Seaweed Diversity and Bioactive Compounds

Subjects: Biotechnology & Applied Microbiology

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Seaweed, a miscellaneous group of marine algae, has long been recognized for its rich nutritional composition and bioactive compounds, being considered nutraceutical ingredient. Seaweeds are abundant sources of essential vitamins, minerals, polysaccharides, polyphenols, and unique secondary metabolites, which reveal a wide range of biological activities. These bioactive compounds possess potential therapeutic properties, making them intriguing candidates for drug leads in various medical applications and pharmaceutical drug development.

seaweed bioactive compounds phenolic compounds pigments polysaccharides biomedical

1. Introduction

Seaweeds, also recognized as macroalgae, are multicellular photosynthetic plant-like organisms found mostly in seas and oceans. They are a commercially significant natural resource that is abundantly available, and their potential as food-grade feedstock should not be overlooked, particularly in the context of bioactive compound forecasts [1]. Furthermore, because seawater covers around 70% of the Earth's surface, sustainable cultivation and harvesting of seaweeds is feasible, as they typically have strong growth rates, do not compete with agriculture for land and drinking water, and emit little or no greenhouse gases [2].

Seaweeds have evolved mechanisms to withstand biotic threats such as bacteria, viruses, and fungal infections over millions of years. Seaweeds have evolved to exist under abiotic environmental and stress circumstances that are varied, harsh, and unfriendly, such as temperature and salinity changes, environmental pollutants, or UV light exposure from sessile plants. As a result, these organisms can produce a wide range of secondary bioactive chemicals, including pigments, vitamins, phenolic compounds, sterols, and other bioactive molecules. In addition, they create amino acids and proteins, saturated and unsaturated fatty acids, and polysaccharides, all of which are directly engaged in the development, growth, and reproduction of organisms, allowing them to execute physiological functions [3]. Furthermore, there are various environmental intrinsic and extrinsic variables that have a substantial influence on seaweed compounds yield and quality, such as season, chemical pollution, maturity, microbiome, sunlight, pH. Because of these ecological effects, there is uncertainty in the yield and bioactive potential and production of seaweed bioactive compounds from wild and cultivated seaweed, making them a problematic raw element for industrial utilization even using established and secure extraction methods [4][5].

Despite this, isolated seaweed chemicals have been examined and found to have anti-bacterial, anti-viral, anti-allergic, anti-diabetic, antioxidant, anti-photoaging, anti-pruritic, hepato-protective, hypotension, neuroprotective, and anticancer activities [6][7].

Furthermore, seaweed compounds, such as the brown seaweed polymer alginate, are used as active agents or as secondary compounds for encapsulating or stabilizing the active agent in a range of medicines and novel therapies [8]. However, phenolic compounds, pigments, and polysaccharides are the most studied seaweed compounds in the biomedical field [9]. Although, there is three major compounds from seaweeds that are being key elements into the RD and pharmaceutical units: polysaccharides, phenolic compounds, and pigments. These three types of compounds are the major compound on seaweeds, thus, high quantity and quality. Moreover, these compounds are already used and applied in various industry, being the extraction and isolation very well known. Although, for pharmaceutical area every method and safety need to be carefully analyzed and used, since impurities or a molecular chemical shifting (in the target compound) can damage the human body.

2. Phenolic Substances

Phenolic compounds (**Figure 1**) are byproducts of seaweed metabolism. They are a complicated class of water-soluble chemical compounds with a hydroxyl group linked to an aromatic hydrocarbon group. Phenols are classed as basic phenolic compounds based on the number of substituents, which include terpenoids, flavonoids, phlorotannins, bromophenols, and many mycosporine-like amino acids [5][8].

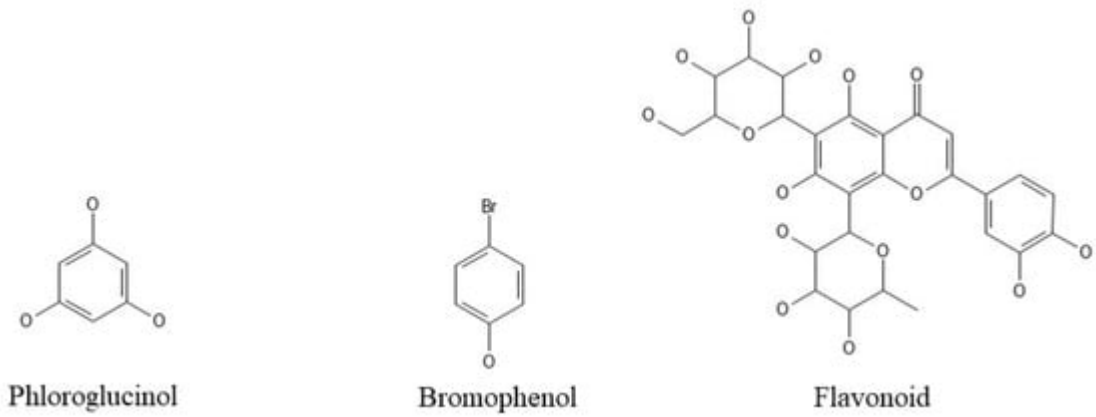

Figure 1. Phenolic compounds structures.

These compounds have a wide range of bioactivities, including anti-tumor, anti-diabetic (commercially available drugs), antiviral, antioxidant, neuroprotective, anti-inflammatory, and sleep-promoting characteristics (for addressing insomnia and other sleep-related disorders) [5].

3. Pigments

As photosynthetic organisms, seaweeds can produce three types of pigments: chlorophylls, carotenoids, and phycobiliproteins. The pigments in seaweed are determined by their color. The green color is caused by the presence of chlorophylls *a* and *b*. The red color is caused by phycobilins such as phycoerythrin and phycocyanin. Brown seaweeds are typically pigmented with chlorophylls a, c1, and c2, b-carotene, and fucoxanthin (**Figure 2**) [10]. These isolated compounds have antibacterial, anti-inflammatory, neuroprotective, antioxidant, and anti-tumor properties [11]. Furthermore, these compounds are being researched for use as fluorescent indicators in the biomedical field [12].

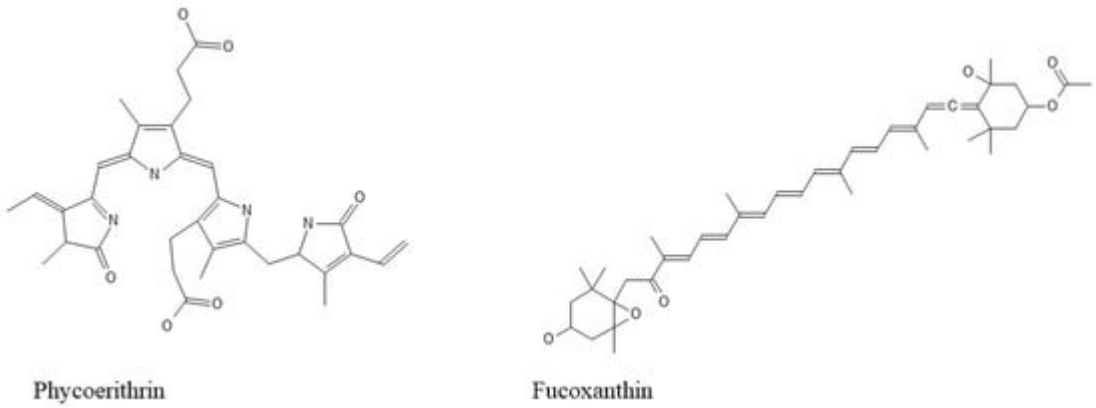

Figure 2. Pigments structures.

4. Polysaccharides

Seaweed-derived polysaccharides (**Figure 3**) with specific structural and functional properties have gotten exceptional investigation interest in the current biomedical field [13].

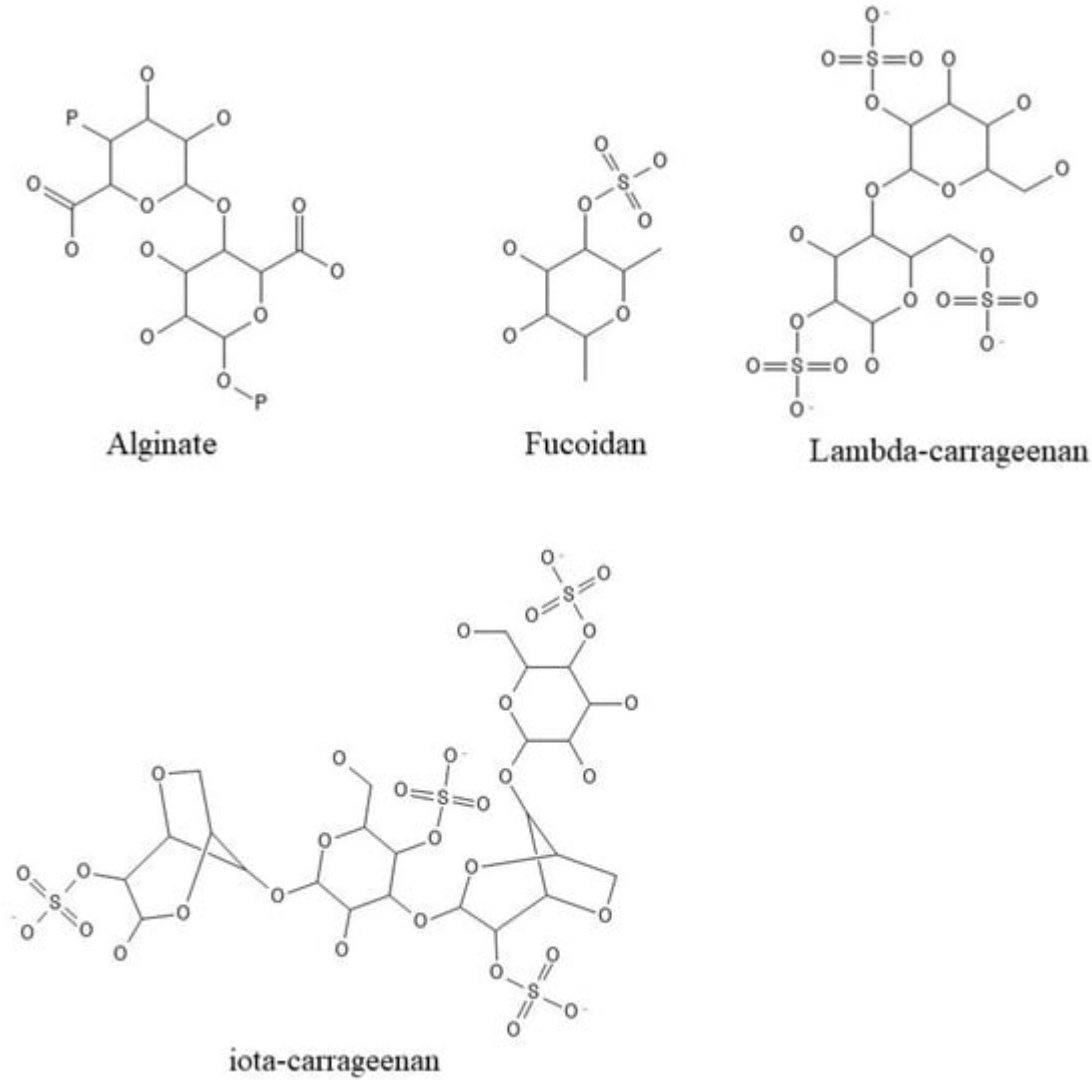

Figure 3. Polysaccharides structures.

Scientists and the industry have been developing novel biomaterials for drug delivery, tissue engineering, and wound dressings by leveraging the advantageous inherent qualities of seaweed polysaccharides. These include characteristics that are biologically adjustable, biocompatible, biodegradable, recyclable, and non-toxic [8][13]. Seaweed polysaccharides have a controlled distribution and are therapeutically effective [13].

Especially with alginate, an anionic polymer with low bioactivity compared to fucoidan, an anionic sulfated polysaccharide extracted from brown seaweed with a wide range of bioactivities including anti-inflammatory, anti-oxidative, anticoagulant, and antithrombotic effects [14]. In the past decade, there has been thorough examination of fucoidan for its potential applications in drug and gene delivery systems, along with diagnostic microparticles [14].

Derived from red seaweed, carrageenan has been a widely employed remedy since ancient times for treating coughs and common colds, a usage supported by both in vitro and in vivo tests. The primary basis for this efficacy lies in carrageenan's capacity to hinder blood platelet aggregation, demonstrating its anticoagulant activity [15][16].

Different carrageenans excel in other demonstrable bioactivities such as anti-tumor, anti-viral, and immunomodulation activities, and their anti-viral properties are commercially exploited [17].

Agar finds application in the biomedical field as a bulking and suspension agent in medicinal solutions and prescription products. Additionally, it is used in capsules and tablets for its anticoagulant and laxative properties. They are also employed to create novel biomedical tools for analysis and characterization [18][19][20].

5. Other Biomedical Compounds of Interest

There are compounds isolated from seaweed that have received little attention in the literature [21][22][23].

Fatty acids hold promise in contributing substantially to the advancement of novel biomedical solutions for immunomodulation drugs, as well as for the treatment and prevention of various conditions such as neoplastic, ocular, cardiovascular, neurodegenerative, and autoimmune disorders [11][21]. Seaweed sterols are plant and animal hormone precursors with numerous bioactivities, including antioxidants, antivirals, antifungals, and antibacterial properties [24].

Seaweeds may be used to extract a variety of secondary bioactive compounds with significant medicinal and industrial potential. Antifungal, antibiotic, antiviral, contraceptive, anti-inflammatory, anticancer, antioxidant, and anticoagulant effects are among the bioactivities of seaweed metabolites.

Despite the biomedical potential of seaweeds, only a limited number of seaweed compounds are presently utilized in the field of biomedicine [5][25][26][27][28][29]. Because biological interest in seaweed is still relatively young, further research and development are needed to explore additional potential seaweed chemicals for this sector. Extraction efficiency in isolating and enhancing the critical bioactive components, as well as optimal agricultural practices, are necessary to maximize the beneficial utilization of seaweed metabolite activities for human health [27][29].

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