



A Comprehensive Review on Nutrients, Phytochemicals, Bioactive Properties and Toxicological Effects of Marine Red algae, *Champia parvula*

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Abstract: *Champia parvula*, a species of red seaweed predominantly found in Southern Europe and Southwest Asia, has recently garnered attention due to its remarkable properties. Extensive research on this marine seaweed has yielded a wealth of information regarding its biological activity, which varies depending on the type of extract used. Over the past two decades, numerous studies have reported that *C. parvula* is rich in polysaccharides, phenolic compounds, flavonoids, fatty acids, vitamins, and other bioactive compounds that offer numerous health benefits. However, there is currently a dearth of literature devoted specifically to its nutritional composition and recent advancements in its potential health benefits. The current review provides a comprehensive summary of the state of understanding of *C. parvula*, including its geographical locality, morphology, taxonomic classification, active chemical constituents, pharmacological activities, and toxicological effects. It also compiles recently discovered beneficial properties over the past two decades. Consequently, this review serves as a foundation for researchers to develop more bioactive products based on *C. parvula*. Therefore, this review presents consolidated data to aid researchers in the development of a new lead compound sourced from the red algae *C. parvula*.

Keywords: Red algae, *C. parvula*, Nutrients, Phytochemicals, Bioactivity, Toxicity.

I. Introduction

Marine macroalgae are categorized into four groups based on their pigmentation, morphology, and anatomy: Chlorophyta (green algae), Phaeophyta (brown algae), Rhodophyta (red algae), and Cyanophyta (blue-green algae) (Baweja *et al.*, 2016; Hamid *et al.*, 2019). Seaweeds, also known as marine macroalgae, are non-flowering marine plants that are in high demand as cosmetic, pharmaceutical, and food additives. Red algae, which comprise the largest group of seaweeds with approximately 6,000 species, are a potential source of phytocompounds. They are the most abundant and commercially valuable, found on rocky shores from intertidal to subtidal zones (Kaliaperumal, 2015). The red pigment phycoerythrin is involved in photosynthesis and masks the green pigment chlorophyll, which is also present in red algae. These photosynthetic organisms produce basic biomass in the intertidal zone and are a rich source of bioactive compounds such as carotenoids, proteins, oligosaccharides, essential fatty acids, antioxidants, vitamins, and minerals. The compounds of red macroalgae differ from species to species, which are valuable in the medical and pharmaceutical industries (Cotas *et al.*, 2020). Many red species are thin and delicate and are harvested for use as food and medicinal products (Cheong *et al.*, 2018). Sulfated polysaccharides, specifically agar, and carrageenans, are the most significant and widely utilized compounds derived from red algae (Lee *et al.*, 2017; Naseri *et al.*, 2019). Additionally, red algae contain other potential molecules such as essential fatty acids, phycobiliproteins, and various secondary metabolites. These compounds might have been shown to possess various biological activities, including antioxidant, anti-inflammatory, antitumor, antimicrobial, antidiabetic, and metabolic regulatory properties (Khalid *et al.*, 2018; Veluchamy & Palaniswamy, 2020).

Champia is a genus of red seaweed that is widely distributed across European countries, the Indian and Pacific Oceans, Africa, Southwest Asia, and Atlantic islands. *Champia parvula* (C. Agardh) Harvey is a marine red algae from the Champiaceae family that is found throughout tropical and subtropical regions of the world (Harvey, 1853). This species has been reported to produce bioactive molecules and metabolites, which possess several therapeutic activities (Vimala, 2015). The multifaceted pharmacological properties of this red algae have led to its classification as a medicinal food of the current era. Further investigations are currently underway to explore and elucidate additional pharmacological benefits that may be derived from its consumption. This review primarily focus on the nutrients, phytochemical constituents, and biological activities associated with potential health benefits of marine red algae *C. parvula*.



Fig 1: Morphological features of *C. parvula*

Sources: <https://www.marinespecies.org/aphia.php?p=image&tid=145804&pic=14763>,
https://www.algaebase.org/search/images/detail/?img_id=5339

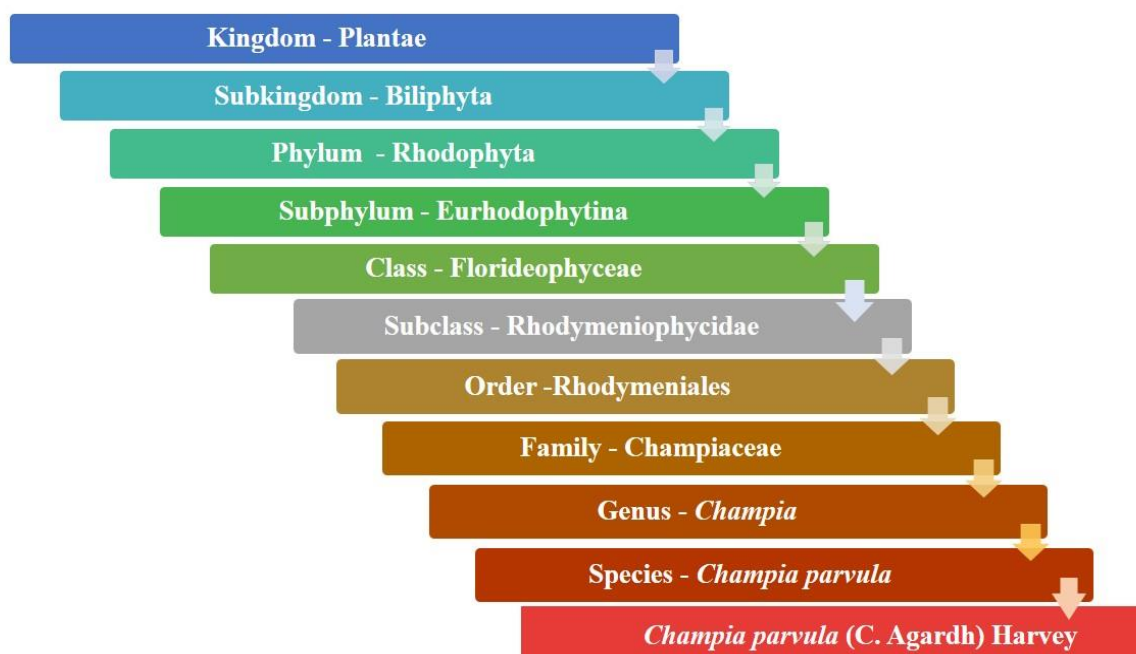
II. Methodology

This study conducted a comprehensive review of the available literature on the red seaweed *Champia parvula* and related articles. The review process involved the collection, identification, screening, selection, and analysis of relevant studies by the recommended reporting parameters. This study utilized various search engines, including Google Scholar, Research Gate, PubMed, Web of Science, ScienceDirect, Mendeley, and Scopus, Wiley, MDPI databases, to identify articles containing the keywords used, alone or in combination with “*Champia parvula*”, “*C. parvula*”, AND “red seaweeds” OR “nutrients” OR “phytochemicals” OR “bioactive compounds” OR “bioactive properties” OR “antioxidant” OR “antibacterial” OR “antidiabetic” OR “anticancer” OR “larvicidal” OR “nanoparticles” OR “toxicity”. The search was limited to articles published between 2000 and 2023 and excluded any publications that were released after the date of this review. Additionally, online theses, conference proceedings, and book chapters were also considered in this study. Only English articles with a full text were considered.

III. Geographical Location

The *Champia* genus (Rhodymeniales, Champiaceae) of red algae comprises 36 species worldwide. Among these, *Champia parvula* (C. Agardh) Harvey is the most commonly reported, with a global distribution ranging from subarctic to tropical regions in Europe, Asia, Australia, the Indian Ocean, Northwest Atlantic, California may represent distinct genetic species (Guiry & Guiry 21; Mathieson & Dawes, 2017). The species is epiphytic and is found on smaller algae in the lower intertidal pools and subtidal regions of south-west England, Ireland, and the Channel Islands (Lane *et al.*, 2017). This species is currently considered to have a panoeceanic distribution. *C. parvula* (C. Agardh) Harvey is primarily found in Spain, including locations such as Cadíz, San Pedro de Veigue, and Sada, as well as some regions in France, including Les Haies de la Conchee, Saint-Malo, Brittany; Saint Lunaire, Brittany; L'Oursier (Sound) iles Chausey, Basse-Normandie, and Plougonvlin, Brittany (Griffith *et al.*, 2017). The protologue for *Champia parvula* (*Chondria parvula* C. Agardh) by Agardh, characterized by its generalized nature, was a common feature of species descriptions during the 19th century. This has led to the identification of numerous specimens with comparable morphologies as this species, from locations both proximate and distant to the type locality, resulting in a distribution that could be deemed cosmopolitan. Japanese populations of *C. parvula* were first recorded by Okamura in the central part of Honshu, and subsequent reports have identified this species in subarctic to subtropical regions throughout the country. The habit of Japanese *C. parvula* is highly variable, and it has been found to grow in the same site in Iwate Prefecture, inhabiting the lower eulittoral zone (Suzuki *et al.* 2013). Furthermore, *C. parvula* from Japan, Australia, the British Isles, Polynesia, and Puerto Rico exhibit differences in certain morphological details, such as pattern, branching prototype, notch of fragment constriction at the diaphragms, and the structures of tetrasporangia and cystocarps. It has been found in various locations, including the Seaward of Media Luna Reef and Culebra in Puerto Rico, offshore Louisiana in the United States, and Hawaii. In Bermuda, historically, only two species of the *Champia* genus have been reported, namely *C. parvula* (C. Agardh) Harvey and *C. salicornioides* Harvey (Schneider *et al.*, 2018).

Taxonomy

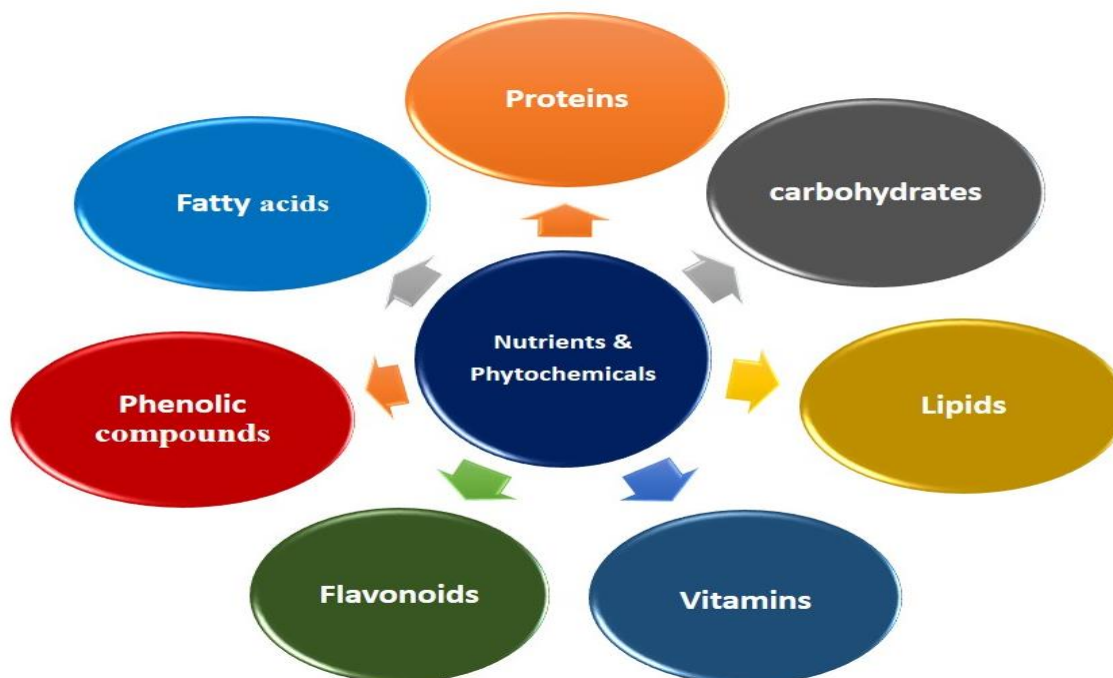


IV. Morphological features

The marine red algae, *C. parvula* is soft, gelatinous, and translucent, with a pinkish to pale reddish or greenish color that can sometimes appear iridescent blue. This species can be found growing on low intertidal to subtidal rocks or epiphytic on larger algae or hard bottoms in the shallow sublittoral zone as intertwined tufts or dense spherical clumps (Suzuki *et al.*, 2013). The thallus is densely tufted, crisply membranous in texture, and measures 2-13 cm in length. The thallus displayed constriction at the branching points, indicating a solid and multiaxial structure. The central region of the thallus was hollow at the inter-nodal region, while it was solid at the nodal regions, with a layer of parenchymatous cells. The basal portion of the thallus was robust, large, and cylindrical, in contrast to the apical region, which had small meristematic cells that facilitated the division and formation of various plant parts (Ravikumar, 2012). The branching system is verticillate or alternate tapered short branches, with segments that taper from 0.3-2.5 mm in diameter and gradually taper towards both the base and the apices are 0.9-1.8 μm long (Malathi *et al.*, 2018). The segments of the branches are hollow, swollen, and barrel-shaped, with slightly constricted joints and obtuse apices. It appears as a bushy, branching, dull red-brown plant, with axis and branches that are coarsely segmented (El-Adl MF, 2014). The tips of the branches are obtuse. This species produces spherical tetrasporangia that are 55-80 (and sometimes up to 100) μm in diameter and tetrahedrally divided. These structures are numerous and form in the surface cortex. Cystocarps are also present and can be either spherical (measuring 500-800 μm in diameter) or urn-shaped (measuring 300-500, and sometimes up to 1500, μm in height and up to 800 μm in diameter). They can be solitary, in pairs, or sometimes in groups (Titlyanov *et al.*, 2017).

V. Nutritional and Phytochemical Profile

The marine red alga, *Champia parvula*, is a rich source of various biochemical constituents, including protein, carbohydrates, polysaccharides (sulfated, carboxylated, and insoluble), pectins, and crude lipids (Ravikumar 2012). Polysaccharides, specifically sulfated galactans, have been identified in *Champia parvula*. The monosaccharide compositions of crude, sulfated, and desulfated polysaccharides of this species include 6-O-Me-galactose, galactose, 3, 6-anhydrogalactose, and glucose (Sanjay Kumar *et al.*, 2011). A comprehensive analysis of the amino acid composition of *C. parvula* revealed the presence of 20 amino acids, including both essential and non-essential amino acids. Notably, elevated levels of essential amino acids, such as methionine, cysteine, leucine, valine, histidine, lysine, tryptophan, phenylalanine, threonine, tyrosine, and isoleucine, were identified. Additionally, non-essential amino acids, such as proline, serine, aspartic acid, glycine, glutamic acid, arginine, asparagine, glutamate, and alanine, were also found (Vinothkumar *et al.*, 2020). *C. parvula* have been found to possess numerous vitamins as fat-soluble vitamins (vitamin A and vitamin E) and water-soluble vitamins including vitamin C and B-complex vitamins, such as vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin B9, and vitamin B12. Among these Vitamin C content is very high (Vinothkumar *et al.*, 2019). In addition to its nutritional value, *C. parvula* contains various phytochemicals, including sterols, glycosides, anthroquinones, phenols, alkaloids, triterpenoids, tannins, saponins, flavonoids, and steroids. Among these phytochemicals, flavonoid compounds, such as rutin, quercetin, kamferol, and phenol compounds, including gallic acid and cinnamic acid, were identified. Furthermore, the fatty acid profile of *C. parvula* was determined to comprise palmitic acid, margaric acid, stearic acid, oleic acid, linolenic acid, alpha-linolenic acid, and moroctic acid (Vinothkumar *et al.*, 2015).

Fig 2: Chemical composition of *C.parvula*

VI. Bioactivity

The finding of health-related functionalities of *C.parvula* has been opened possibilities for its numerous biological and pharmacological activities. Table 1 highlights the documented biological activities of *C. parvula* in the literature over the past decade.

a) Antioxidant activity

Free radicals such as superoxide anion radical, hydroxyl radical, hydrogen peroxide, singlet oxygen, nitric oxide radical, and lipid peroxides are referred to as reactive oxygen species (ROS) which are formed during normal cellular physiological or biochemical processes. They prompt oxidative stress which causes cellular damage and play an important role in the pathogenesis of several diseases. Antioxidants guard the cells against the damage produced by oxidative stress either by scavenging free radicals or by preventing the formation of free radicals. Hence, the progression of diseases induced by oxidative stress can be prevented by supplementing with natural antioxidants.

An investigation was conducted to determine the antioxidant activity of methanol extract from the marine red alga *Champia purvula*, using the DPPH and ABTS assays (Vinothkumar *et al.*, 2019). The radical scavenging activity was observed at various concentrations ranging from 100 to 900 µg/mL. The IC₅₀ value of DPPH radical was found to be 33 µg/mL, while that of ABTS was 33.5 µg/mL, both of which were compared to the standard. The results indicate that *C. purvula* possesses potent antioxidant activity, suggesting its potential use in the development of pharmaceutical drugs. The antioxidant potential of Cp-AuNPs was evaluated using DPPH, H₂O₂, and FRAP radical scavenging assays (Viswanathan *et al.*, 2022). The DPPH scavenging assay demonstrated the highest inhibition of 80.2% for Cp-AuNPs at a concentration of 50 mg/mL. In the H₂O₂ scavenging assay, Cp-AuNPs exhibited 74.7% inhibition at 50 mg/mL, which was significantly higher than that of ascorbic acid. Furthermore, Cp-AuNPs displayed significantly higher ferric-reducing power, with 85.2% inhibition at 50 mg/mL. These findings indicate that seaweed-synthesized gold nanoparticles possess excellent antioxidant activity, which can be attributed to the presence of antioxidant-rich components. The antioxidant capacity of Cp-AgNPs was assessed through DPPH, H₂O₂, and ferrous-reducing power assays (Viswanathan *et al.*, 2023). In the DPPH scavenging experiment, Cp-AgNPs exhibited a $91.34 \pm 1.2\%$ inhibition of DPPH radicals at a concentration of 50 µg/mL. In the hydrogen peroxide scavenging experiment, Cp-AgNPs demonstrated a $76.4 \pm 2.8\%$ inhibition of hydrogen radicals at the same concentration. The synthesized Cp-AgNPs also displayed a ferric ion-reducing ability of $75.6 \pm 1.3\%$ at 50 µg/mL, which was comparable to that of standard antioxidant vitamin C ($77.4 \pm 0.8\%$). Findings from these studies revealed that silver nanoparticles derived from seaweed possess potent antioxidant properties. Seaweed extract contains various secondary metabolites that act as nanomaterial stabilizing or capping agents, and capped nanoparticles exhibit higher antioxidant capacity and oxygen radical absorbance action.

b) Antidiabetic activity

Diabetes is a metabolic disorder characterized by elevated levels of plasma glucose, resulting from insufficient insulin production by the pancreas or inadequate insulin utilization by the body. Consequently, an effective therapeutic approach for diabetes management involves addressing postprandial hyperglycemia, which can be achieved by inhibiting carbohydrate

hydrolyzing enzymes. Alpha amylase and alpha-glucosidase are key digestive enzymes responsible for breaking down long-chain carbohydrates, starch, and disaccharides into glucose. Inhibiting these enzymes presents a promising avenue for the development of lead compounds in diabetes treatment. By inhibiting hydrolytic enzymes, the absorption of glucose from the intestinal tract into the bloodstream is reduced, leading to a decline in postprandial hyperglycemia. Moreover, research has demonstrated that polyphenols derived from macroalgae possess antioxidant activity, and many of these algae species also exhibit hypoglycemic properties. In a previous in vitro study, the antidiabetic activity of the red alga *Champia parvula* (C. Agardh) was evaluated using alpha-amylase and alpha-glucosidase inhibition assays (Vinothkumar *et al.*, 2017). The crude methanol extract of *Champia parvula* exhibited the highest percentage of alpha-amylase inhibition at 900 µg/mL, with a value of 98.50 ± 0.02 µg/g, and showed the inhibitory activity at the dose of 173 µg/mL for α-amylase activity. Similarly, the highest percentage of alpha-glucosidase inhibition was observed at 900 µg/mL, with a value of 91.48 ± 0.02 µg/g and it showed inhibitory activity at the dose of 81 µg/mL for α-glucosidase activity. However, the IC₅₀ value of alpha-amylase was found to be twofold higher than that of alpha-glucosidase. These findings suggest that *C.parvula* may be effective in the treatment of diabetes through the inhibition of alpha-amylase and alpha-glucosidase enzymes, and may lead to the development of natural drugs in the pharmaceutical field.

Table 1: Biological activities reported in *C.parvula*

Reported Biological activities	Extract from <i>C. parvula</i>	Methods/Model of Study	Dosage level	References
Antioxidant activity	Methanolic extract	<i>In-vitro</i> DPPH and ABTS assays	100 to 900 µg/mL	Vinothkumar et al, 2019
	Cp-AuNPs	DPPH, H ₂ O ₂ , and ferrous-reducing power assay	10 to 50 µg/mL	Viswanathan et al, 2022
	Cp- AgNPs	DPPH, H ₂ O ₂ , and ferrous-reducing power assay	10 to 50 µg/mL	Viswanathan et al, 2023
Antidiabetic activity	Methanolic extract	<i>In-vitro</i> alpha-amylase and alpha-glucosidase inhibition assays	100 to 900 µg/mL	Vinothkumar et al, 2017
Antibacterial activity	Acetone, Benzene, Chloroform, Methanol, and Ethyl acetate extracts	Disc diffusion method - <i>Klebsiella pneumoniae</i> , <i>Proteus vulgaris</i> , <i>Bacillus cereus</i> , <i>Bacillus subtilis</i> , <i>Staphylococcus aureus</i> , and <i>Salmonella typhi</i>	100 µg/mL	Vinothkumar et al, 2015
	Cp-AgNPs	Well diffusion method - <i>Streptococcus mutans</i> , <i>Staphylococcus aureus</i> , and <i>Enterococcus faecalis</i>	25, 50, and 100 µL	Viswanathan et al, 2023
Anticancer activity	Cp-AuNPs	Human lung (A549) cancer	3 –50 µg/mL	Viswanathan et al, 2022
	Cp- AgNPs	Human lung (A549) cancer and colon (HT-29) cancer cells	3.125 –50 µg/mL	Viswanathan et al, 2023
Antifungal activity	Hexane, Ethyl acetate, Chloroform, Methanol, and Aqueous extracts	<i>Candida albicans</i> , <i>Candida tropicalis</i> , <i>Trichophyton mentagrophytes</i> , and <i>Aspergillus flavus</i>	25 -100 µg/mL	Vinothkumar et al, 2019
Antifouling Potential	Methanolic extract	Epiphytic diatoms - <i>Navicula subinflata</i> and <i>Nitzschia palea</i>	100 and 250 µg	Sivadasan Deepa et al
Larvicidal activity	Ethanolic extract	Dengue mosquito vector <i>Aedes aegypti</i> (Linn.).	20-100 ppm	Yogarajalakshmi et al, 2020

c) Antibacterial activity

Bacterial infections are recognized as a major public health concern, prompting researchers to undertake extensive investigations aimed at discovering innovative antimicrobial drugs from diverse origins. Despite notable progress in the development of antibacterial agents, the emergence of multidrug-resistant bacteria has created an urgent demand for the identification of novel antibacterial agents. In recent years, macroalgae or seaweeds have gained attraction due to diverse health-promoting characteristics and are a viable source of organic compounds with a wide range of biological properties including antimicrobial activity that can be used in pharmacological, cosmetic, and food industries.

A previous investigation has demonstrated the antimicrobial inhibitory effect of *Champia parvula*, a red alga, on pathogenic bacteria such as *Klebsiella pneumoniae*, *Proteus vulgaris*, *Bacillus cereus*, *Bacillus subtilis*, *Staphylococcus aureus*, and *Salmonella typhii* (Vinothkumar *et al.*, 2015). The study employed the disc diffusion method and utilized various solvents at a concentration of 100 µg/mL. The results indicate that the methanol extract alone exhibited a higher zone of inhibition against *Salmonella typhii* (15.4 ± 0.2), *Bacillus subtilis* (13.8 ± 0.1), *Staphylococcus aureus* (10.7 ± 0.2), and *Proteus vulgaris* (10.6 ± 0.1). The acetone, benzene, chloroform, and ethyl acetate extracts showed moderate activity against most of the pathogens, while the chloroform extract was inactive only against *Bacillus cereus*. The antimicrobial efficacy of *C. parvula*-synthesized AgNPs was evaluated against clinical pathogens using the agar well diffusion method (Viswanathan *et al.*, 2023). Cp-AgNPs significantly inhibited the growth of bacterial pathogens such as *Streptococcus mutans*, *Staphylococcus aureus*, and *Enterococcus faecalis*, as well as the fungal species *Candida albicans*, at different concentrations. Cp-AgNPs were found to be particularly effective against *S. mutans* (23 mm), *S. aureus* (21 mm), *E. faecalis* (20 mm), and *C. albicans* (20 mm) at a concentration of 100 µL/mL.

d) Antifungal activity

Fungal infections represent a significant threat to human health, with the emergence of resistance to fungal strains leading to a substantial number of individuals worldwide suffering from such infections. The currently available antifungal drugs are either prohibitively expensive or associated with numerous adverse effects. However, medicinal plants have shown promise in treating a range of fungal infections, with some exhibiting broad-spectrum antifungal activity. This highlights the potential of natural products as a source of novel antifungal agents. Notably, various seaweeds have demonstrated potential in treating a range of fungal infections, with some exhibiting broad-spectrum antifungal activity. A previous study has demonstrated the antifungal activity of red seaweed *Champia parvula* (Vinothkumar *et al.*, 2019). In order to investigate the antifungal properties of *C. parvula*, crude extracts were obtained using various solvents including n-hexane, ethyl acetate, chloroform, methanol, and water. Results indicate that the methanol extracts of *C. parvula* exhibited potent antifungal activity, particularly against *C. albicans* with a zone of inhibition of 76.66%. The highest inhibition was observed against *C. tropicalis* at 16.7 mm, while the minimum inhibition concentration was found to be 12.5 µg/mL and the minimum fungal concentration was 25 µg/mL in the methanolic extract.

e) Antifouling activity

Marine biofouling communities are intricate and dynamic ecosystems that comprise a diverse array of organisms. The establishment of such communities commences with bacterial adhesion, succeeded by the colonization of higher organisms, including invertebrate larvae and algal spores. Recent reports suggest that fungi, akin to bacteria, are ubiquitous inhabitants of marine waters and are present in surface-dwelling communities (unpublished data). Additionally, diatoms, flagellates, and grazing protozoa are frequently associated with biofilms. The interactions among these diverse organisms govern the formation of the mature biofouling community. Moreover, secondary metabolites produced by marine animals and seaweeds can regulate the colonization of fouling organisms. Marine macroalgae exhibit a remarkable resistance to fouling organisms in the marine environment. This resistance is attributed to their ability to produce antifouling compounds, as well as to regulate the attachment of micro and macrofoulers. In a recent study conducted by Sivadasan Deepa *et al.*, the antifouling activity of *C. parvula* against the epiphytic diatoms *Navicula subinflata* and *Nitzschia palea* was evaluated. The results indicated that *C. parvula* exhibited significant antialgal activity against the fouling diatom *Nitzschia palea*, with an inhibition zone of 2.12±0.54 at 250 µg / well, suggesting a species-specific inhibition.

f) Larvicidal activity

The eradication of mosquito larvae has been identified as a more practical approach to controlling mosquito populations compared to targeting adult mosquitoes and nymphs. However, the use of chemical insecticides for this purpose has been found to pose significant environmental risks and has led to the emergence of resistance in numerous mosquito species against synthetic insecticides. Consequently, traditional larvicidal compounds from natural sources have emerged as a promising alternative for mosquito control. A study was conducted to investigate the toxicological and biochemical effects of red algae *C. parvula* on the dengue mosquito vector *Aedes aegypti* (Yogarajalakshmi *et al.*, 2020). The results showed that ethanolic extract of *C. parvula* (Ex-Cp) exhibited potential larvicidal and repellent effects, as well as strong enzyme inhibition activity against major digestive and detoxifying enzymes such as carboxyl esterase (α and β), GST, and CYP450 in the dengue mosquito. The non-target toxicity of Ex-Cp and Temephos on the beneficial aquatic mosquito predators' *A. bouvieri*, *Tx. splendens*, and *D. indicus* was observed to have a significant mortality rate across various treatment dosages. Notably, the treatment dosage of Ex-Cp exhibited comparatively lower toxicity towards both species as compared to the chemical pesticide Temephos.

g) Anticancer activity

Seaweeds contain phytochemical substances that possess a diverse range of pharmacological properties and are utilized in an eco-friendly method to produce stable metal nanoparticles that are less harmful. Considerable attention has been devoted to exploring the medicinal properties of natural compounds derived from plants and seaweeds. Among the various activities of marine drugs, antitumor activity has emerged as a particularly significant area of investigation. Numerous algae and their metabolites have

demonstrated potent cytotoxicity, thereby contributing significantly to the development of novel pharmaceutical compounds for antitumor drugs derived from algae.

Recent research has revealed that biocompatible gold nanoparticles (AuNPs) synthesized through a biogenic method utilizing the red marine algae *C. parvula* exhibit significant potential in the development of next-generation anti-cancer medicine (Viswanathan *et al.*, 2022). Additionally, investigations into the anti-cancer activity of Cp-AuNPs on lung cancer (A549) cells have demonstrated a high potential for anti-cancer efficacy, with an IC₅₀ value of 36.08 mg/mL. These results underscore the potential of biogenic Cp-AuNPs as a promising candidate for the development of novel anti-cancer therapeutics. The extract of red seaweed *Champia parvula*, which is rich in antioxidants, has gained attention for its potential in preventing human diseases. Previous research has explored the phytoconstituents composition of the aqueous extract derived from *C. parvula*, as well as its ability to synthesize silver nanoparticles (Viswanathan *et al.*, 2023). The *in vitro* antitumor activity of Cp-AgNPs against human lung (A549) and colon cancer (HT-29) cell lines was also investigated. The half inhibitory concentration was found to be 21.54 µg/mL in A549 cells, while the IC₅₀ value for HT-29 cells was approximately 42.36 µg/mL. This study suggests that Cp-AgNPs-treated A549 cells exhibited stronger activity at lower concentrations than HT-29 cells. *C. parvula*-synthesized AgNPs demonstrated potential anticancer activity in lung and colon cancers at minimal concentrations. The study provides evidence that Cp-AgNPs can control cancer cell proliferation.

VII. Toxicological effects

The available literature on pesticide data about aquatic microorganisms primarily focuses on algae, with comparatively fewer studies conducted on aquatic bacteria and protozoa. Endosulfan, a synthetic, chlorinated cyclodiene insecticide, is commonly utilized in the cultivation of grains, tea, fruits, vegetables, tobacco, and cotton. The application of endosulfan has been found to have deleterious effects on the growth of red algae. Thurby's research revealed that chronic exposure to endosulfan concentrations of 47 and 130 mg/L impaired female growth and tetrasporophytes, respectively, in the marine red alga *Champia parvula*. Furthermore, higher concentrations of 360 to 600 mg/L resulted in chronic reproductive effects in the alga. The maximum allowable toxicant concentration for endosulfan in *C. parvula* was determined to be 47 mg/L (DeLorenzo *et al.*, 2001).

Metals are naturally present in seawater, and several of them, including copper, cobalt, iron, manganese, nickel, selenium, vanadium, and zinc serve as essential nutrients for marine organisms. However, when uptake rates exceed the capacity of excretory, metabolic, storage, and detoxification mechanisms, toxic effects may occur (Kumar, 2021). Various techniques are employed to evaluate the impact of metals, spanning from cellular to community levels of biological organization. Disturbances in lower-order biochemical responses may be closely linked to disruptions in vital life processes, such as growth and reproduction, which can ultimately impact the health and survival of individuals, populations, and communities (Ferrara, 2022).

Marine algae can accumulate arsenate from seawater, which is then reduced to arsenite and subsequently oxidized to form a variety of organoarsenic compounds. These compounds, including arsenite, methylarsonic acid, and dimethylarsinic acid, are released by the algae into the surrounding seawater. It has been observed that dissolved arsenite and arsenate are more toxic to marine phytoplankton than to marine invertebrates and fish. This may be attributed to the limited ability of marine animals to bioconcentrate inorganic arsenic from seawater, while they can bioaccumulate organoarsenic compounds from their food. Inorganic arsenic is known to be moderately toxic to marine organisms. Previous study have shown that exposure to arsenite inhibits mature cystocarp formation in the macroalga *C. parvula* at a concentration of 95 mg/L, while exposure to 300 mg/L arsenite results in the mortality of the alga. However, a concentration of 10,000 mg/L arsenate in seawater does not have lethal effects on *Champia* (Neff, 1997). It is noteworthy that the toxicity of arsenate increases as the concentration of phosphate in the exposure water decreases, indicating that dissolved phosphate affects the bioavailability of arsenate.

Thurby *et al.* conducted a study to assess the toxicity of ambient water in the Hudson/Raritan Estuary towards the sea urchin *Arbacia punctulata* and the marine red alga *C. parvula*. The results indicated that the toxicities towards the two species were not correlated. Specifically, the data for *A. punctulata* demonstrated a significant improvement in water quality in four out of seven areas, namely the Hudson River, East River, Kill van Kull, and Raritan Bay. However, the water became more toxic to *C. parvula* overall, although there was a significant decrease in toxicity in some parts of the Hudson River and Raritan Bay. Furthermore, there was no consistent relationship between the toxicity of a sample towards *C. parvula* and *A. punctulata*. Toxicity identification evaluations conducted on samples from two stations suggested that cationic metals were the source of the observed toxicity.

The exposure of Nickel in marine waters is a result of various anthropogenic and natural sources, with mining being a significant concern. The primary sources of Nickel are magmatic sulfides and lateritic ores, which are formed due to the extensive chemical and physical weathering of ultramafic rock, commonly found in tropical regions (Gissi *et al.*, 2020). However, the lack of chronic toxicity data for tropical marine waters poses a challenge for environmental management. To address this issue, temperate data is often extrapolated to other climatic regions. The Ni toxicity test was conducted at New England Bioassay facility located in Manchester, CT. Parametrix reported that the chronic reproduction test conducted with the red macroalgae, *Champia parvula*, exposed to nickel chloride hexahydrate toxicity test, yielded an EC₁₀ value of 144 µg/L in artificial seawater with a salinity of 30‰, supplemented with GP2/ASW growth media, and exposed to nickel for 48 hours (DeForest and Schlekat, 2013).

Cobalt is a naturally occurring metal that is often found in complexes with other metals. It is commonly obtained through mining activities that also yield nickel and copper. In marine environments, cobalt is predominantly present in the form of the free cobalt ion (Co²⁺). The chronic toxicity of cobalt against marine red algae *C. parvula* was demonstrated by using a species sensitivity distribution approach to develop international water quality standards. This involved determining a predicted-no-effect concentration and ambient water quality criteria. The lowest series of cobalt spiking occurred in the *C. parvula* test, with nominal concentrations ranging from 5-2500 µg/L. When comparing measured total cobalt to nominal target concentrations, the *C. parvula* test showed measured total cobalt between 36 and 81% of nominal, from low to second highest dose. *Saili et al.*, reported no adult female *C. parvula* mortality at the end of the recovery period. The most sensitive endpoint for *C. parvula* was reproduction, which was affected by cobalt in 8 of 9 exposures, resulting in an EC10 of 1.23 µg dissolved Co/L. It was found that *C. parvula*, as a marine organism, was generally less sensitive to dissolved cobalt than freshwater organisms.

VIII. Conclusion

This review presents a comprehensive compilation of the nutritional and phytochemical composition of *C. parvula*. The analysis encompasses carbohydrates and fiber, proteins and amino acids, lipids and fatty acids, minerals, vitamins, pigments, and antioxidant profiles. Additionally, the bioactive properties of *C. parvula*, including antioxidative, antibacterial, anticancer, anti-diabetic, and larvicidal activities, as reported in previous studies, are described and discussed. Despite the impressive nutrient profile of *C. parvula*, it remains underutilized and is only cultivated in the wild on a global scale. It is hoped that future research will focus on functional food development and cultivation techniques for *C. parvula*, as it has the potential to address food and nutrient security issues worldwide. Furthermore, extensive studies on the isolates and extracts from *C. parvula* are crucial to understanding its bioactivity and mechanisms of action, while highlighting its commercialization potential, particularly for nutraceutical and pharmaceutical applications.

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Conflicts of interests

The author declare that the content of this article has no conflict of interest

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