

Antioxidant and Photoprotective Activity of Brown Seaweed from North Sulawesi Coast

by Deiske Sumilat 5

Submission date: 20-Aug-2019 09:48AM (UTC+0700)

Submission ID: 1161602881

File name: otective_Activity_of_Brown_Seaweed_from_North_Sulawesi_Coast.pdf (481.28K)

Word count: 5851

Character count: 32352



Antioxidant and Photoprotective Activity of Brown Seaweed from North Sulawesi Coast

Chatrien A. Sinjal^{1*}, Rizald M. Rompas¹,
Deiske A. Sumilat¹, Edi Suryanto²

¹Department of Marine Science, Postgraduate Program,
Sam Ratulangi University, Manado, Indonesia

²Department of Chemistry, Faculty of Mathematics and Natural Science,
Sam Ratulangi University, Manado, Indonesia

Abstract : Marine ecosystems have a high diversity of living organism compared to terrestrial ecosystems and provide abundant resources for human nutrition and health. The aims of this research were to determine total phenolic content, examine antioxidant and photoprotective activity, and characterize brown seaweed *Sargassum* sp, *Turbinaria* sp, and *Padina* sp from North Sulawesi coast component. The total phenolic content was determined using folin ciocalteau method, antioxidant activity was evaluated using total antioxidant, photoprotective was evaluated using Sun Protector Factor (SPF), and characterization of brown seaweed extract using UV-vis and IR Spectrophotometry. The results showed that total phenolic content from *Sargassum* sp 5,20 mg GAE/g, *Turbinaria* sp 1,47 GAE/g, and *Padina* sp 27,45 GAE/g. Total antioxidant of *Sargassum* sp 0,496 mg AAE/g, *Turbinaria* sp mg AAE/g, and *Padina* sp 0,295 mg AAE/g. The SPF value of *Padina* sp extracted with hexane 20.530, ethyl acetate 28.505, butanol 11.040, ethanol 13.705, and acetone 3.403. Characterisation of brown seaweed extract using spectrophotometer UV-vis consists of phenolic compound, carotenoid, and chlorophyll. FTIR spectra of brown seaweed extract showed that *Sargassum* sp contain (C-H), (N-O), (C=O), (N-H), (C-H) and (OH) groups, *Turbinaria* sp (C-halide), (C=C), (N-H), (C-H) and (OH) groups, and *Padina* sp (C-halide), (C=C), (N-H), (C-H) and (OH) groups. Brown seaweed possesses antioxidant and photoprotective activity.

Keywords : brown seaweed, total phenolic content, antioxidant, Sun Protector Factor, North Sulawesi.

Introduction

Marine ecosystems have a high diversity of living organisms compared to terrestrial ecosystems and provide abundant resources for human nutrition and health¹. Marine invertebrates are a diverse group with habitats in all ocean ecosystems, ranging from the intertidal zone to the deep sea environment. Marine invertebrates can be classified into several major phyla, namely, Porifera (sponges), Cnidaria (corals, sea

Chatrien A. Sinjal *et al* /International Journal of ChemTech Research, 2018,11(06): 121-133.

DOI= <http://dx.doi.org/10.20902/IJCTR.2018.110617>

anemones, hydrozoans, jellyfish), Annelida (Polychaetes, marine worms), Bryozoa (moss animals or sea mats), Mollusca (oysters, abalone, clams, mussels, squid, cuttlefish, octopuses), Arthropoda (lobsters, crabs, shrimps, prawns, crayfish), and Echinodermata (sea stars, sea cucumbers, sea urchins)². This diverse group also includes macroalgae, microalgae, bacteria, cyanobacteria, certain fish species and crustaceans that produce secondary metabolites as an adaptation to their hostile marine environment.

Seaweed (macroalgae) is one of marine organism. It called thallus because seaweeds are primitive non-flowering plants without root, stem, and leaves³. About 6000²³ species of seaweeds have been identified and are grouped into three major groups based on it pigment namely Chlorophyceae (green algae), Rhodophyceae (red algae) and Phaeophyceae (brown algae)⁴. The three classes of seaweed were significantly important because of economic value and chemical composition⁵.

In general, *Sargassum* sp, *Turbinaria* sp, and *Padina* sp are brown seaweeds that grow in shallow waters of tropical regions. They are harmless, very easy to collect, and a potential source of phytomedicines. These organisms are largely exposed to a combination of sunlight and oxygen that leads to the formation of free radicals. However, the absence of oxidative damage on the structural components of seaweeds and their stability to oxidation during storage indicate that their cells should have potent protective antioxidative defense systems⁶.

Tropical seaweeds are expected to develop a very effective antioxidant defense system due to the strong UV radiation in the tropical environment^{7,8}. Antioxidant compounds play an important role against various diseases (e.g., atherosclerosis⁴⁴ chronic inflammation, cardiovascular disorders, and cancer) and aging processes⁹. In fact, previous studies have demonstrated that UV radiation induces the promotion of antioxidant defense in macroalgae^{10,11}.

Recently, the potential antioxidant compounds were identified as some pigments (fucoxanthin, astaxanthin, carotenoid e.g.) and polyphenols (phenolic acid, flavonoid, tannins e.g.). Those compounds are widely distributed in plants or seaweeds and are known to exhibit higher antioxidant activities. Seaweeds are noted to contain not only labile antioxidants (i.e. ascorbate, glutathione) when fresh¹², but also, more stable molecules such as carotenoids¹³, mycosporine-like amino acids¹⁴, and a variety of polyphenols (e.g. catechins, phlorotannins)¹⁵. More reports that are recently revealed seaweeds to be a rich source of antioxidant compounds¹⁶⁻¹⁹.

The brown seaweeds contain a lot assemblage of species that predominate in the coastal shelf area of Manado, North Sulawesi. Among various seaweeds, *Sargassum* sp, *Turbinaria* sp, and *Padina* sp are abundantly available in this area throughout different sea⁵², and therefore these species has been short listed for the present study. Pharmacological properties of several seaweed species are still unexplored and unidentified. The present study is focused to analyze the in vitro antioxidant and photo-protective activities of three selected seaweeds from North Sulawesi coast.

Experimental

Standard and Chemicals

Gallic acid and ascorbic acid were purchased from Sigma Chemical Co. (St. Louis, Missouri, USA). The chemicals were acetone, butanol, ethyl acetate, ethanol, hexane, sodium carbonate, sulfuric acid, sodium phosphate, ammonium molybdate, folin-Ciocalteu reagent were pro analysis grade and purchased from Merck (Darmstadt, Germany).

Sample collection and preparation

Live and healthy samples of edible brown seaweed *Sargassum* sp, *Turbinaria* sp and *Padina* sp were collected between June-July 2017 from the intertidal region of North Sulawesi coast (latitude 1°28'55"N and longitude 124°50'56"E). Collected samples were immediately brought to the laboratory in new plastic bags containing normal sea water to prevent evaporation and some of seaweed samples were identified by the Department of Fisheries and Marine Science, University of Sam Ratulangi, Manado. Plants were washed

thoroughly with tap water to remove extraneous materials and shade dried. Dry plant material was ground in an electric mixer and stored at 4°C until future use.

Extraction

Fine powder of dry seaweed (20 g) was extracted with 60 mL of ethyl acetate at room temperature for 2 h. The extraction procedure was repeated thrice and the extract was filtered through Whatmann No. 1 filter paper. The filtrate was concentrated to dryness under reduced pressure using a rotary evaporator (crude extract). The ethyl acetate phase (crude) was stored at 4°C until future use.

Determination of Total Phenolic content

The total phenolic content was determined using Jeong et al.²⁰ method. The seaweed extract (14 mL) was diluted with deionized water (7.9 mL). Folin-Ciocalteu phenol reagent (0.5 mL) was added, and the contents were mixed thoroughly. After 3 minutes, 2 mL of 20% sodium carbonate solution was added, and the mixture was mixed thoroughly. The mixture was allowed to stand for 30 minutes. After incubation at 37°C, the absorbance of the blue color product was measured at 750 nm, using the Shimadzu 1800 UV VIS spectrophotometer. Phenolic content was expressed in milligrams per gram of dry weight (seaweed extract) based on a standard curve of gallic acid (GA), which was expressed as milligrams per gram of gallic acid equivalent (GAE).

Determination of total antioxidant

Total antioxidant activities of the all the extracts were determined according to the method of Prieto et al.²¹. Briefly, 0.3 mL of sample was mixed with 0.0 mL reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The reaction mixture was incubated at 95°C for 90 min under water bath. The absorbance of all the sample mixture was measured at 695 nm. Total antioxidant activity expressed as the number of equivalence of ascorbic acid. A calibration curve of ascorbic acid was prepared and the total antioxidant activity was standardized against ascorbic acid and was expressed as mg ascorbic acid equivalents per gram of sample on a dry weight (DW) basis.

Determination of Sun protection factor (SPF)

Determination of photoprotective activity was conducted by examining SPF in vitro value using spectrophotometer (Spectrophotometer UV-Vis Shimadzu 1800)^{22,23}. Brown seaweed was extracted with ethanol, acetone, butanol, ethyl acetate, and hexane. Each extract was made into concentration 1 µg/mL in ethanol. The absorbance of extract solution in 1 cm cuvette was read using Shimadzu 1800 UV VIS spectrophotometer at λ 290-320 nm with 5 nm interval. The absorbance of the solution shows the effect of substance which absorbs or reflect UV light in solution. Mansur et al.²⁴ develop a simple mathematical equation to calculate SPF value. $SPF = CF \times I(\lambda) \times \text{absorbance}$ Note: CF: Correction factor (10), EE: erythemal efficiency, λ: wavelength, I: sunlight spectrum simulation and Abs: sunscreen product absorbance.

Characterization

Brown seaweed *Sargassum* sp, *Tilapia* sp, and *Padina* sp were characterized using Ultraviolet and Visible (UV-Vis) Spectrophotometry and Fourier Transform-Infrared (FT-IR). Firstly, the UV-Visible spectra of brown seaweed extracts were recorded on a Shimadzu 1800 UV VIS spectrophotometer equipped with 1.0 cm quartz cells. The width of excitation slits was set to 1.0 nm. The spectra collected with subsequent scanning spectra from 200 to 800 nm at 1.0 nm increments. Secondly, spectra of brown seaweed extracts were determined using an FTIR spectrophotometer (Shimadzu, Japan.) with KBr pellets in the range 4000–400 cm⁻¹.

Statistical analysis

All experiments were performed in triplicates. Experimental data presented as mean values ± standard deviations and analyzed by the analysis of variance (ANOVA) and the significant differences among means were determined by Duncan's multiple range test using SPSS version 23.

Result and Discussions

Total Phenolic Content

The total phenolic content of brown seaweed was determined using Folin-Ciocalteu reagent. The mechanism is based on the reduction of phosphomolibdate-phosphotungstate complex in Folin-Ciocalteu reagent by phenolic compound in an extract. The complex is then turned into molybdenum, which can be identified qualitatively by the formation of blue color and thus detectable with a spectrophotometer at 750 nm.

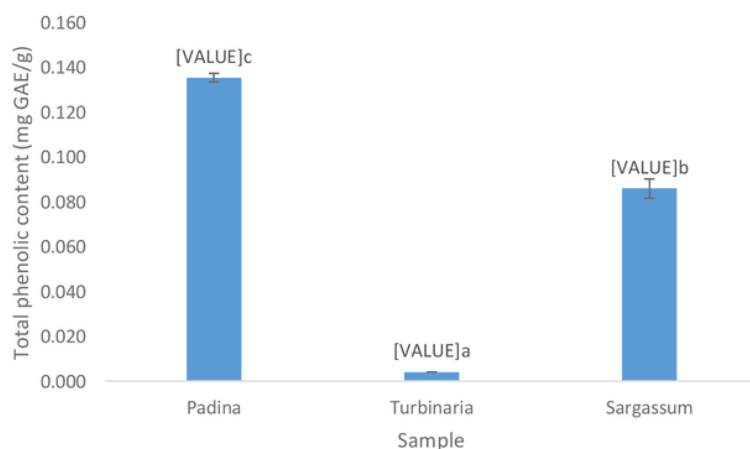


Fig. 1: Total Phenolic Content. Data are expressed as mean of triplicates with standard deviation. Values with the same superscript letter are not statistically significant at the 5% level

According to Hu ³⁴ et al.²⁴, all phenolic substances including simple phenols can react with Folin-Ciocalteu reagent. Figure 1 shows the total phenolic content of *Sargassum* sp, *Turbinaria* sp, and *Padina* sp. The highest total phenolic was found in *Padina* Sp 0,135 mg GAE/g followed with *Sargassum* sp 0,084 mg GAE/g, and the lowest *Turbinaria* sp 0,004 mg GAE/g. Statistical analysis revealed that total phenolic of the three species of brown seaweed was significantly different ($p < 0,05$).

Phenolic compound generally easy to be extracted with semi polar and polar organic solvent²⁵. Brown seaweed possesses high total phenolic content compared with red seaweed⁸. Polyphenolic content in seaweed varies depend on the season, harvest time, geographical location, and seaweed species²⁶.

Phenolic compounds exhibit their antioxidant activity by several mechanisms such as donating hydrogen atoms to free radicals, scavenging other reactive species such as OH[•], NO₂[•], N₂O₃, ONOOH, and HOCl. Some phenolic, mostly di and polyphenolic, can react with O₂^{•-} or by binding transition metal ions (especially iron and copper), often resulting in forms poorly active in promoting free radical reactions and hence can also interfere with the uptake of metals from the diet^{27,28}.

Total Antioxidant

The total antioxidant is a better way of depicting of the combined effect of phenolic, flavonoids, and other reduction compounds in a plant extracts and expressed in terms of ascorbic acid equivalents (AAE). The Phosphomolybdenum method is based on the reduction of Mo(VI) to Mo(V) by the action of antioxidant compounds and the formation of green phosphate-Mo(V) complex with a maximal absorption at 695 nm. Figure 3 shows total antioxidant of *Sargassum* sp, *Turbinaria* sp and *Padina* sp.

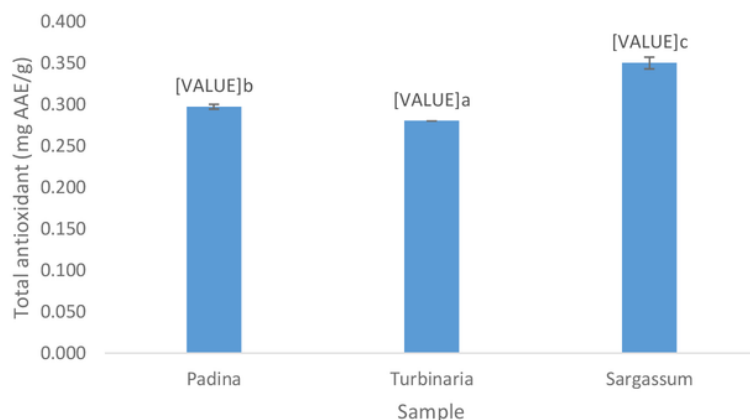


Fig. 2: Total antioxidant of brown seaweed. Data are expressed as mean of triplicates with standard deviation. Values with the same superscript letter are not statistically significant at the 5% level

The highest total antioxidant was found in *Sargassum* sp 0,3050 mg AAE/g followed by *Padina* sp 0,297 AAE/g, and the lowest *Turbinaria* sp 0,280 AAE/g. Based on statistic analysis, total antioxidant between the three seaweeds was different significant ($p < 0,05$). Total antioxidant of sample was related with it electron donor ability. The total antioxidant capacity value follows the same order as that of phenolic content in the extracts respectively.

Boi et al.²⁹ reported that *Sargassum serratum* possess antioxidant activity. Antioxidant activities of *Sargassum serratum* was depended on the extracting conditions. Brown algae *Sargassum serratum* has high antioxidant phlorotannin content. Other findings reported that free radical scavenging activity of *Sargassum* extracts was affected by extracts types, seasons, sites and species. The tropical macroalgae developed an effective antioxidant defense system which might reflect an adaptation to high solar radiation³⁰. This screening emphasized the great antioxidant potential, i.e., free-radical, superoxide anion radical scavenging, reducing activity and inhibition of lipid peroxidation⁷.

Setha et al.³¹ stated that *Padina* sp extract exhibit antioxidant activity against free radicals. The antioxidant activity of methanol crude extract of seaweed *Padina* sp to give IC_{50} value of 200.88 mg/L, crude extract of ethyl acetate to give IC_{50} value of 483.09 mg/L and extract n-hexane gave IC_{50} value of 900.00 mg/L. *Padina tetrastomatica* also show radical scavenging and singlet oxygen quenching activity³².

Furthermore, Preethi et al.³³ have evaluated the methanolic extract of *Turbinaria ornata* for anti-oxidant activity. The result shows the presence of antioxidants and concluded the presence of antioxidant activity in *Turbinaria ornata*. The same result also founded by Parthiban et al.³⁴. Acetone and ethanolic extract of *Turbinaria ornata* for antioxidant activity result show the presence of antioxidants and concluded the presence of antioxidant property.

Sun Protector Factor (SPF)

The SPF value is used as the world standard for sunscreen effectivity. *Padina* sp extract was used for SPF evaluation because of it high total phenolic content. SPF value of brown seaweed extract is presented in figure 3. Ethyl acetate extract exhibit the highest SPF value followed with hexane, ethanol, butanol, and acetone. The SPF value were 28.505; 20.530; 13.705; 11.040; 3.403, respectively. Based on statistic analysis, SPF value between the five *Padina* sp. extracts was different significant ($p < 0,05$).

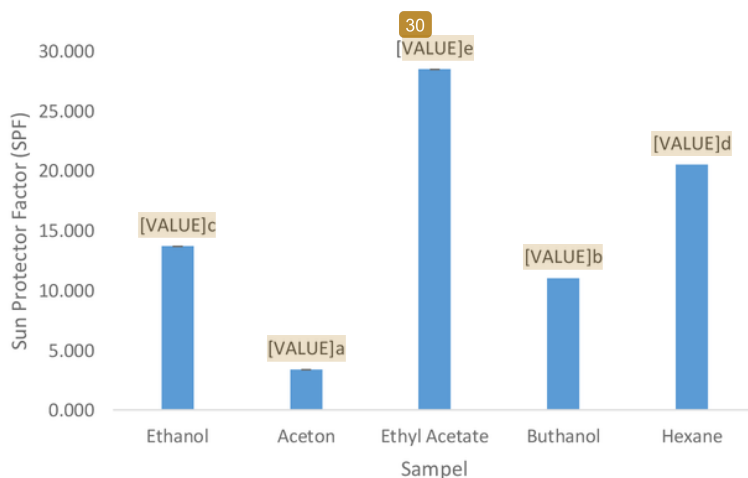


Fig. 3: Sun Protector Factor of brown seaweed extract. Data are expressed as mean of triplicates with standard deviation. Values with the same superscript letter are not statistically significant at the 5% level

Bioactive component such as phenol hydroquinone, flavonoids, and triterpenoids expected to have photo-protective activity³⁵. Based on data above, SPF from extract with different solvent exhibit different SPF characteristic. Saewan and Jimtaisong³⁶ state that flavonoid which found in seaweed can act as ultraviolet protector. Phenolic compound especially flavonoid classes consist of chromophore groups that can absorb ultraviolet light so it can reduce the damage of skin³⁷. Steinberg³⁸ associated the quantity of photoprotective compounds of brown seaweed to the specific area in which the seaweed was collected. For example, tropical algal species tend to use their phenolic as photoprotectors, while those in temperate areas (e.g., kelp species) synthesise secondary metabolites as a defense against herbivores.

Among brown algae, several secondary ⁴⁶abolites might be used for photoprotective purposes, such as phenolic compounds³⁹, carotenoids^{40,41}, and mycosporine-like amino acids (MAAs). The synthesis of photoprotective compounds in brown algae may be regulated by extrinsic factors such as UV radiation and PAR. MAA synthesis is rarely reported in brown macroalgae, and is most commonly studied in red macroalgae^{42,43}. Phenolic compounds^{44,45} and carotenoids⁴⁶ are known to be the most abundant compounds in brown macroalgae and their syntheses have been directly related to solar radiation levels. In addition to their role in photoprotection, these compounds have shown high antioxidant activity⁴⁷⁻⁴⁹ and antitumoral activities⁵⁰⁻⁵².

Characterization

Ultraviolet Visible Spectrum

The species of brown seaweeds showed similar absorption profiles for the taxonomic group with the detection of ten main regions of UV-Vis absorbances. Considering the UV spectral ranges and putative absorption substances, four bands were selected and designated as Band A (200-260 nm), Band B (265-300 nm), Band C (305-347 nm), and Band D (358-377 nm). In the case of Photosynthetically Active Radiation (PAR) spectra, six main bands were also considered as follows: Band E (400-425 nm), Band F (440-455 nm), Band G (490-520 nm), Band H (530-545 nm), Band I (580-640 nm), and Band J (650-670 nm).

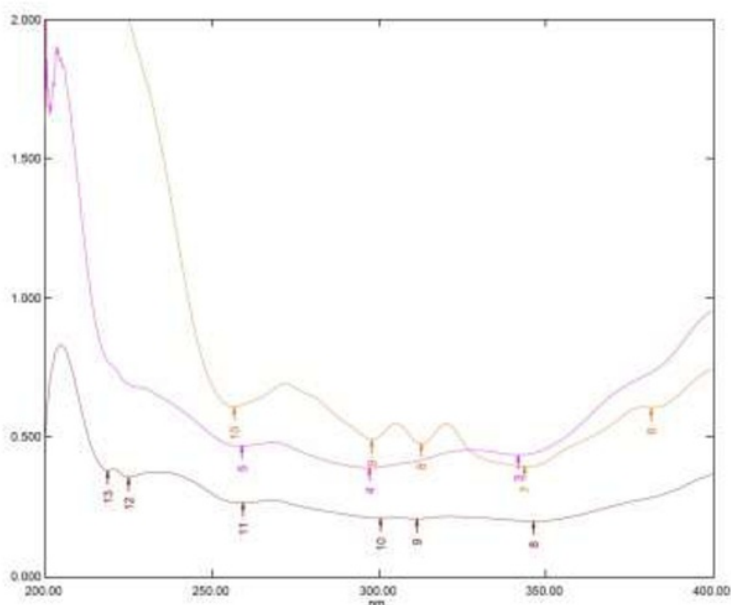


Fig. 4: Ultraviolet Radiation spectrum from brown seaweed extracts

Figure 4 showed the absorption spectra of brown seaweed extracts measured in ethanol at wavelength regions of 200-400 nm for phenolic compound and 400-600 nm for carotenoid and chlorophyll presented by Figure 5. These results indicate that *Sargassum* sp, *Turbinaria* sp, and *Padina* sp extract contain phytochemicals such as phenolic, carotenoid (fucoxanthin) and chlorophyll which potential as antioxidant active component.

Slovehenko and Merlzlyak⁵³ considered that phenolic compounds-phlorotannins absorbance spectrum showed two bands, one being located in the range between 240 and 280 nm, which covers Band A and B of brown seaweed spectra. In other seaweed groups, the wavelength absorption range of Band C is characterized by absorption due to mycosporine-like amino acids⁵⁴. However, these compounds have not been recognized as abundant in brown seaweed^{43,55}. Band D (358–377 nm) is characterized in macro seaweed by the presence of coumarins⁵⁶, another family of phenolic compounds. In brown seaweed, the main phenolic compounds recognized as photoprotective agents against UV radiation are phlorotannins^{44,57}.

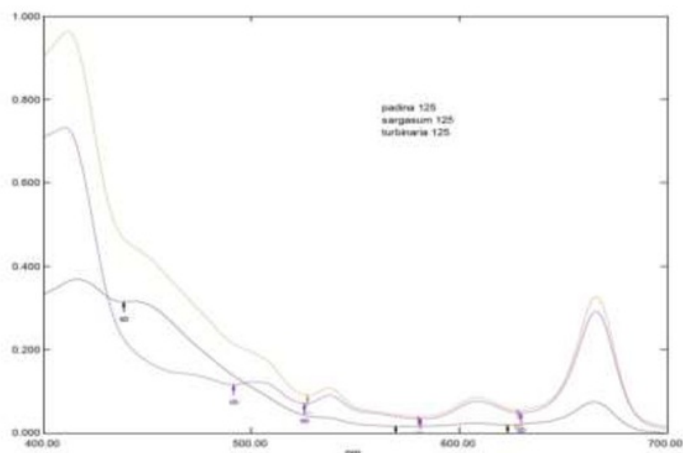


Fig. 5: Photosynthetically active radiation spectrum from brown seaweed extracts

The second area (400–700 nm) with a predominant and evident peak group was separated in Bands E, F, G, H, I, and J. This absorption section may be characterized by a consortium of the blue absorbance peak of chlorophylls and carotenoids. Carotenoid (fucoxanthin) in the sample can be evaluated by its peak absorbance at 420 nm. Ethyl acetate extract of *Sargassum sp.*, *Padina sp.*, and *Turbinaria sp.* contains fucoxanthin. The highest fucoxanthin content is in *Padina sp.*, followed with *Sargassum sp.* and the lowest is *Turbinaria sp.* Beside carotenoid (fucoxanthin) seaweeds extract contains chlorophyll which exhibits maximum absorbance at 672 nm. *Padina sp.* shows the highest chlorophyll, followed with *Sargassum sp.* and the lowest *Turbinaria sp.*

Infra Red Spectrum

Firstly, the FT-IR spectral analysis of *Sargassum sp.* extract revealed that the spectral range of obtained functional group ranged between 400 and 4000 cm^{-1} shown in Fig. 6. From the results, it was observed that the peaks 378.05 cm^{-1} may be due to C-halide bond. Followed by peak signals recorded in 925.83 cm^{-1} may be due to nitrogen grouping (N-O). A peak at 1712.79 cm^{-1} may be due to the presence of carbon, oxygen (C=O). A sharp peak observed in 2360.87 cm^{-1} represents the possible presence of nitrogen, hydrogen atoms (N-H) bond. The vibration stretch recorded at 2854.65 and 2924.09 cm^{-1} represents the presence of (C-H) bond. Finally, a broad band at 3363.86 cm^{-1} may be phenol hydroxyl group (OH-).

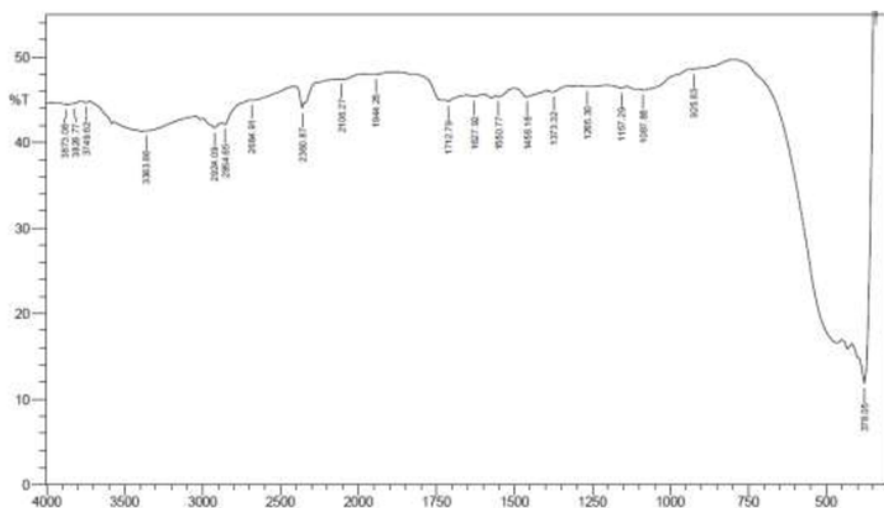


Fig. 6: IR spectrum of *Sargassum sp.* extract

Moubay ³ *et al.*⁵⁸ analyze chemical constituents of *Sargassum sp.* cells using FTIR Spectroscopy. High O–H absorption ranging between 3400 cm^{-1} and 3300 cm^{-1} which related to the main chemical groups phenols namely hydroxyl amide I, amide II and primary amine groups present on the cell walls. FTIR Chemical analysis revealed that the major constituents particularly in *Sargassum sp.* were phenolic nature^{59,60} to which both potent antimicrobial and antioxidant activities are associated.

Secondly, The *Padina sp.* extract FT-IR spectral analysis is shown in Fig. 7. It was observed that the peaks 376.05, 432.05 and 470.63 cm^{-1} may be due to C-halide bond. The peak 1242.16 to 2237.50 cm^{-1} may possible presence of carbon (C=C) double bond. The sharp peak observed in 2360.67 cm^{-1} represents the possible presence of nitrogen, hydrogen atoms (N-H) bond. The vibration stretch recorded at 2854.65 and 2924.09 cm^{-1} represents the presence of (C-H) bond. Finally, a broad band at 3371.57 cm^{-1} may be phenol hydroxyl group (OH-).

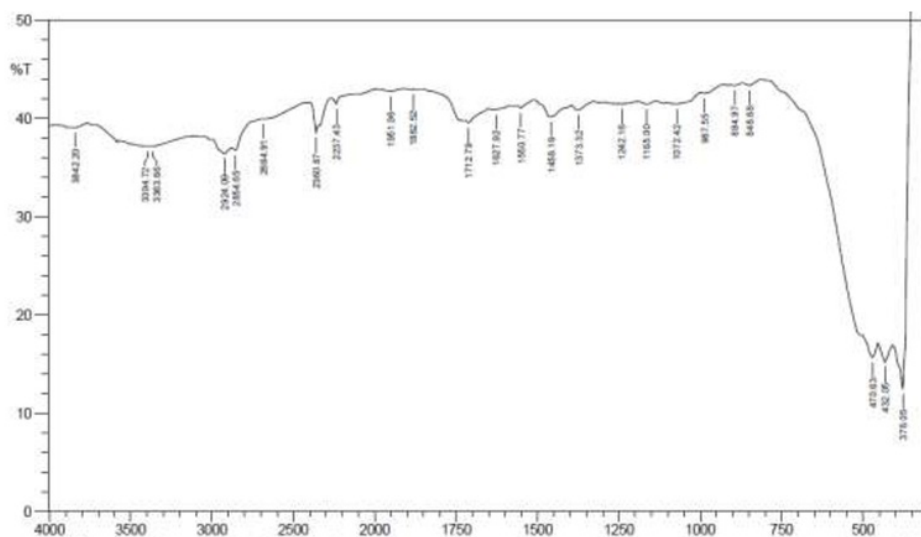


Fig. 7: IR spectrum of *Padina* sp extract

Padina australis shows absorbance at 3462.20 cm^{-1} that represent of hydroxyl (OH-) group, and 2923.33 cm^{-1} and 2852.43 cm^{-1} represent of alkane (C-H) group⁶¹. It also shows absorbance at 1242.16 to 2237.50 cm^{-1} which indicated the presence of carbon (C=C) double bond. Furthermore, absorbance at 1737.74 cm^{-1} that represent of (C=O) group and 1031 cm^{-1} that represent of symmetric C-O-C group was found in *Padina australis* extract.

The last, FT-IR spectral analysis of *Turbinaria* sp extract revealed that the spectral range of obtained functional group ranged between 400 and 4000 cm^{-1} shown in Fig. 8. From the results, it was observed that the peaks 339.47 cm^{-1} may be due to C-halide bond. A sharp peak at 1627.92 cm^{-1} represents of carbon, carbon (C=C) bond. The sharp peak observed in 2360.87 cm^{-1} represents the possible presence of nitrogen, hydrogen atoms (N-H) bond. The vibration stretch recorded at 2854.65 and 2924.09 cm^{-1} represents the presence of (C-H) bond. Finally, a broad band at 3394.72 cm^{-1} may be phenol hydroxyl group (OH-).

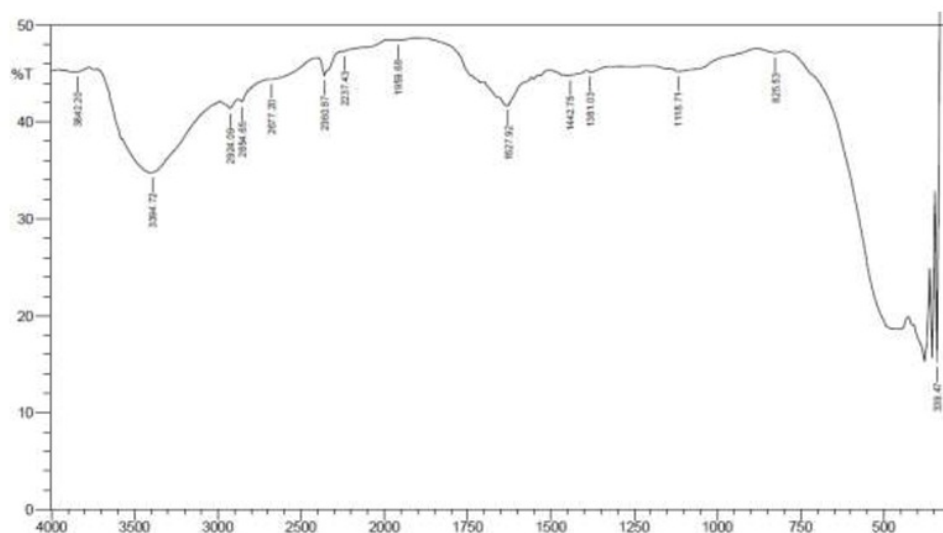


Fig. 8: IR spectrum of *Turbinaria* sp extract

Hemalatha et al.⁶² analysis revealed that the spectral range of obtained functional group from *T. ornata* ranged between 400 and 4000 cm⁻¹. It contains C-Br bond, nitrogen grouping (N-O), carbon, oxygen (C-O) bond, carbon (C=C) double bond, nitrogen, hydrogen atoms (N-H) bond, (C-H) bond, and phenol hydroxyl group (OH-). *T. ornata* Fraction contains phenolic (phlorotannins), based on the UV-Vis and FT-IR spectral analysis⁶². Phenolic compounds could elevate the value of seaweeds as functional ingredients in pharmaceuticals or functional foods.

Conclusion

³⁷ Total phenolic content of *Sargassum* sp 5,20 mg GAE/g, *Padina* sp 27,45 GAE/g and *Turbinaria* sp 1,47 GAE/g. Total antioxidant of *Sargassum* sp 0,496 mg AAE/g, *Padina* sp 0,295 mg AAE/g, and *Turbinaria* sp mg AAE/g, and. SPF value of *Padina* extract was ethyl acetate followed with hexane, ethanol, butanol and acetone. The SPF value were 28.505; 20.530; 13.705; 11.040; 3.403, respectively. Brown seaweed extract consists of phenolic compound, carotenoid and chlorophyll using spectrophotometer UV-vis. FTIR spectra of brown seaweed extract show *Sargassum* sp contain (C-halide), (N-O), (-C=O), (N-H), (C-H) and (OH) groups, *Padina* sp (C-halide), (C=C), (N-H), (C-H) and (OH-) groups, and *Turbinaria* sp (C-halide), (C=C), (N-H), (C-H) and (OH) groups.

¹⁹ Conflict of interest statement

We declare that we have no conflict of interest.

References

- Hill RT, Fenical W. Pharmaceuticals from marine natural products: Surge or ebb? *Curr. Opin. Biotechnol.* 2010. 21: 777-779
- Thorpe JP, Sole-Cava AM, Watts PC. Exploited marine invertebrates: Genetics and fisheries. *Hydrobiologia.* 2000. 420: 165-184
- Sathya R, Kanaga N, Sankar P, Jeeva S. Antioxidant properties of phlorotannins from brown seaweed *Cystoseira trinodis* (Forssk.) C. Agardh. *Arabian Journal of Chemistry* (2013). In press
- Devi GK, Manivannan K, Thirumaran G, Rajathi FAA, Anantharaman P. In vivo antioxidant activities of selected seaweeds from southeast coast of India. *Asian Pacific Journal of Tropical Medicine.* 2011. :205-211
- Soenardjo N. Aplikasi budi daya rumput laut *Eucheuma cottonii* (weber van bosse) dengan metode jaring lepas dasar (net bag) model Cidaun. *Buletin Oseanografi Marina.* 2011. 1: 36-44.
- Sampath-Wiley P, Neefus CD, Jahnke LS. Seasonal effects of sun exposure and emersion on intertidal seaweed physiology: Fluctuations in antioxidant contents, photosynthetic pigments and photosynthetic efficiency in the red alga *Porphyra umbilicalis* Kützting (Rhodophyta, Bangiales). *J Exp Mar Biol Ecol.* 2008. 361: 83-91.
- Zubia M, Robledo D, Freile-Pelegrin Y. Antioxidant activities in tropical marine Macroalgae from the Yucatan Peninsula, Mexico. *Journal of Applied Phycology.* 2007. 19: 449-458.
- Matanjun P, Mohamed S, Mustapha NM, Muhammad K, Ming CH. Antioxidant activities and phenolic content of eight species of seaweeds from north Borneo. *J. Applied Phycol.* 2008. 20: 367-373.
- Kohen R, Nyska A. Invited review: Oxidation of biological systems: Oxidative stress phenomena, antioxidants, redox reactions and methods for their quantification. *Toxicol. Pathol.* 2002. 30: 620-650.
- Aguilera J, Bischof K, Karsten U, Hanelt D, Wiencke C. Seasonal variation in ecophysiological patterns in macroalgae from an Arctic fjord. II. Pigment accumulation and biochemical defence systems against high light stress. *Mar. Biol.* 2002. 140: 1087-1095
- Bischof K, Hanelt D, Aguilera J, Karsten U, Vogele B. Seasonal variation in ecophysiological patterns in macroalgae from an Arctic fjord. I. Sensitivity of photosynthesis to ultraviolet radiation. *Mar. Biol.* 2002. 140: 1097-1106
- Kakinuma M, Park CS, Amano H. Distribution of free L-cysteine and glutathione in seaweeds. *Fish Sci* 2001; 67: 194-196
- Yan X, Li X, Zhou C, Fan X. Fucoxanthin as the major antioxidant in *Hijikia fusiformis*, common edible seaweed. *Biosci Biotech Biochem.* 1999. 63: 605-607.

14. Nakayama R, Tamura Y, Kikuzaki H, Nakatani N. Antioxidant effect of the constituents of susabinori (*Porphyra yezoensis*). *J Am Oil Chem Soc.* 1999. 76: 649–653.
15. Yoshie Y, Wang W, Petilo D, Suzuki T. Distribution of catechins in Japanese seaweeds. *Fish Sci.* 2000. 66: 998–1000.
16. Lim SN, Cheung PCK, Ooi VEC, Ang PO. Evaluation of antioxidative activity of extracts from a brown seaweed *Sargassum siliquastrum*. *J Agri and Food Chem.* 2002. 50: 3862–3866.
17. Park PJ, Shahidi F, Jeon YJ. Antioxidant activities of enzymatic extracts from and edible seaweed *Sargassum horneri* using ESR spectroscopy. *J Food Lipids.* 2004. 11: 15–27.
18. Kuda T, Tsunekawaa M, Goto H, Araki Y. Antioxidant properties of four edible algae harvested in the Noto peninsula Japan. *J Food Comp Anal.* 2005. 18: 625-633.
19. Duan XI, Zhang WW, Li XM, Wang BG. Evaluation of antioxidant property of extract and fractions obtained from red alga *Polysiphonia urceolata*. *Food Chem.* 2006. 95: 37–43.
20. Jeong SM, Kim SY, Kim DR, Jo SC, Nam KC, Ahn DU, Lee SC. “Effect of Heat Treatment on the Antioxidant Activity of Extracts from Citrus Peels”. *J. Agric. Food Chem.* 2004. 52: 3389-3393.
21. Prieto P, Pineda M, Aguilar M. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. *Analytical Biochemistry.* 1999. 269: 337-341.
22. Mansur JS, Breder MNR, Mansur MCA, Azulay RD. Determinacio do fator de protecllo solar por espectrofotometria. *An B Dermatol.* 1986. 61: 121-124.
23. Walters C, Keeney A, Wigal CT, Johnstom CR, Cornelius RD. The spectrophotometric analysis and modeling of sunscreens. *J Chem Educ.* 1997. 74: 99-102.
24. Huang D, Ou B, Prior RL. The chemistry behind antioxidant capacity assays. *Journal of Agriculture Food Research.* 2005. 53: 1841–1856.
25. Septiana AT, Muchtadi D, Zakaria FR. Aktivitas antioksidan ekstrak diklorometana dan air jahe pada asam linoleat. *Jurnal Teknologi dan Industri Pangan.* 2002. 3: 105-110.
26. Rajauria G, Foley B, Abu-Ghannam N. Identification and characterization of phenolic antioxidant compounds from brown irish seaweed *Himanthalia elongata* using LC-DAD-ESI-MS/MS. *Journal Innovative Food Science and Emerging Technologies.* 2016. 37: 261-268.
27. Zim Z, Hamid M, Osman AA, Saari N. Antioxidative activities of chromatographic fractions obtained from root, fruit and leaf of mengkudu (*Morinda citrifolia* L). *Food Chemistry.* 2006. 94:169-178
28. Taubert D, Breitenbach T, Lazar A, Censarek P, Harlfinger S, Berkels R, Klaus W, Roesen R. Reaction rate constant of O₂⁻ scavenging by plant antioxidants. 2003. 35: 1599
29. Boi VN, Cuong DX, Vinh PTK. Effects of extraction conditions over the phlorotannin content and antioxidant activity of extract from brown algae *Sargassum serratum* (Nguyen Huu Dai 2004). *Free Radicals and Antioxidants.* 2017. 7: 115-122.
30. Budhiyanti SA, Raharjo S, Djagal W, Marseno, Iwan Y, Lelana B. Antioxidant Activity of Brown Algae *Sargassum* species Extract from the Coastline of Java Island. *American Journal of Agricultural and Biological Sciences.* 2012. 7: 337-346.
31. Setha B, Gasperz FF, Puspa SA, Idris, Rahman S, Malloa MN. Potential seaweed *Padina* sp as a source of antioxidant. *Int. Journal of Scientific and Technology Research.* 2013. 2: 221-224
32. Sachindra NM, Airanthi MK, Hosokawa WA, Miyashita K. Radical scavenging and singlet oxygen quenching activity of extracts from Indian seaweeds. *J Food Sci Technol.* 2010. 47: 94–99
33. Preethi K, Shunmuga PT. Phytochemical analysis and antioxidant activity of *Turbinaria ornate* seaweeds from thoothukudi coastal area. *International Journal of Bioscience Research.* 2013. 2:
34. Parthiban C, Saranya C, Giriya K, Hemalatha A, Suresh M, Acantharean P. Evaluation of in vitro antioxidant properties of some selected seaweeds from Tuticorin coast. *International Journal of Current Microbiology and Applied Sciences.* 2013. 2: 64-73.
35. Nurjanah, Nurimala, Hidayat M, Sudirdjo T. Characteristics of seaweed as raw materials for cosmetics. *Aquatic Procedia.* 2016. 7: 177–180.
36. Saewan N, Jimtaisong A. Photoprotection of natural flavonoids. *J. of Applied Pharmaceutical Science.* 2013. 3 : 129-141
37. Wolf R, Wolf D, Morganti P, Ruocco V. Sunscreens. *J. Clinic. Dermatol.* 2001. 19: 452-459.
38. Steinberg PD. Chemical defenses and the susceptibility of tropical marine brown algae to herbivores. *Oecologia.* 1986. 69: 628–630.

39. Fariman GA, Shastan SJ, Zahedi MM. Seasonal variation of total lipid, fatty acids, fucoxanthin content, and antioxidant properties of two tropical brown algae (*Nizamuddinina zanardinii* and *Cystoseira indica*) from Iran. *J. Appl. Phycol.* 2016. 28: 1323–1331.
40. Zubia M, Fabre MS, Kerjean V, Le Lann K, Stiger-Pouvreau V, Fauchon M, Deslandes E. Antioxidant and antitumoural activities of some Phaeophyta from Brittany coasts. *Food Chem.* 2009. 116: 693–701.
41. Ramlov F, Souza J, Faria AV, Maraschin M, Horta PA, Yokoya NS. Growth and accumulation of carotenoids and nitrogen compounds in *Gracilaria domingensis* (Kütz.) Sonder ex Dickie (Gracilariales, Rhodophyta) cultured under different irradiance and nutrient levels. *Rev. Bras. Farmacol.* 2011. 21: 255–261.
42. Bischof K, Hanelt D, Tueg H, Karsten U, Brouwer PE, Wiencke C. Acclimation of brown algal photosynthesis to ultraviolet radiation in Arctic coastal waters (Spitsbergen, Norway). *Polar Biol.* 1998. 20: 388–395.
43. Gröniger A, Sinha RP, Klisch M, Häder DP. Photoprotective compounds in cyanobacteria, phytoplankton and macroalgae database. *J. Photochem. Photobiol. B Biol.* 2000. 58: 115–122.
44. Pavia H, Cervin G, Lindgren A, Aeberg P. Effects of UV-B radiation and simulated herbivory on phlorotannins in the brown alga *Ascophyllum nodosum*. *Mar. Ecol. Prog. Ser.* 1997. 157: 139–146.
45. Toth G, Pavia H. Lack of phlorotannin induction in the brown seaweed *Ascophyllum nodosum* in response to increased copper concentrations. *Mar. Ecol. Prog. Ser.* 2000. 192: 119–126.
46. Heo SJ, Jeon YJ. Protective effect of fucoxanthin isolated from *Sargassum siliquastrum* on UV-B induced cell damage. *J. Photochem. Photobiol. B Biol.* 2009. 95: 101–107.
47. Stahl W, Sies H. Antioxidant activity of carotenoids. *Mol. Asp. Med.* 2003. 24: 345–351.
48. Iwamoto K, Shiraiwa Y. Salt-regulated mannitol metabolism in algae. *Mar. Biotechnol.* 2005. 7: 407–415.
49. Connan S, Delisle F, Deslandes E, Ar Gall E. Intra-thallus phlorotannin content and antioxidant activity in Phaeophyceae of temperate waters. *Bot. Mar.* 2006. 49: 39–46.
50. Deslandes E, Pondaven P, Auperin T, Roussakis CC, Guézennec J, Stiger V, Payri C. Preliminary study of the in vitro antiproliferative effect of a hydroethanolic extract from the subtropical seaweed *Turbinaria ornata* (Turner) J. Agardh on a human non-small-cell bronchopulmonary carcinoma line (NSCLCN6). *J. Appl. Phycol.* 2000. 12: 257–262.
51. Gann PH, Ma J, Giovannucci E, Willett W, Sacks FM, Hennekens CH, Stampfer MJ. Lower prostate cancer risk in men with elevated plasma lycopene levels: results of a prospective analysis. *Cancer Res.* 1999. 59: 1225–1230.
52. Giovannucci E. Tomatoes, tomato-based products, lycopene, and cancer: review of the epidemiologic literature. *J. Natl. Cancer Inst.* 1999. 91: 317–331
53. Slovehenko and Merlzlyak53 (2008) Slovehenko and Merlzlyak [103] Solovchenko AE, Merzlyak MN. Screening of visible and UV radiation as a photoprotective mechanism in plants. *Russ. J. Plant Physiol.* 2008. 55: 7–19.
54. Korbee N, Figueroa FL, Aguilera J. Acumulación de aminoácidos tipo micosporina (MAAs): biosíntesis, fotocontrol y funciones ecofisiológicas. *Rev. Chil. Hist. Nat.* 2006. 79: 119–132
55. Karsten U, Franklin LA, Lüning K, Wiencke C. Natural ultraviolet radiation and photosynthetically active radiation induce formation of mycosporine-like amino acids in the marine macroalga *Chondrus crispus* (Rhodophyta). *Planta.* 1998. 205: 257–262.
56. Pérez-Rodríguez E, Aguilera J, Figueroa FL. Tissular localization of coumarins in the green alga *Dasycladusv ermicularis* (Scopoli) Krasser: a photoprotective role. *J. Exp. Bot.* 2003. 54: 1093–1100.
57. Swanson AK, Druehl LD. Induction, exudation and the UV protective role of kelp phlorotannins. *Aquat. Bot.* 2002. 73: 241–253
58. Moubayed NMS, Al Hourri HJ, Al Khulaifi MM, Al Farraj DA. Antimicrobial, antioxidant properties and chemical composition of seaweeds collected from Saudi Arabia (Red Sea and Arabian Gulf). *Saudi Journal of Biological Sciences.* 2017. 24:162-169
59. Reguant C, Bordons A, Arda L, Roze N. Influence of phenolic compounds on the physiology of *Oenococcus oeni*. *J. Appl. Microbiol.* 2000. 88: 1065–1071
60. Alberto MR, Faryas ME, Manca de Nadra MC. Effect of gallic acid and catechin on *Lactobacillus hilgardii* growth and metabolism of organic compounds. *J. Agric. Food Chem.* 2001. 49: 4359–4363.
61. Zaelani K, Kartikaningsih H. Studi Identifikasi crude fukosantin dan fukosantin hasil isolasi dari alga coklat (*Padina australis*) dengan pengujian spektroskopi FTIR. (Proceeding). *Green Technology* 3. 2016.

62. Hemalatha GK, Saranya C, Parthiban C, Anantharaman P. Extraction and isolation of phlorotannins from brown seaweed *Turbinaria Ornata* (Turner) J. Agardh and its antioxidant activity. International of Bioassays. 2013.

Antioxidant and Photoprotective Activity of Brown Seaweed from North Sulawesi Coast

ORIGINALITY REPORT

19%

SIMILARITY INDEX

11%

INTERNET SOURCES

12%

PUBLICATIONS

10%

STUDENT PAPERS

PRIMARY SOURCES

- 1** Submitted to University of California, Los Angeles **2%**
Student Paper
- 2** L LABY, L KLEIN, J YAN, M GREENBLATT. "Ionic conductivity in lithium aluminosilicate xerogels and gel films", Solid State Ionics, 1995 **1%**
Publication
- 3** fac.ksu.edu.sa **1%**
Internet Source
- 4** Chakraborty, Kajal, and Deepu Joseph. "Antioxidant potential and phenolic compounds of brown seaweeds Turbinaria conoides and Turbinaria ornata (class: Phaeophyceae)", Journal of Aquatic Food Product Technology, 2016. **1%**
Publication
- 5** nopr.niscair.res.in **1%**
Internet Source

Soolmaz Soleimani, Soheila Moein, Morteza

6	<p>Yousefzadi, Narges Amrollahi Bioki. "Determination of In Vitro Antioxidant Properties, Anti-inflammatory Effects and A-Amylase Inhibition of Purple Sea Urchin Extract of Echinometra mathaei from the Persian Gulf", Jundishapur Journal of Natural Pharmaceutical Products, 2016 Publication</p>	1%
7	<p>ijpba.info Internet Source</p>	1%
8	<p>tessera.spandidos-publications.com Internet Source</p>	1%
9	<p>www.derpharmachemica.com Internet Source</p>	1%
10	<p>bic.web.id Internet Source</p>	1%
11	<p>Nadine M.S. Moubayed, Hadeel Jawad Al Hourri, Manal M. Al Khulaifi, Dunia A. Al Farraj. "Antimicrobial, antioxidant properties and chemical composition of seaweeds collected from Saudi Arabia (Red Sea and Arabian Gulf)", Saudi Journal of Biological Sciences, 2017 Publication</p>	1%
12	<p>Submitted to Sheffield Hallam University Student Paper</p>	1%

Submitted to Universiti Kebangsaan Malaysia

13

Student Paper

1%

14

www.ijppsjournal.com

Internet Source

1%

15

SABRINA COX. "EFFECT OF PROCESSING CONDITIONS ON PHYTOCHEMICAL CONSTITUENTS OF EDIBLE IRISH SEAWEED HIMANTHALIA ELONGATA : EFFECT OF PROCESSING ON HIMANTHALIA ELONGATA", Journal of Food Processing and Preservation, 11/2011

Publication

<1%

16

antiox.org

Internet Source

<1%

17

Ganeshan Petchidurai, Joseph Amruthraj Nagoth, Maria Sindhura John, Kitherian Sahayaraj, Natesan Murugesan, Sandra Pucciarelli. "Standardization and quantification of total tannins, condensed tannin and soluble phlorotannins extracted from thirty-two drifted coastal macroalgae using high performance liquid chromatography", Bioresource Technology Reports, 2019

Publication

<1%

18

Rashmi C Vinayak. "Bio-screening of a few green seaweeds from India for their cytotoxic

<1%

and antioxidant potential", Journal of the
Science of Food and Agriculture, 10/2011

Publication

19

www.jclmm.com

Internet Source

<1%

20

Submitted to Higher Education Commission
Pakistan

Student Paper

<1%

21

Haifeng Zhao, Jianjun Dong, Jian Lu, Jian
Chen, Yin Li, Lianju Shan, Yan Lin, Wei Fan,
Guoxian Gu. " Effects of Extraction Solvent
Mixtures on Antioxidant Activity Evaluation and
Their Extraction Capacity and Selectivity for
Free Phenolic Compounds in Barley (L.) ",
Journal of Agricultural and Food Chemistry,
2006

Publication

<1%

22

Submitted to Chonnam National University

Student Paper

<1%

23

tidalmarshmonitoring.org

Internet Source

<1%

24

journal.ugm.ac.id

Internet Source

<1%

25

Zhongrui Li, Bin Wang, Qihong Zhang, Youle
Qu, Huanzhi Xu, Guoqiang Li. "Preparation and
antioxidant property of extract and semipurified

<1%

fractions of *Caulerpa racemosa*", Journal of Applied Phycology, 2012

Publication

26	www.ishs.org Internet Source	<1%
27	www.science.gov Internet Source	<1%
28	dk.abe.vxyq.at Internet Source	<1%
29	Submitted to Arizona State University Student Paper	<1%
30	www.coursehero.com Internet Source	<1%
31	www.ncbi.nlm.nih.gov Internet Source	<1%
32	skemman.is Internet Source	<1%
33	Makapedua, D.M.. "Genome size, GC percentage and 5mC level in the Indonesian coelacanth <i>Latimeria menadoensis</i> ", Marine Genomics, 201109 Publication	<1%
34	d-nb.info Internet Source	<1%

35	www.jcsp.org.pk Internet Source	<1%
36	ijpjournal.com Internet Source	<1%
37	www.internationalscienceindex.org Internet Source	<1%
38	<p>Navarro-Rosales, Maribel, Carlos Alberto Ávila-Orta, María Guadalupe Neira-Velázquez, Hortensia Ortega-Ortiz, Ernesto Hernández-Hernández, Silvia Guadalupe Solís-Rosales, Beatriz Liliana España-Sánchez, Pablo González-Morones, Rosa Martha Jiménez-Barrera, Saúl Sánchez-Valdes, and Pascual Bartólo-Pérez. "Effect of Plasma Modification of Copper Nanoparticles on their Antibacterial Properties : Plasma Modification of Copper Nanoparticles", Plasma Processes and Polymers, 2014.</p> <p>Publication</p>	<1%
39	Submitted to Southern Illinois University Student Paper	<1%
40	Submitted to Cranfield University Student Paper	<1%
41	Submitted to Institute of Technology, Tallaght Student Paper	<1%

42

Submitted to Universiti Malaysia Pahang

Student Paper

<1%

43

Klervi Le Lann, Gwladys Surget, Céline Couteau, Laurence Coiffard et al. "Sunscreen, antioxidant, and bactericide capacities of phlorotannins from the brown macroalga *Halidrys siliquosa*", *Journal of Applied Phycology*, 2016

Publication

<1%

44

epdf.tips

Internet Source

<1%

45

www.revistas.una.ac.cr

Internet Source

<1%

46

Algal Chemical Ecology, 2008.

Publication

<1%

47

Submitted to University of Hull

Student Paper

<1%

48

Jitlada Vichapong, Yanawath Santaladchaiyakit, Rodjana Burakham, Supalax Srijaranai. "Cloud-point extraction and reversed-phase high performance liquid chromatography for analysis of phenolic compounds and their antioxidant activity in Thai local wines", *Journal of Food Science and Technology*, 2011

Publication

<1%

49 Z. Yosefi, R. Tabaraki, H. A. Asadi Gharneh, A. A. Mehrabi. "Variation in Antioxidant Activity, Total Phenolics, and Nitrate in Spinach", International Journal of Vegetable Science, 2010
Publication <1%

50 Eighteenth International Seaweed Symposium, 2007.
Publication <1%

51 Do Thi, Nhuan, and Eun-Sun Hwang. "Effects of laver extracts on adhesion, invasion, and migration in SK-Hep1 human hepatoma cancer cells", Bioscience Biotechnology and Biochemistry, 2014.
Publication <1%

52 Submitted to VIT University
Student Paper <1%

53 T. K. Lim. "Edible Medicinal And Non-Medicinal Plants", Springer Nature, 2013
Publication <1%

Exclude quotes On

Exclude matches Off

Exclude bibliography On