Macroalgae Compounds Against Foodborne Pathogens

Subjects: Plant Sciences

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The search for food resources is a constant in human history. Nowadays, the search for natural and safe food supplies is of foremost importance. Accordingly, there is a renewed interest in eco-friendly and natural products in substitution of synthetic additives. In addition, microbial contamination of food products during their obtaining and distribution processes is still a sanitary issue, target for the food industry to avoid food contamination and its related foodborne illnesses. These diseases are fundamentally caused by certain microorganisms listed in this review and classified according to their Gram negative or positive character. Algae have proven to possess high nutritional value and a wide variety of biological properties due to their content in active compounds. Among these capabilities, macroalgae are recognized for having antimicrobial properties. Thus, the present paper revises the actual knowledge of microbial contaminants in the food industry and proposes antimicrobial algal compounds against those pathogenic bacteria responsible for food contamination as valuable molecules for its growth inhibition. The capacity of algae extracts to inhibit some major food pathogen growth was assessed. Moreover, the main applications of these compounds in the food industry were discussed while considering their favorable effects in terms of food safety and quality control.

Keywords: macroalgae ; microbial contaminants ; antimicrobial compounds ; food industry ; safety and quality

1. Introduction

Even though the taxonomic classification of algae is a delicate subject, since each researcher classifies them according to different criteria, generally, marine algae are divided into microalgae and macroalgae or seaweed. Focusing on macroalgae, they are further classified into three main groups: green (Chlorophyta), brown (Phaeophyta), and red algae (Rhodophyta). Thousands of species are found in these three subgroups, many of them being of food interest[1]. In addition, they have been used in traditional medicine for many years against various diseases (tuberculosis, arthritis, colds, and influenza)[2][3]. Eeaweeds are part of the diet in many cultures, especially in Asia since they present a high nutritional value. Algae are a valuable source of protein (5%–14%), fiber, lipids (<3%), and carbohydrates (13%–19%), in addition to its content in micronutrients (such as salts, minerals, and vitamins) necessary for the correct and healthy functioning of the organism[4][5]. Likewise, they are also rich in several secondary metabolites such as phenolic compounds, phycobiliproteins, carotenoids, alkaloids, terpenes, sulfated polysaccharides, or phytosterols[6][7].

For these reasons, algae have been attracting curiosity also in the pharmaceutical industry for a few years, as they are very varied natural matrices that contain a great diversity of compounds with bioactive capabilities. Some of those beneficial biological functions to human health are antioxidant, anti-inflammatory, cardioprotective, antimicrobial, antifungal, antiviral, and anticancer activities, among others[8]. Phytosterols extracted from various algae have demonstrated antimicrobial, analgesic, and antioxidant functions, fucosterol being the predominant sterol in brown algae[4][9]. Other well-known molecules present in algae are sulfated polysaccharides which, in addition to presenting capabilities as gelling and thickening agents such as alginates and carrageenan, are associated with antioxidant, anticoagulant, antiviral, antitumor, anti-inflammatory, and immunostimulant properties, such as the fucoidans present in the cell walls and the extracellular matrices of algae, especially the brown ones[10]. These reasons make them of great interest to the healthcare and food industries[11][12].

Phenolic compounds are associated with a strong antioxidant capacity, which is also associated with other beneficial properties such as anti-inflammatory, antimicrobial, and anticancer. Phenolic compounds constitute a very heterogeneous group of molecules that can be classified in different ways. Notable among them are flavonoids, phenolic acids, lignans, and tannins[13]. Within this last group are classified the so-called phlorotannins, molecules whose structure corresponds to polymers of phloroglucinol (1,3,5-trihydroxybenzene), which are present exclusively in algae, especially in brown. Phlorotannins can be deeper divided into four major groups (fuhalols and phlorethols, fucols, fucophloroethols, and eckols), and are associated with powerful biological activities such as antioxidant, anti-inflammatory, antimicrobial,

antifungal, antibiofilm or antifouling, hepatoprotective and antiviral[14][15]. Moreover, some fatty acids such as palmitic acid, linoleic acid, linolic acid, palmitoleic acid, eicosapentaenoic acid, stearic acid, or oleic acid have also demonstrated cardioprotective, antitumor, and antimicrobial activities[16][17].

As described, the compounds contained in algae show numerous activities beneficial to health. Regarding the antimicrobial capacity of algae extracts, they have been successfully analyzed against various pathogens of great concern to human health. Some of the Gram-positive bacteria studied are strains of *Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus, Enterococcus faecalis* or *Micrococcus luteus*, while the Gram-negative bacteria analyzed include *Klebsiella pneumoniae*, *Serratia marcescens*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella* Typhimirium, or *Vibrio cholerae*[18]. The antimicrobial mechanisms of action associated with compounds extracted from marine algae are varied. These include the changes that occur in the permeability of the membranes thanks to the interaction with proteins and lipids present in them, or the ability to inhibit enzymes[17][19]. Some examples of specific compounds extracted from algae that have shown antimicrobial function are phlorotannins, laminarin, sargafuran, peyssonoic acid, bromophycolides, neurymenolides, acetylmajapolene and phycobiliproteins, phytol, fucosterol, neophytadiene, palmitic, palmitoleic and oleic acids[20][21].

2. The current applications of algae compounds

The main current applications of algae include their use as fertilizers, in the production of biofuels, in the cosmetic industry, and, of course, in food and agriculture[5][22]. An example of the application of compounds with antimicrobial capabilities obtained from macroalgae is their use in the livestock industry as food supplements since it is a good strategy to reduce the use of antibiotics in animal feed. This substitution of antibiotics by natural functional molecules would help to combat the current growing resistance to antibiotics by pathogenic microorganisms[14][20]. Therefore, this abundant and ubiquitous source of bioactive compounds represented by algae could be used to obtain extracts rich in such antimicrobial compounds to be applied in the agri-food, cosmetic or pharmaceutical industries.

Nowadays, many molecules have been recognized as permitted additives. They mostly avoid food spoilage induced by oxidant reactions, microbial growth, and/or browning processes. Some of the permitted additives with antioxidant capacity are ascorbates, tocopherols, gallates, butylates, lactates, citrates, or phosphates, among many others[23]. Those additives considered to exert microbial inhibition growth include acetic, malic, lactic, benzoic, sorbic, and propionic acids and some of their salts, as well as parabens. Sulfites are the most used additives for avoiding food browning caused by any chemical or enzymatic reactions. Nevertheless, several natural compounds represent a current alternative to the use of chemical anti-browning ingredients, such as erythorbic acid, cysteine, 4-hexylresorcinol, and some phenolic acids [24]. In fact, this is the current trend in the food industry - the replacement of chemically synthesized compounds with natural ones. Consumers' claims have prompted this shift due to the side effects related to the consumption of chemically synthesized molecules. Currently, macroalgae represent a promising source of natural molecules with a variety of recognized bioactivities such as antioxidant and anti-microbial, among many others. The high content in polyphenols, such as the phlorotannins that can reach up to 15% of the dry matter, or pigments, such as carotenoids and chlorophylls, are mainly responsible for their antioxidant activities[25]. It is also known that the diversity of polysaccharides present in macroalgae, carrageenan, and agar from red algae, fucoidans from brown and ulvans from green ones, possess antibacterial capacities[26]. Apart from their richness in biomolecules and bioactivities, macroalgae have been demonstrated to represent a cheap, available, and eco-friendly source of compounds, which results in being very interesting for the food industry[25][27][28]. Currently, algae extracts have been evaluated as food additives for food preservation, as ingredients for creating biodegradable films or core ingredients in active packaging with several functions such as anti-biofilm or anti-fouling agents, as shown in Figure 1.

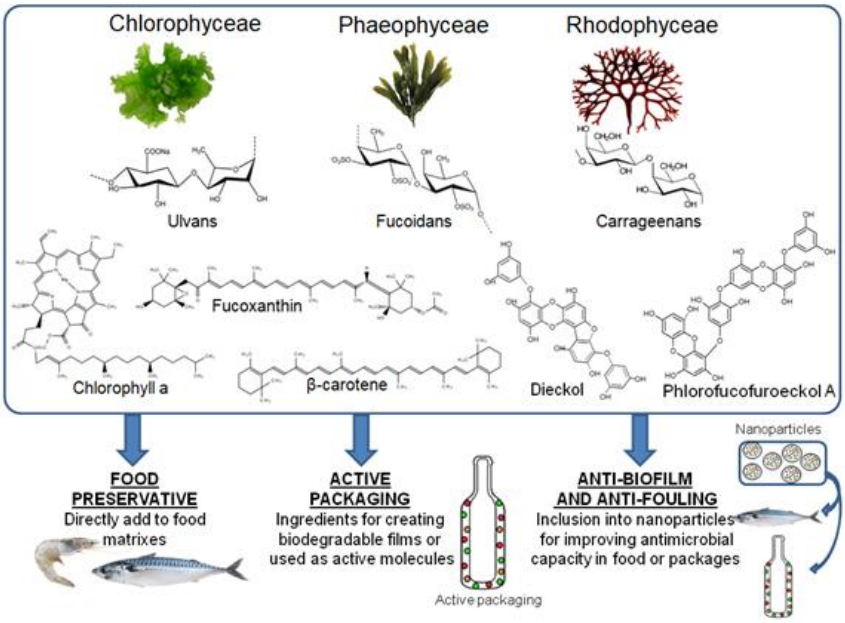

Figure 1. Food applications of macroalgae extracts. Green (Chlorophyceae), brown (Phaeophyceae), and red (Rhodophyceae) macroalgae biomolecules can be used for: (a) their direct application into food products, (b) the development of biodegradable packages, and/or for their incorporation as active ingredients into films (active packaging), (c) for their inclusion into encapsulation systems that can be further used for their application in food matrixes or active packaging.

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