, which are cross-linked, provide support for the skin. Hyaluronic acid (HA) is also a major component of the dermis, where it is involved in tissue repair. HA is of fundamental importance in water retention, and can absorb water about 1000 times its own volume. Nevertheless, collagen and HA break down with aging, causing wrinkles to appear and the skin to lose firmness. The third layer, the hypodermis, is composed mainly of fat and a layer of loose connective tissue. It provides insulation to the body, storing energy, and mechanically allows the attenuation and dispersion of externally applied pressure (Benbow, 2009).

1.2. The cosmetics industry and consumer requirements

According to the definition of the Federal Food, Drug & Cosmetic Act of the US FDA and article L5131-1 of the French Public Health Code, a cosmetic product is any substance or preparation that is to be rubbed, poured, sprinkled, or sprayed on, introduced into or applied to external parts of the body, in particular the epidermis, hair and capillary systems, nails, lips and external genitals, or to the teeth and the mucous membranes of the oral cavity as the product cleans, perfumes, protects them, modifies their appearance, keeps them in good condition or helps to reduce body odors. In short, it is a set of cosmetic procedures and treatments to reach personal hygiene and beautification. Fig. S2 (supplementary materials) shows the customer requirements for cosmetic products, which are that such items are safe, effective, protective, resilient, natural, and have good sensory quality.

The cosmetics industry has an estimated annual turnover of US$170 billion according to the financial analysis reported by a French-based company – Eurostaf (Arora et al., 2012). The use of cosmetics is driven by the pursuit of beauty, which a biological trait based on Darwinian principles. In much the same way that animals evolve certain visual features to attract, intimidate or protect, humans engage in conscious manipulation of visual signals using tools to achieve a similar functions. Etcoff et al. (2011) proposes that features which are seen as composing a beautiful face are important biological signals of mate value, and suggests a possible correlation with judgments of various social attributes, such as attractiveness, competence, likeability, and trustworthiness.

The most recent study of the world beauty market, carried out by Eurostaf (Arora et al., 2012), indicate that cosmetic industry will continue to grow, with one significant contributing factor being the development of the middle classes in many emerging countries. However, despite this promising future, more research must be implemented to improve cosmetic products, and one area of interest is the greater utilization of natural ingredients to achieve the requests from customers.

1.3. The increasing need for natural and environmentally sustainable products

Recently, consumers become suspicious about chemical ingredient, and the need is back to fundamental or basic cosmetic products. There is an increasing demand for natural and environmentally sustainable products, with, for example, extracts of microalgal biomass having a significant market value in this regard. Researchers have found that marine algae-derived compounds can be utilized as cosmeceuticals. For example, phylogenetically archaic cyanobacteria produce substances that exhibit antioxidative effects, polyunsaturated fatty acids (PUFA), heat-induced proteins, or immunologically effective and virostatic compounds (Pulz and Gross, 2004).

1.4. Functions and industrial applications of algae

More than 70% of the earth is covered by ocean, which is home to up to 90% of the planet's organisms. The ocean provides many unique environments and rich resources, and there are numerous marine organisms with great potential to produce bioactive compounds that can be used as pharmaceuticals, nutraceuticals and cosmeceuticals. Therefore, more research is necessary to explore, identify, understand, and eventually make use of the organisms living in the ocean (Gomez et al., 2009).

Over the last 2.45 billion years, algae have adapted to extremely harsh and competitive environments by producing an array of compounds and secondary metabolites for chemical defense, and are thus able to live in a wide range of ecological niches (Kelman et al., 2012). They can be found in all ecosystems, both in water and on land, even in places that cannot grow crops, such as deserts and seashores. Algae are extraordinarily diverse within the domains of Eukaryotes and Eubacteria, and have had many highly complex interrelations among each other in their evolutionary paths. Among several major subgroups of Eukaryotes that can produce energy by photosynthesis, algae are present in three out of four. That is, many algae are mostly photosynthetic and have similar biological and ecological functions to those of plants (Stengel et al., 2011). Nevertheless, algae and plants do not share a common evolutionary background, and their biochemistry differs significantly. To date, more than 20,000 species of algae have been identified (Christaki et al., 2012), and they are responsible for about 40–50% of the photosynthesis that occurs on the planet each year, and contribute significantly to the mitigation of greenhouse gas emissions (Qin et al., 2012). The size of marine algae ranges from microscopic individual cells of microalgae to much larger organisms, called *Macrocystis*, that are more than 30 m long (Gomez et al., 2009).

Microalgae are unicellular or simple multicellular species that grow rapidly, living in harsh conditions and withstanding environmental stressors, such as heat, cold, anaerobiosis, salinity, photo-oxidation, osmotic pressure and exposure to ultra-violet radiation (Christaki et al., 2012). Microalgae are superior to conventional plants in terms of productivity, limited seasonal variation, easier extraction and abundant raw materials (Christaki et al., 2012). They are cultivated in artificial batch, fed-batch and continuous modes. Microalgae have considerable plasticity, making it possible to use the same process for many different applications. For instance, microalgae can be utilized for wastewater treatment, biofuels, food production, feed additives and chemicals. Moreover, microalgae can also transform solar energy and carbon dioxide into valuable biomass.

Macroalgae (seaweeds) can be found in coastal areas, and without the organs that are common in terrestrial plants, they have rather simple structures. Macroalgae can be divided into three groups based on their dominant pigments: *Chlorophyceae* (green algae), *Phaeophyceae* (brown algae) and *Rhodophyceae* (red algae). Green algae can absorb a huge amount of light energy, while red and brown algae cannot as they live in deeper waters where there is insufficient sunlight. Brown algae account for approximately 59% of the total macroalgae cultivated in the world, followed by red algae at 40% and green algae at less than 1% (Christaki et al., 2012). Macroalgae can be cultivated on seashores on a large scale. Their growth rate is relatively rapid, and it is possible to control the production of their bioactive compounds such as proteins, polyphenols and pigments by manipulating the culture conditions (Christaki et al., 2012). Investigations indicate that metabolites derived from brown algae, such as phloroglucinol, can have