IN VITRO ANTIOXIDANT AND CYTOTOXIC PROPERTIES OF FUCOIDAN FROM THREE INDIAN BROWN SEAWEEDS

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ABSTRACT

Objective: In the present study, fucoidan extracted from three brown algae, Sargassum wightii, Turbinaria ornata, and Padina tetrasdromatica, was purified, characterized, and evaluated for antioxidant and cytotoxic properties.

Methods: Algal powders were sequentially extracted with five solvents based on polarity and residue was subjected to acid extraction. The filtrates were precipitated for alginate, and result supernatant was precipitated for fucoidan. The precipitate was centrifuged; pellet dialyzed and lyophilized to yield crude fucoidan, which was purified by diethylaminoethyl cellulose chromatography and characterized by biochemical tests and Fourier-transform infrared (FT-IR) spectrometry. Solvent extracts and fucoidans were subjected to 2,2-diphenyl-1-picrylhydrazyl assay. Fucoidans were subjected to trypan blue cytotoxicity assay.

Results: Antioxidant activity was highest in methanol extracts and Padina crude fucoidan, while lowest in hexane extracts and purified Sargassum fucoidan. Sargassum yielded the highest amount of fucoidan (7.14%). Total carbohydrates increased as Sargassum > Padina > Turbinaria, sulfates as Padina > Turbinaria > Sargassum, and protein content was 0.1±0.01%. Cytotoxicity increased in a dose-dependent manner; the highest and lowest for Padina at 200 mg mL⁻¹ (40%) and 10 mg mL⁻¹ (4%), respectively. Antioxidant and cytotoxic properties exhibited a positive correlation with sulfate content. FT-IR spectral values were characteristic to fucoidan.

Conclusion: Fucoidans from the three algae effectively scavenged free radicals and showed good cytotoxic activity. There was a positive correlation between sulfate content and bioactivity of fucoidans, supporting its structure-function relationship. Thus, extracts and fucoidans from these algae are found to be potential candidates for pharmacological applications.

Keywords: Antioxidant, Cytotoxic, Fucoidan, Brown algae, Sargassum wightii, Turbinaria ornata, Padina tetrasdromatica

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INTRODUCTION

Fucoidans refer to a class of fucose-containing sulfated cell wall polysaccharides with complex, heterogeneous, and diverse chemical composition and structure. These polysaccharides in common have a backbone of (1 → 3)-linked α-L-fucopyranosyl residues or of alternating (1 → 3)- and (1 → 4)-linked α-L-fucopyranosyl residues but may also include sulfated galactofucans with backbones of (1 → 3)-β-D-galacto and/or (1 → 2)-β-D-mannopyranosyl units with fucose. It contains L-fucose as main sugar unit and varying amounts of minor monosaccharides such as D-galactose, D-xylene, D-glucose, D-mannose, D-glucuronic acid, and D-uronic acid along with other substitutions [1]. A wide range of biological activities has been reported for fucoidans extracted from different brown seaweeds, namely, antioxidant [2], anti-inflammatory [3], anticancer [4,5], immunomodulatory [6], anticoagulant [7], antithrombotic [8,9], antiviral [10], antiarthritic [11], antidiabetic [12], and antiallergic [12] effects among many others. Several methods are available for fucoidan extraction such as hot water, acidic, alkaline, microwave-assisted [14], ultrasound-assisted [15], and enzymatic methods [16]. Purification, and characterization of fucoidan [17]. The molecular weight, structure, chemical composition, and bioactivity of fucoidan depend on these methods as well as the species, location, and season of the collection [18].

Oxidative stress and the release of free radicals are one of the major causes for several disease conditions such as rheumatism, cancers, aging, neural disorders, ulcerative colitis, and cardiovascular disorders. Free radicals released evoke inflammatory responses by damaging the important macromolecules and membrane system of cells. Antioxidants can neutralize these free radicals, thereby protecting from such diseases. The commercially available synthetic antioxidants are found to exert harmful effects, and hence, there is a quest for exploring natural antioxidants. Fucoidan derived from many brown seaweeds has been reported to have an excellent antioxidant property [11].

The World Health Organization, through its cancer research agency, International Agency for Research on Cancer, has conducted research and reported that cancer is the second leading cause of death globally and was responsible for 8.8 million deaths in 2015. Globally, nearly 1 in 6 deaths is due to cancer [19]. Nowadays, a combination of therapies is used to treat cancers, wherein chemotherapy is the most commonly employed and it has been found that the synthetic chemotherapeutic drugs used to affect both cancer and normal healthy cells alike, causing multiple side effects. Natural alternatives like fucoidan from various brown algae have shown promising effects against different types of cancers, while also causing no or minimum side effects and, in turn, improving the overall health and life expectancy of the individuals [20].

In this context, the present study is aimed at utilizing the three brown algal species, Sargassum wightii Greville, Turbinaria ornata (Turner) J. Agardh, and Padina tetrasdromatica Hauck for the extraction, purification, and characterization of fucoidan, and to evaluate its antioxidant and cytotoxic properties as a natural and safe therapeutic agent.
MATERIALS AND METHODS

Materials

Analytical grade chemicals were used in all the studies. The chemicals and analytical grade reagents were purchased from HiMedia and Sisco Research Laboratories, Mumbai and Chennai, India.

Seaweed sample collection and identification

Fresh, matured biomass of three brown seaweeds S. wightii, T. ornata, and P. tetrastromatica was collected from the coast of Kilikarai (latitude 9°14’ N and longitude 78°50’ E) in Gulf of Mannar located in Southeast coast of Tamil Nadu, India. The collected seaweeds were identified and documented in Centre for Advanced Studies in Botany, University of Madras, Chennai, Tamil Nadu, India. The algae were washed thoroughly in seawater, followed by tap water until all epiphytes, sand particles, associated fauna, and other extraneous materials were removed. Seaweeds were shade dried for 5 days, followed by oven drying (Sandy Scientific Instruments and Co., Chennai, India) for 12 h at 60°C, and the dry weight of the sample was determined. The material was hand crushed and ground using electronic mixer grinder (Philips HL 1643/04 Vertical Mixer Grinder, India). The powder was processed further for the extraction of sulfated polysaccharide fucoidan.

Extraction of sulfated polysaccharide fucoidan

The extraction of fucoidan was done according to a modified protocol of Suresh et al., 2013 [21]. A total of 50 g of each algal powder were sequentially extracted in a Soxhlet apparatus, with 700 mL of five different solvents such as hexane, chloroform, ethyl acetate, acetone, and methanol, in the increasing order of polarity. The process was continued until the extract turned colorless in each solvent, to ensure the complete decolonization and defatting of the dry biomass. This biomass was then dispersed in 2 L of 0.1 M HCl (pH 2.0–2.5) and boiled at 100°C for 4 h twice, with constant stirring. The boiled solution was filtered through a sieve, filter paper as well as Whatman No. 1 filter paper, and the filtrates were pooled. Equal volumes of 2% Na₂CO₃, followed by 1% CaCl₂ were added to the filtrate and kept at 4°C overnight to precipitate the alginates. The resultant precipitate was centrifuged (HERMLE Labortecnik GmbH, Z 32 HK, Germany) at 3900×g for 10 min, at 28°C. The supernatants were pooled, added with double the volume of pre-cooled acetone, and kept at 4°C overnight, to precipitate out the fucoidan. The precipitate was centrifuged at 3900×g for 10 min, at 28°C. The pellet was collected, dissolved in water, and dialyzed against glass distilled water using a membrane (Molecular Weight Cutoff, [MWCO] 14,000; HiMedia Laboratories Pvt. Ltd., Mumbai, India) at 18°C for 2 days. Then, the dialysate was centrifuged at 15,680 ×g for 10 min, at 28°C, and the supernatant was lyophilized. This yielded the partially purified fucoidan or crude fucoidan.

Purification of fucoidan by ion-exchange chromatography

The crude polysaccharide weighing 500 mg was redissolved in 5 mL glass distilled water and loaded on to diethylaminoethyl (DEAE) cellulose column (HiMedia Laboratories Pvt. Ltd., Mumbai, India) (25 cm×4 cm), previously washed with 25 mL of 1 M NaCl, glass distilled water, and then 0.1 M sodium phosphate buffer (pH 7.2). This was followed by step-wise elution with solutions of 0.1 M sodium phosphate buffer, 0.2, 0.7, and 1.5 M NaCl. The flow rate was maintained at 60 mL h⁻¹. Eluants of 10 mL each were collected, and the carbohydrate content was determined by the phenol-sulfuric acid method (Dubois et al., 1956), using D-glucose as the standard. Three fractions were obtained, F₁, F₂, and F₃. The fractions containing the higher amount of carbohydrates were pooled, added with double the volume of pre-cooked acetone, and kept at 4°C overnight, to precipitate fucoidan. The precipitated fucoidan was centrifuged at 15,680 ×g for 10 min, at 28°C and the pellet was redissolved and dialyzed in glass distilled water for 2 days and lyophilized. This yielded the purified fucoidan which was stored at 4°C for further study.

Characterization of fucoidan

Chemical analyses

The total sugar was determined by the phenol-sulfuric acid method using L-fucose as the standard [22]. The sulfate content was measured using the BaCl2-gelatine method using potassium sulfate as the standard [23]. The protein content was estimated by Bradford’s method with bovine serum albumin as the standard [24]. The cysteine HCl-sulfuric acid method was performed as a qualitative test for fucoidan [25].

Fourier-transform infrared (FT-IR) spectroscopy analysis

The functional groups of fucoidan were analyzed in the FT-IR spectrophotometer (PerkinElmer System One, PerkinElmer (India) Pvt. Ltd., Maharashtra, India). The sample (2 mg) was grinded with 100 mg potassium bromide and pressed into the disc under vacuum. The infrared spectrum was recorded over a range of 4000–450 cm⁻¹, using 64 scans at a resolution of 4 cm⁻¹.

In vitro antioxidant activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay

The antioxidant activity of samples was carried out according to the procedure available [26]. Different volume levels of standard ascorbic acid and test samples (100, 200, 300, 400, and 500 µL) were taken into test tubes and made 1 mL each dose level by dilution with the respective solvent in which it was extracted, followed by dilution up to 3 mL. Further, 150 µL DPPH solution was added to each test tube. Absorbance was taken at 516 nm in ultraviolet (UV)-visible spectrophotometer (Hitachi U2900, UV-vis double-beam spectrophotometer, Hitachi High Technologies America, Inc.) after 15 min using methanol as blank. About 150 µL of DPPH solution was added to 3 mL methanol and absorbance was taken immediately at 516 nm for control reading. The free radical scavenging activity (FRSA) or percentage antiradical activity was calculated using the following equation:

\[
\text{FRSA} = \left(1 - \frac{A_{	ext{test}}}{A_{\text{control}}} \right) \times 100
\]

Each experiment was carried out in triplicate and the results are expressed as mean percentage antiradical activity ± standard deviation.

In vitro cytotoxicity analysis

Trypan blue exclusion method

The fucoidan was studied for a short-term in vitro cytotoxicity using Dalton’s lymphoma ascites (DLA) cells. The tumor cells aspirated from the peritoneal cavity of tumor-bearing mice were washed thrice with phosphate-buffered saline (PBS) or normal saline. Cell viability was determined by trypan blue exclusion method. Viable cell suspension (1×10⁶ cells in 0.1 mL) was added to tubes containing various concentrations (10, 20, 50, 100, and 200 mg mL⁻¹) of the test compounds dissolved in dimethyl sulfoxide, and the volume was made up to 1 mL using PBS. Control tube contained only cell suspension. These assay mixtures were incubated for 3 h at 37°C. Further, the suspension of cells was mixed with 0.1 mL of 1% trypan blue and kept for 2–3 min before loading on a hemocytometer. Dead cells took up the blue color of trypan blue while live cells did not take up the dye. The number of stained and unstained cells was counted separately. The percentage of cytotoxicity was calculated by the following equation:

\[
\text{Cytotoxicity} = \left(1 - \frac{N_{\text{dead cells}}}{N_{\text{total cells}}} \right) \times 100
\]

Table 1: The weight (in gram) of solvent extracts obtained from the three algal species

| S. No. | Solvents | Sargassum wightii (g) | Turbinaria ornata (g) | Padina tetrastromatica (g) |
|-------|----------|-----------------------|-----------------------|---------------------------|
| 1     | Hexane   | 1.04                  | 0.92                  | 0.25                      |
| 2     | Chloroform | 1.05                | 1.42                  | 0.98                      |
| 3     | Ethyl acetate | 0.48              | 0.43                  | 0.36                      |
| 4     | Acetone  | 0.15                  | 0.27                  | 0.12                      |
| 5     | Methanol | 0.37                  | 0.45                  | 0.34                      |
RESULTS

Depigmenting and defatting (solvent extraction) of algal samples

The powdered algal samples of *S. wightii, T. ornata,* and *P. tetrastromatica* were extracted with five solvents hexane, chloroform, ethyl acetate, acetone, and methanol sequentially in the increasing order of their polarities, to obtain crude extracts (Fig. 1). The amount of solvent extracts obtained from the three algae is given in Table 1. The sequential solvent extraction was found to be a very effective pre-treatment method for eliminating all possible contaminants before acidic extraction of the algae.

Extraction, purification, and characterization of fucoidan

The algal powders post-solvent extraction was subjected to hot acidic water extraction, precipitated with acetone, dialyzed, and lyophilized. From the crude fucoidans thus obtained, the one that yielded the highest amount of total carbohydrates, i.e. *Sargassum,* was purified by DEAE column chromatography to obtain three fractions F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> (Fig. 2). The fucoidans retained in the dialysis membrane (MWCO 14,000) were considered to be of the molecular weight of 14 kD [27]. The yield of crude fucoidan obtained was highest in *S. wightii* followed by *P. tetrastromatica* and *T. ornata* (Table 2) while the yield of purified fucoidan or the column fractions F<sub>1</sub> (corresponding to 0.2 M NaCl elution), F<sub>2</sub> (corresponding to 0.7 M NaCl elution), and F<sub>3</sub> (corresponding to 1.5 M NaCl elution) of *S. wightii* was approximately 20 mg. The total carbohydrates content was the highest in *S. wightii* followed by *P. tetrastromatica* and *T. ornata,* while the sulfates content was the highest in *Padina* followed by *Turbinaria* and *Sargassum.* The protein content was 0.1% in all the samples. The percentage of total sugars, proteins, and sulfates in the purified fraction, F<sub>3</sub> of *Sargassum* is also given (Table 2). In the cysteine HCl-sulfuric acid test for fucose, the development of a greenish-yellow color that persisted for 24 h indicated the presence of L-fucose in all the crude as well as purified sample solutions of fucoidan.

FT-IR analysis of fucoidans

FT-IR spectra of the three crude fucoidan samples, as well as the purified fraction F<sub>3</sub> of *S. wightii,* showed characteristic absorption bands of sulfated polysaccharides (Figs. 3 and 4). The broad, intense bands in the regions of 3600–3200 cm<sup>−1</sup> (i.e. 3434 cm<sup>−1</sup>, 3428 cm<sup>−1</sup>, 3409 cm<sup>−1</sup>, and 3433 cm<sup>−1</sup> here) can be attributed to the stretching vibrations of the hydroxyl group (-OH) common to all polysaccharides [13]. Stretch bands at 2926 cm<sup>−1</sup> and 2925 cm<sup>−1</sup> indicated C-H stretching of the pyranoid ring and C-6 group of fucose and galactose [28]. The bands at 2138 and 2144 cm<sup>−1</sup> corresponds to C-H stretching [8,29]. Asymmetric and symmetric stretching vibrations of the carboxylic group (-COO-) gave characteristic bands at 1638, 1632, 1611, and 1644 cm<sup>−1</sup> and bands at 1423, 1425, and 1422 cm<sup>−1</sup>, respectively. It thus proves the acidic nature of polysaccharides and hence the existence of uronic acids [30,31]. The 1365 cm<sup>−1</sup> in the FT-IR graph of F<sub>3</sub> fraction, on the other hand, indicated the presence of sulfate groups [32] and 1151 cm<sup>−1</sup> indicated hemiacetal stretching [31]. The signal at 1251 cm<sup>−1</sup> indicates primary

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**Table 1:** Five solvent extracts of the three brown algae; (i) solvent extracts of *Sargassum wightii,* (ii) solvent extracts of *Turbinaria ornata,* and (iii) solvent extracts of *Padina tetrastromatica;* (a) hexane extract, (b) chloroform extract, (c) ethyl acetate extract, (d) acetone extract, and (e) methanol extract

**Table 2:** Percentage yield and composition of fucoidans extracted

| Type of fucoidan | % yield | Total carbohydrates (%) | Sulfates (%) | Proteins (%) |
|-----------------|---------|-------------------------|--------------|--------------|
| SCF             | 7.14    | 42.19±0.3               | 3.11±0.4     | 0.162±0.001  |
| TCF             | 0.94    | 29.69±0.7               | 4.76±0.3     | 0.162±0.001  |
| PCF             | 4.28    | 33.13±0.2               | 6.70±0.1     | 0.164±0.002  |
| F<sub>3</sub>   | 0.04    | 19.72±0.1               | 4.32±0.2     | 0.121±0.001  |

SCF: *Sargassum* crude fucoidan, TCF: *Turbinaria* crude fucoidan, PCF: *Padina* crude fucoidan, F<sub>3</sub>: Purified fraction of *Sargassum* fucoidan. Values are mean±standard deviation from three independent tests.

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and secondary O-sulfate groups characteristic to marine-sulfated polysaccharides and stands for asymmetric stretching vibrations of sulfate esters (S=O) \[8,28,33\]. Absorption bands at 1054, 1051, and 1062 cm\(^{-1}\) correspond to the stretching vibrations of C-O-C and C-O-H groups \[33,34\] while the band 1098 cm\(^{-1}\) in F\(_3\) graph corresponds to C-O and C-C stretching vibrations of pyranose ring. Absorption at 898 cm\(^{-1}\) indicated \(\alpha\)-glycosidic linkages. An absorption peak at 820 cm\(^{-1}\) can be ascribed to the bending vibrations of C-O-S of sulfates at axial C-2 and/or C-3, C-O-O and complex substitution of C-4 and C-6 monosaccharide units \[33,35\]. From these data, it can be inferred that the fucoidan obtained from the three algae is acidic sulfated polysaccharides with the presence of fucose and galactose as the main monosaccharide units, has uronic acid content and sulfate esters at axial positions.

**In vitro antioxidant activity**

The in vitro antioxidant activities of the solvent extracts were evaluated by DPPH scavenging assay. When a solution of DPPH is mixed with that of a substrate (AH) that can donate a hydrogen atom, then this gives rise to the reduced form with the loss of its violet color. Among the five solvent extracts of *S. wightii*, the methanol extract of the concentration of 500 mg mL\(^{-1}\) showed the maximum DPPH scavenging activity of 86.88±0.29%. The lowest activity observed was 19.88±0.62% in the 100 mg mL\(^{-1}\) concentration of hexane extract (Fig. 5a). The maximum activity among solvent extracts of *P. tetrastromatica* observed was 86.52±1.05% by the 400 mg mL\(^{-1}\) concentration of methanol extract, and the lowest was 74.35±0.16% by the 100 mg mL\(^{-1}\) concentration of hexane extract (Fig. 5b). In case of solvent extracts of *T. ornata*, the maximum activity was 93.47±1.28% in the 400 mg mL\(^{-1}\) concentration of methanol extract, while the lowest was 46.47±0.36% in the 100 mg mL\(^{-1}\) concentration of hexane extract (Fig. 5c). There is a linear increase in the DPPH scavenging activity in a dose-dependent manner although some extracts exhibited altered activity with an increase in extract concentration.

The DPPH scavenging assay was also conducted for the crude and purified fucoidans. In all samples, there is an increase in the antioxidant activity as the concentration of sample increased. The highest activity was shown by the crude fucoidan of *Padina* and the lowest by the crude fucoidan from *Sargassum* (Fig. 5d).

**In vitro cytotoxicity analysis of crude and purified fucoidan**

The cytotoxic nature of crude and purified fucoidans was investigated by conducting trypan blue exclusion method of cytotoxicity analysis. The Dalton’s ascites lymphoma cells were treated with varying concentrations of the crude and purified fucoidans (10, 20, 50, 100, and 200 mg mL\(^{-1}\)) to observe the following results. The activity was measured as percentage cytotoxicity. The maximum cytotoxicity was exhibited by 200 mg mL\(^{-1}\) of crude fucoidan from *Padina* (40%), whereas the least toxicity was observed in the 10 mg mL\(^{-1}\) concentration of *Padina*. There is an increase in the cytotoxic effect of the fucoidans in a dose-dependent manner. On contrary to this, only the 200 mg mL\(^{-1}\) concentration of *Sargassum* showed activity, while for all other concentrations, there was no cytotoxicity observed. At very lower concentrations like 10 or 20 mg mL\(^{-1}\), only *Padina* fucoidan showed some activity. The effect of samples on the cells can be seen in the figures that follow. The dead cells took up the trypan blue dye and can be seen as blue entities against a background of uncolored live cells (Fig. 6).
DISCUSSION

Fucoidan constitutes about 5–10% of the dry algal biomass. The composition of fucoidan varies in brown algae with respect to its species, environment, and collection season. Hayakawa and Nagamine (2009) also reported that purified fucoidan contains <0.1% of protein contamination. The difference in the previous reports and the current study may be due to the differing habitats, seasons, extraction, and purification methods, and the type of species studied [36]. From the FT-IR data, it was concluded that the fucoidan obtained from the three algae is acidic sulfated polysaccharides with the presence of fucose and galactose as the main monosaccharide units, has uronic acid content and sulfate esters at axial positions.

Fig. 5: 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity of (a) Sargassum extracts, (b) Padina extracts, (c) Turbinaria extracts, and (d) various crude and purified fucoidans. PCF: Padina crude fucoidan, TCF: Turbinaria crude fucoidan, SCF: Sargassum crude fucoidan, and SPF: Sargassum purified fucoidan (F3). Values are mean±standard deviation from three independent tests.

Fig. 6: Percentage cytotoxicity of fucoidans on Dalton’s ascites lymphoma cells.
A linear increase in the DPPH scavenging activity in a dose-dependent manner was observed in case of both the solvent extracts and fucoidans of the three algae. These results are comparable with those reported [37,38]. Reports said that this antioxidant potential of solvent extracts of algae may be attributed to the contents of polyphenols, pigments, flavonoids, and phlorotanins present in them.

Earlier, many reports have discussed the antioxidant, anticancer, cytotoxic, and antiproliferative properties of fucoidan extracted from several brown seaweeds, especially Sargassum. In 2014, Anjana et al. had reported the anticancer effect of the ethanolic extract of S. wightii Greville on DLA cells using trypan blue exclusion method [39]. The dose-dependent antioxidant potential of methanolic extract of Sargassum swartzii was also reported and was attributed to the phenolic compounds in the extract [40]. The findings of the present study coincided with this finding. In another report, the F$_2$ fraction of fucoidan from Sargassum plagiophyllum, containing higher sulfate content was found effective against human liver cancer (HepG2) and lung cancer (A549) cell lines [21]. Similar observations were also made in Sargassum polycystum, in which of the four fractions obtained, F2 showed highest yield %, fucose and sulfate content, and DPPH radical scavenging activity (55.94±0.69%) [41]. In contrary to these findings, it is the F$_2$ fraction of S. wightii that exhibited high contents and hence the activity. The current study was also supported by a report on the polysaccharide fraction from S. wightii which significantly reduced the proliferation of breast cancer cells (MCF7 and MDA-MB-231) in a dose-dependent manner [42]. Whereas the fucoidan isolated from Padina boryana (0.23%) containing 18.6% sulfates, exhibited 79% suppression of colony formation in human colon cancer cells DLD-1 at a concentration of 200 mg mL$^{-1}$ [43], and the fucoidan from P. tetrastromatica with a yield of 8.18% and 0.7% sulfur showed a 50% reduction in the viability of HeLa cells at a concentration of 1.2 mg mL$^{-1}$ [44]. The yield of fucoidan from P. tetrastromatica in the current study was comparatively higher (4.28%) with 6.70±0.1% sulfates and exhibited maximum cytocytotoxicity of 40% at 200 mg mL$^{-1}$ concentration. The difference observed hints to the relation between sulfate content in fucoidan and its bioactivity. Although the ethanolic extract of P. gymnospora has been reported to contain a number of bioactives compared to many other algae, its sulfate content and antioxidant activity were found lower comparatively [45]. The antioxidant and FRSA of the methanolic extract of T. ornata are also already known [46]. The demand for seaweeds has enormously increased recently as it is a source of numerous bioactive compounds that are targeted for biomedical applications as well as the food industry [47]. In this scenario, the fucoidan extracted from the brown algae such as Sargassum and Padina, exhibiting good antioxidant and cytotoxic activities, is a promising candidate for various pharmaceutical applications.

CONCLUSION

We can say that this study demonstrated the antioxidant and cytotoxic potential of fucoidans from the three brown algae, S. wightii, P. tetrastromatica, and T. ornata from the coast of Kilikaral, Gulf of Mannar located in Southeast coast of Tamil Nadu, India. These fucoids which comprise carbohydrates, uronic acid, and sulfate esters effectively scavenged free radicals. The solvent extracts also showed good antioxidant activity. As reported in some earlier studies, there was a positive correlation between the sulfate content and the bioactivity of fucoidans. This finding strengthens the existing attempts to elucidate the structure-function relations of fucoidan. Hence, these algae, its extracts, and fucoidans are found to be potential candidates for pharmacological applications. Further studies are required for the full-fledged utilization of this highly interesting biomolecule.

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AUTHORS’ CONTRIBUTIONS

Sreekala K. G conceived the project, collected and processed the samples, and performed analysis. Dr. Nagaraj Subramani supervised and guided the research work and preparation of the manuscript. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

All authors report no conflicts of interest regarding this manuscript.

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