

Antioxidant activity of Brown Seaweed *Sargassum* sp. extract from Tanjung Tinggi Beach, Belitung Island

Sabri Sudirman^{1*}, Andreas Al Faragih Dwi Putra¹, Herpandi Herpandi¹,
Indah Widiastuti¹, Susi Lestari¹, Sherly Ridhowati¹, Miftahul Janna¹

¹Fisheries Product Technology, Faculty of Agriculture, Universitas Sriwijaya 30662, Indralaya, South Sumatra, Indonesia

ARTICLE HISTORY

Received: Nov. 20, 2024

Accepted: Feb. 18, 2025

KEYWORDS

Antioxidant,
Flavonoid,
Polyphenol,
Sargassum,
Seaweed.

Abstract: Oxidative stress occurs when there is an imbalance between free radicals and the body's ability to counteract them with antioxidants. Antioxidants are compounds that help neutralize or prevent the formation of free radicals. This study aimed to evaluate the effects of different extraction solvents (70% ethanol, 70% acetone, and aquadest) on the polyphenol content of *Sargassum* sp., harvested from Tanjung Tinggi Beach (Belitung Island, Indonesia), and to determine its antioxidant activity using the 2,2-diphenyl-1-picrylhydrazyl method. The results showed that distilled water (aquadest) extraction yielded the highest total phenolic (7.32 mg GAE/g) and tannin (10.47 mg TAE/g) contents, while 70% ethanol extraction resulted in the highest total flavonoid content (6.40 mg QE/g). Fourier transform infrared analysis detected hydroxyl groups, indicating the presence of polyphenol compounds in the *Sargassum* extract. Furthermore, the aquadest extract exhibited the highest radical scavenging activity (43.65%) compared to other solvents. These findings indicate that *Sargassum* extract may act as a natural antioxidant and holds potential for use as a pharmaceutical agent.

1. INTRODUCTION

A free radical is a highly reactive molecule due to an unpaired electron in its outer orbital (Lobo *et al.*, 2010). Oxidative stress occurs when the concentration of free radicals exceeds the body's antioxidant capacity (Rad *et al.*, 2020). In such cases, the body requires external sources of antioxidants to restore balance, known as exogenous antioxidants. Antioxidants are substances that can reduce or prevent the formation of free radicals. These can be obtained from natural sources, such as dietary supplements or functional foods (Xu *et al.*, 2017). Polyphenols, vitamins, and polysaccharides are well-known antioxidant sources that can be extracted from natural resources, including plants (Lourenço *et al.*, 2019).

A polyphenol compound is a type of secondary metabolite commonly found in plants. These compounds include phenolic acids, flavonoids, tannins, stilbenes, and lignans. Polyphenols are recognized for their antioxidant properties, as they help inhibit the formation of free radicals. It functions as radical scavengers by donating hydrogen atoms or through electron transfer

*CONTACT: Sabri SUDIRMAN ✉ sabrisudirman@unsri.ac.id 📧 Fisheries Product Technology, Faculty of Agriculture, Universitas Sriwijaya 30662, Indralaya, South Sumatra, Indonesia

The copyright of the published article belongs to its author under CC BY 4.0 license. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>

mechanisms. Polyphenols can be extracted from aquatic plants, such as water lettuce (*Pistia stratiotes*) (Herpandi *et al.*, 2021; Sudirman *et al.*, 2022), *Limnocharis flava* (Sudirman, Herpandi, *et al.*, 2024), and *Nypa fruticans* husk (Sudirman, Wardana, *et al.*, 2024). Seaweed is a varied group of marine macroalgae that has become a valuable source of bioactive compounds, including phenolic compounds, and is widely known as a potential source of natural antioxidants (Ismail *et al.*, 2023; Kumar *et al.*, 2021; Sadeghi *et al.*, 2024).

Sargassum sp. is a species of seaweed belonging to the Phaeophyceae (brown seaweed) class. *Sargassum* species usually possess a highly branched thallus with hollow, berry-like floats (pneumatocysts), and their numerous fronds are typically small, leaf-shaped, and have toothed edges (Jin *et al.*, 2014; Widyartini *et al.*, 2017). *Sargassum* spp. has been reported to contain bioactive compounds, including polyphenols, and to exhibit antioxidant activity (Catarino *et al.*, 2023). A previous study has reported the polyphenol content (6.81 ± 1.07 mg GAE/g) and antioxidant activity (IC_{50} 73.48 ± 0.57 ppm) of brown seaweed *S. crassifolium* that were harvested from Madura Island, East Java (Indonesia) (Bambang *et al.*, 2013). Also, *Sargassum oligocystum* from the Persian Gulf (Iran) reported that it is a source of polyphenols (0.02 mg/g) and exhibits antioxidant activity (IC_{50} 0.61 ± 0.04 mg/mL) (Mehdinezhad *et al.*, 2016). Additionally, seaweed species from northern coasts of the Persian Gulf contain total phenolic content ranged from 1.25 to 5.08 mg GAE/g (Farasat *et al.*, 2014). According to these previous studies, different species and harvested locations also show different polyphenol content and antioxidant activity. The polyphenol content from natural resources may vary depending on some factors, such as species, location, climate, maturity stage, cultivar, cultural practice, and other factors (Gao *et al.*, 2023; Uddin *et al.*, 2022). Due to the lack of information related to utilization of the *Sargassum* sp. from Tanjung Tinggi Beach, Belitung Island (Indonesia), in this present study, *Sargassum* sp. was used as a source of polyphenol compounds and natural antioxidants.

Polyphenol compounds can be extracted from seaweed by using organic solvents, water, or a mixture of these solvents with water, such as methanol, ethanol, acetone, water, 70% methanol, 70% ethanol, and 50% ethanol (Ismail *et al.*, 2020; Mehdinezhad *et al.*, 2016; Wu *et al.*, 2022). A previous study reported that acetone is the best solvent for extracted polyphenol compounds from *Turbinaria decurrens*, whereas ethanol for *S. muticum* and water for *Padina pavonica* (Ismail *et al.*, 2020). Seventy percent (70%) methanol, 50% ethanol, and 70% acetone have been used to extract polyphenol compounds of *S. polycystum* from Fengjiawan Bay, Hainan Province (China) (Wu *et al.*, 2022). Additionally, 70% ethanol was used to extract the polyphenol compounds of *Porphyra tenera* seaweed from Wando, Jeonnam (Korea) (Hwang & Thi, 2014). According to these previous studies, different solvents have been used to extract polyphenol compounds from seaweed species and also affected their bioactivity, including antioxidant activity. Thus, we hypothesized that different solvents also have a significant effect on the polyphenol content of *Sargassum* sp. extract from Tanjung Tinggi Beach (Belitung Island, Indonesia), and antioxidant activity. Therefore, this study aimed to determine the effects of different extraction solvents (70% ethanol, 70% acetone, and Aquadest) on the polyphenol contents of *Sargassum* sp. that were harvested from Tanjung Tinggi Beach (Belitung Island, Indonesia) and determined its antioxidant activity.

2. MATERIAL and METHODS

2.1. Sample Collection and Preparation

The fresh *Sargassum* sp. was collected in January 2024 from Tanjung Tinggi Beach, Belitung Island, Indonesia (2.5519° S, 107.7138° E). The sample was collected directly by hand from the substrate, washed, and placed in plastic bags for identification and further experiments. It was then transported to the laboratory, where it was identified at the Fisheries Microbiology and Biotechnology Laboratory of Fisheries Product Technology, Universitas Sriwijaya (FPT0020012024). Small pieces of the seaweed were dried in a dehydrator at 45°C for 24 hours

and ground into dried seaweed powder using a grinding machine (Microphyte Disintegrator B-One DM-120M).

2.2. Extraction Process

The dried seaweed powder was extracted using maceration method with three different extraction solvents (70% ethanol, 70% acetone, Aquadest). The extraction was carried out by following the previous method (Sudirman, Wardana, *et al.*, 2024). Briefly, 20 g of dried seaweed powder was placed into an Erlenmeyer flask containing 200 mL of extraction solvent. After 2 hours of maceration, the filtrate and residue were separated using filter paper (Whatman No. 42). The filtrate was transferred to a new collection tube, and the residue was re-extracted with fresh solvent under the same conditions as the first extraction, for a total of five extractions. Once the extraction process was complete, the filtrates were combined in a new collection tube, and the solvent was evaporated using a rotary vacuum evaporator at 40°C to yield a paste. The paste was then completely dried using a freeze dryer.

2.3. Quantitative Bioactive Contents Analysis

The total phenol content was determined using Folin-Ciocalteu's method, following the procedure outlined in a previous study (Chandra *et al.*, 2014). Briefly, 0.2 mL of a 10 mg/mL extract was mixed with Folin-Ciocalteu's phenol reagent in a reaction tube and allowed to react for 5 minutes. Afterward, 8% sodium carbonate (Na₂CO₃) was added, and the volume was adjusted to 3 mL with distilled water. The mixture was incubated in the dark for 30 minutes. The supernatant was then separated by centrifugation at 3,000 rpm for 5 minutes. The absorbance of the supernatant was measured at 765 nm using a spectrophotometer (Genesys 150 ThermoScientific, Massachusetts, USA). Gallic acid was used as a standard to calculate the total phenol content, expressed as mg gallic acid equivalent (GAE) per gram of dried sample (mg GAE/g sample).

The total flavonoid content was determined using the aluminum chloride colorimetric method, as described in a previous study (Chandra *et al.*, 2014). In brief, 1.0 mL of a 10 mg/mL extract solution was mixed with 2% aluminum chloride (1:1 ratio) and incubated at room temperature for 60 minutes. After the reaction, 1 mL of the mixture was transferred to a new reaction tube and diluted to 5 mL. The solution was allowed to stand for 5 minutes, after which the absorbance was measured at 420 nm using a spectrophotometer (Genesys 150 ThermoScientific, Massachusetts, USA). Quercetin was used as a standard to calculate the total flavonoid content, expressed as mg quercetin equivalent (QE) per gram of dried sample (mg QE/g sample).

Total tannin content analysis was measured using the Folin-Ciocalteu's method (Balaky *et al.*, 2021). Meanwhile tannic acid is used as a standard. Tannic acid stock solution was prepared at a concentration of 100 µg/mL and diluted to several concentrations to obtain a standard curve for tannic acid. A total of 0.1 mL of sample solution (1 mg/mL) was pipetted into a 10 mL measuring flask containing 7.5 mL of distilled water, 0.5 mL of Folin-Ciocalteu's reagent and 1 mL of 35% sodium carbonate and added distilled water until the volume reached 10 mL. The mixture was then stirred and incubated at room temperature for 30 minutes. Absorbance was measured at a wavelength of 700 nm using a spectrophotometer. Whereas, total tannin was expressed as mg tannic acid equivalent (TAE) per g of dried weight of sample (mg TAE/g sample).

2.4. Functional Group Analysis

The FT-IR analysis was used to detect the functional group of polyphenols. FT-IR spectra of polyphenols were obtained by mixing polyphenol extract with potassium bromide, further it was pressed to form pellets. The analysis used a Fourier transform infrared (InfraRed Bruker Tensor 37) and was performed according to previous methods (Bhateja *et al.*, 2020).

2.5. Antioxidant Activity Assay

The antioxidant activity of the seaweed extract was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Sudirman *et al.*, 2022). In brief, the extract was dissolved in ethanol to achieve a concentration of 1.25 mg/mL. Then, 1 mL of each sample (0 mg/mL and 1.25 mg/mL) was mixed with an equal volume (1:1, v/v) of 0.2 mM DPPH solution and incubated at 37°C for 30 minutes. The absorbance was immediately measured at 517 nm using a UV-Vis spectrophotometer (Genesys 150 ThermoScientific). The antioxidant activity was calculated as the inhibition of the extract on the DPPH radical according to this formula:

$$\text{Percentage (\%)} \text{ inhibition} = \frac{(\text{Abs}_{\text{blank}} - \text{Abs}_{\text{sample}})}{\text{Abs}_{\text{blank}}} \times 100\%$$

Whereas: $\text{Abs}_{\text{blank}}$, the absorbance at 517 nm without sample; $\text{Abs}_{\text{sample}}$, the absorbance at 517 nm with sample.

2.6. Data Analysis

All data are presented as mean \pm standard deviation (SD). Statistical analysis was analyzed using one-way analysis of variance (one-way ANOVA), followed by Duncan's Multiple Range test (DMRT) in SPSS v22.0 (IBM Corporation, Armonk, NY, USA). Graphics were generated using GraphPad Prism v5.0 software (GraphPad Software, Inc., San Diego, CA, USA).

3. RESULTS

3.1. Total Phenolic, Flavonoid, and Tannin Contents

The total phenolic content (TPC) of *Sargassum* sp. extract is shown in Figure 1. TPC of distilled water (aquadest, 7.32 mg GAE/g) significantly ($p < 0.05$) higher than 70% ethanol (2.29 mg GAE/g) and 70% acetone (1.75 mg GAE/g). Whereas, there is no significant difference ($p > 0.05$) of 70% ethanol and 70% acetone solvents. The total flavonoid content (TFC) of *Sargassum* sp. extracts is shown in Figure 2. TFC of 70% ethanol (6.40 mg QE/g) significantly ($p < 0.05$) higher than other solvents (70% acetone, 2.71 mg QE/g; aquadest, 2.06 mg QE/g). Whereas, there is no significant difference ($p > 0.05$) of 70% acetone and aquadest solvents. Total tannin content (TTC) of *Sargassum* sp. extracts is shown in Figure 3. TTC of aquadest solvent (10.47 mg TAE/g) was significantly ($p < 0.05$) higher than other solvents (70% ethanol, 5.25 mg TAE/g; 70% acetone, 3.06 mg TAE/g).

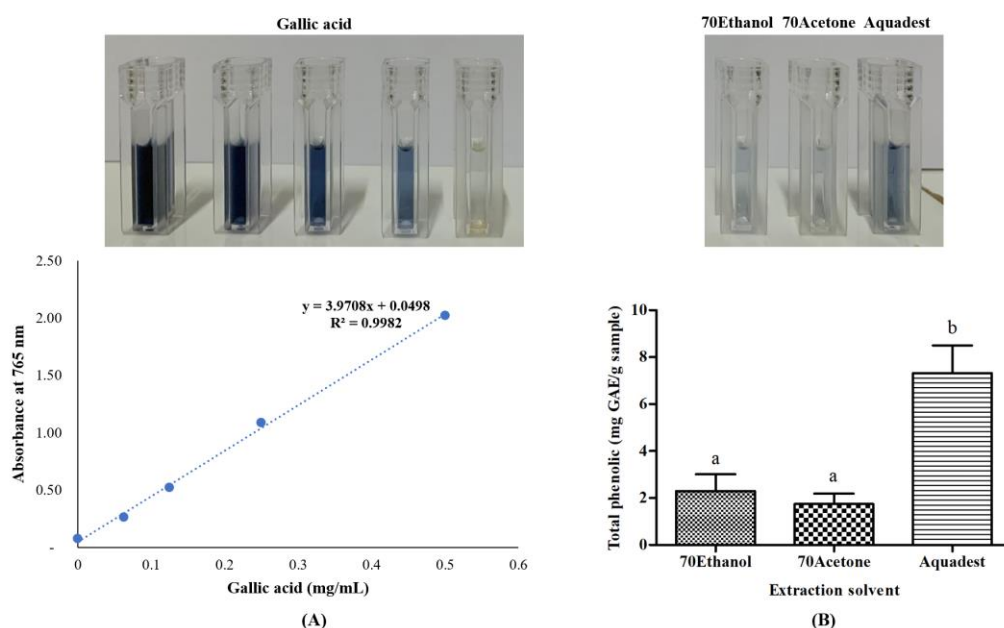


Figure 1. (A) Gallic acid standard curve and (B) total phenolic content of *Sargassum* sp. extracts. Data is shown as mean \pm standard deviation ($n=3$). Different superscript letters indicate significant differences at $p < 0.05$.

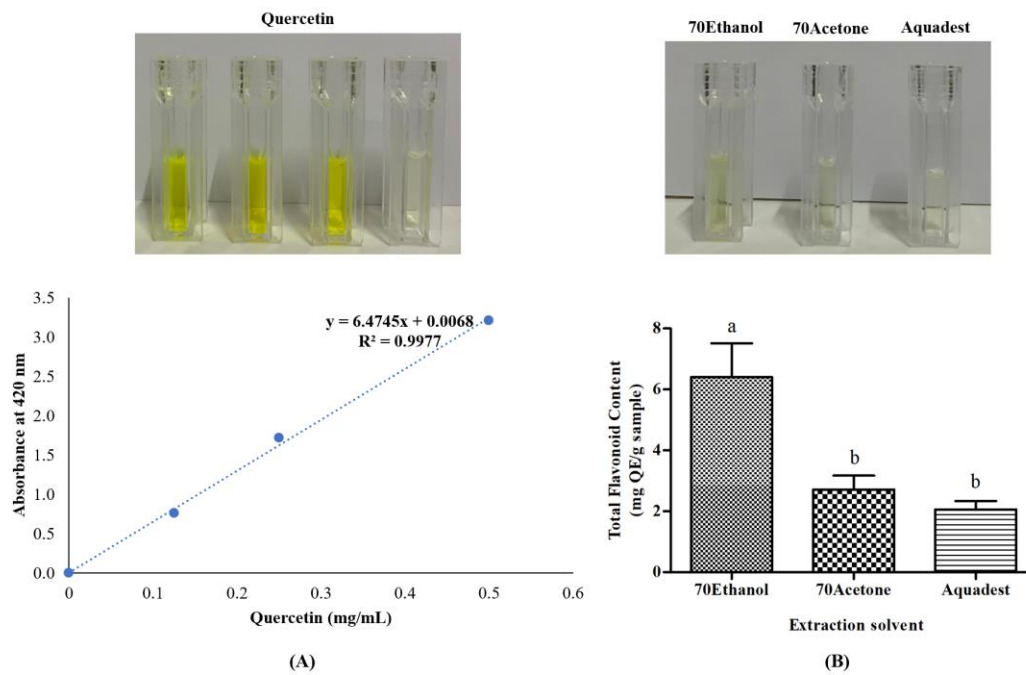


Figure 2. (A) Quercetin standard curve and (B) total flavonoid content of *Sargassum* sp. extracts. Data is shown as mean \pm standard deviation ($n=3$). Different superscript letters indicate significant differences at $p<0.05$.

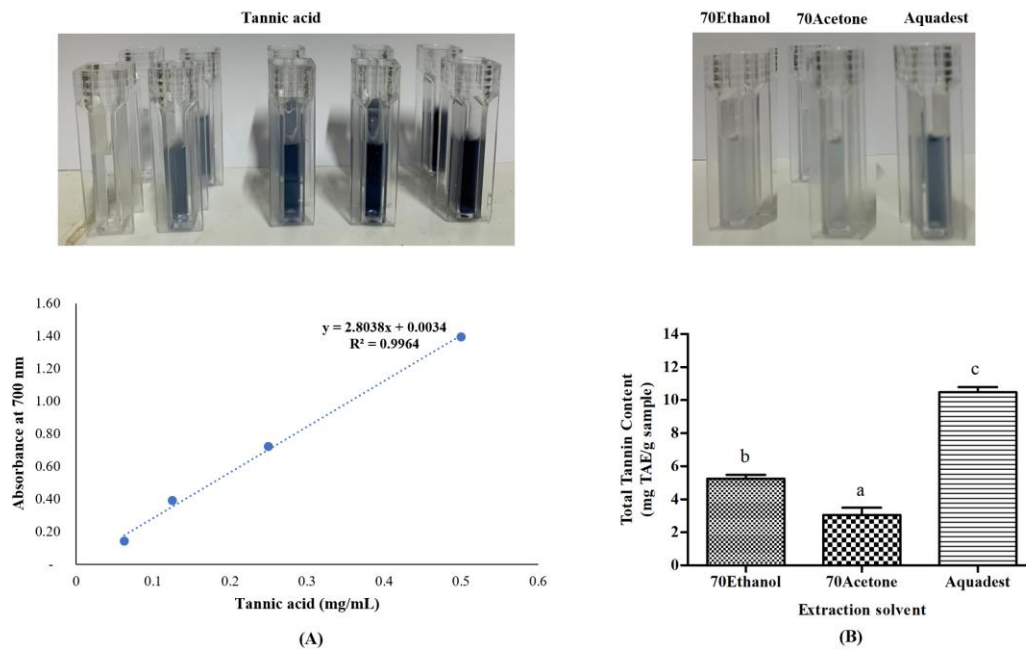


Figure 3. (A) Tannic acid standard curve and (B) total tannin content of *Sargassum* sp. extracts. Data is shown as mean \pm standard deviation ($n=3$). Different superscript letters indicate significant differences at $p<0.05$.

3.2. Fourier Transform Infrared (FTIR) Spectra

The functional groups in the *Sargassum* sp. extract are shown in Figure 4. According to Figure 4, the spectra peaks of polyphenol compounds in the *Sargassum* extract were observed at 3840.30 cm^{-1} , 3743.90 cm^{-1} , 3295.58 cm^{-1} , 2341.56 cm^{-1} , 1565.84 cm^{-1} , 1420.40 cm^{-1} , and 1095.13 cm^{-1} , as analyzed by Fourier Transform Infrared (FTIR) spectroscopy.

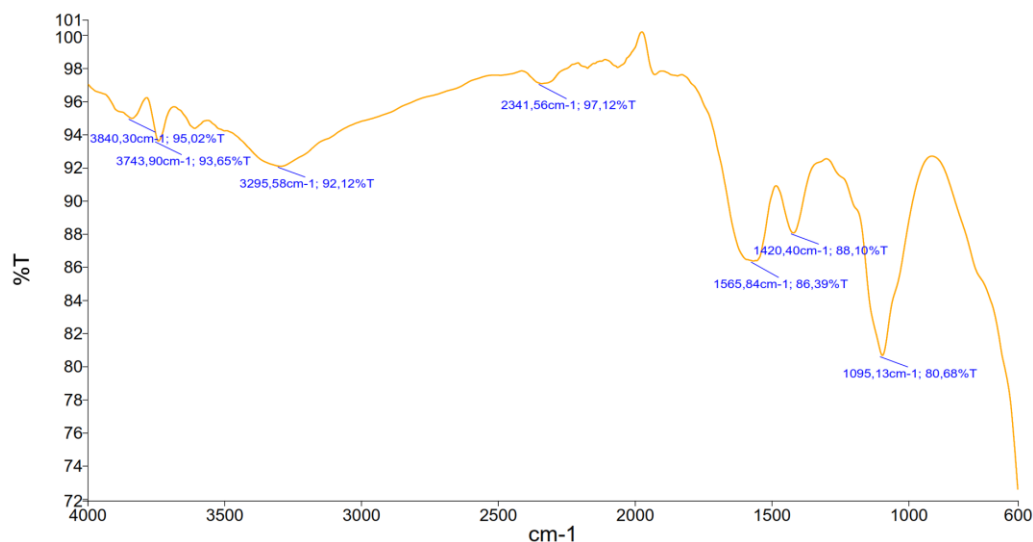


Figure 4. Fourier Transform Infrared (FTIR) spectra peaks of *Sargassum* sp. extract at an extraction solvent of aquadest.

3.3. Antioxidant Activity

The antioxidant activity of *Sargassum* sp. extract is shown in **Figure 5**. The antioxidant activity represented as percent of free radical scavenging activity (% of inhibition), whereas aquadest (43.65%) is significantly ($p < 0.05$) higher inhibition when compared to 70% acetone (17.36%) and 70% ethanol (15.53%). Whereas, there is no significant difference ($p > 0.05$) between 70% ethanol and 70% acetone solvents.

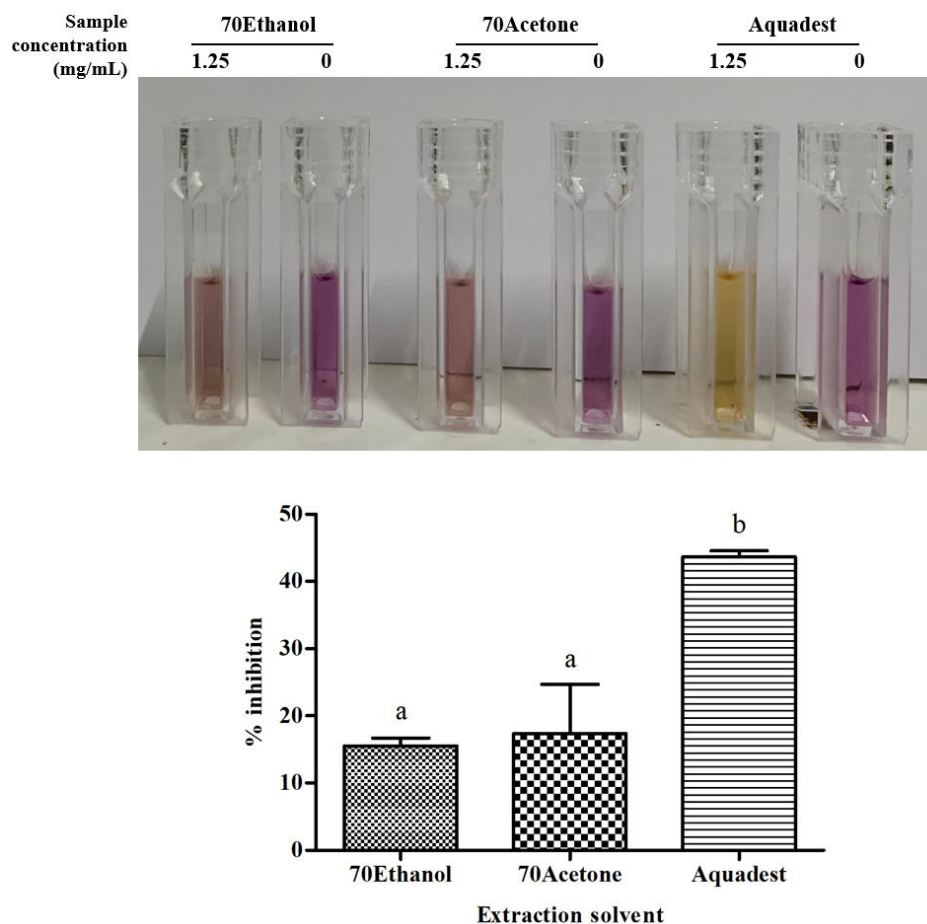


Figure 5. Antioxidant activity of *Sargassum* sp. extracts as determined by DPPH method. Data is shown as mean \pm standard deviation ($n=3$). Different superscript letters indicate significant differences at $p < 0.05$.

4. DISCUSSION and CONCLUSION

In this study, polyphenol compounds were successfully extracted from the brown seaweed *Sargassum* sp. using different solvents. The polyphenols in the *Sargassum* extract are characterized by the presence of phenolic acids, flavonoids, and tannins. According to Figure 1, the total phenolic acid content ranges from 1.75 mg GAE/g to 7.32 mg GAE/g. The highest phenolic acid content was observed when *Sargassum* was extracted using distilled water (aquadest). A previous study reported that the total phenolic acid content of the seaweed *Padina pavonica* from Abou Qir Bay, Alexandria, ranged from 1.8 mg GAE/g to 3.4 mg GAE/g. The study also noted that the highest phenolic acid content was obtained when distilled (aquadest) was used as the extraction solvent (Ismail et al., 2020). The total flavonoid content of *Sargassum* sp. extracts ranged from 2.06 mg QE/g to 6.40 mg QE/g (Figure 2). The highest flavonoid content was observed when *Sargassum* was extracted using 70% ethanol. A previous study reported that total flavonoid content of *Sargassum* sp. from Queenscliff Harbour, Victoria, Australia when extracted using 70% ethanol (0.96 mg QE/g) also higher when compared to 70% acetone (0.34 mg QE/g) (Subbiah et al., 2023). The total tannin content of the *Sargassum* extract ranged from 3.06 mg TAE/g to 10.47 mg TAE/g, with the highest content observed when the *Sargassum* was extracted using distilled water (aquadest) as shown in Figure 3. A previous study reported that total tannin content of *Sargassum* ethanol extract from Takalar District, South Sulawesi, Indonesia, was approximately 0.51±0.09% (Fauzi et al., 2018). Additionally, tannin content of distilled water extract of seaweed *Kappaphycus alvarezii* about 2.94±0.41 CAE/g (Das et al., 2023).

This study reported that different extraction solvents produced varying total polyphenol contents. A previous study indicated that polyphenol compounds, such as total phenolic, flavonoid, and tannin content, in seaweed depend on the species, origin, and solvent used (Sadowska et al., 2024). Additionally, the polyphenol content from natural resources may vary depending on factors such as species, location, climate, maturity stage, cultivar, cultural practices, and other variables (Gao et al., 2023; Uddin et al., 2022). Another study also found that the polyphenol content in Echinacea plant extracts depended on the growth region, growth period, and species (Vergun et al., 2024). On the other hand, the type of solvent used for extracting polyphenols from plants plays a crucial role in determining the yield of these compounds. The polarity of the solvent affects the solubility of phenolic compounds, directly influencing extraction efficiency. The appropriate solvent for polyphenol extraction depends on the specific plant material and the composition of its polyphenolic content (Baron et al., 2021; Mohammed et al., 2022).

According to the FT-IR analysis (Figure 4), O-H stretching and H-bonding were observed at 3804.30 cm⁻¹, 3743.90 cm⁻¹, and 3295.58 cm⁻¹; C=C stretching vibrations at 1565.84 cm⁻¹; C-H bending at 1420.40 cm⁻¹; and C-O stretching vibrations at 1095.13 cm⁻¹ (Nandiyanto et al., 2019). These peaks indicate the presence of phenolic hydroxyl groups in the *Sargassum* extract. A previous study reported that an O-H stretching band at 3211.88 cm⁻¹ also indicates the presence of phenolic hydroxyl groups (Prajapati & Parmar, 2024). Another study noted that the region between 3400 and 3200 cm⁻¹ is associated with asymmetric and symmetric stretching of hydrogen bonds and polymeric hydroxyl groups, a characteristic feature of polyphenolic compounds (Wongsa et al., 2022).

Figure 5 illustrates the antioxidant activity of the polyphenol extract from *Sargassum* sp., expressed as the inhibition of DPPH free radicals by the polyphenols. The greater the percentage of inhibition, the more effective the antioxidant activity. The highest inhibition was observed with the aqueous solvent (aquadest), which is attributed to the higher concentration of polyphenolic compounds, such as phenolic acid and tannins, in the aquadest extract. Previous studies have highlighted that the effectiveness of bioactive compounds is influenced by factors such as the extraction method, the grinding of the raw material, and the properties of the solvent used (Zhang et al., 2018). Polyphenol compounds are recognized for their antioxidant

properties, as they inhibit free radical formation by acting as radical scavengers, either through hydrogen donation or electron transfer mechanisms (Andrés *et al.*, 2023). As shown in [Figure 5](#), the percentage of inhibition ranged from 15.53% to 43.65% at a concentration of 1.25 mg/mL. For comparison, a previous study found the radical scavenging activity of laver (red seaweed extract) to be 23.05% at 1.0 mg/mL (Hwang & Thi, 2014).

Overall, the polyphenol compounds were successfully extracted from *Sargassum* sp., with different extraction solvents resulting in varying quantities of polyphenols, including phenolic acids, flavonoids, and tannins. Among the solvents tested, the distilled water solvent (aquadest) yielded the highest amount of polyphenols, which also corresponded to the highest antioxidant activity, as indicated by the highest percentage of free radical inhibition. These findings suggest that *Sargassum* extract could serve as a valuable source of natural antioxidants and potentially be used in pharmaceutical applications.

Acknowledgments

This work was financially supported by the Universitas Sriwijaya within the framework of the Indonesia Directorate General of Higher Education, Research and Technology Project, Ministry of Education, Culture, Research, and Technology, with the Contract Number: 090/E5/PG.02.00.PL/2024.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Authorship Contribution Statement

Sabri Sudirman: Supervision and Writing – original draft, editing and final approval. **Andreas Al Faragih Dwi Putra:** Formal Analysis. **Herpandi Herpandi:** Supervision and Validation. **Indah Widiastuti:** Validation. **Susi Lestari:** Formal Analysis. **Sherly Ridhowati:** Supervision. **Miftahul Janna:** Methodology and Formal Analysis

Orcid

Sabri Sudirman  <https://orcid.org/0000-0003-2821-3772>
Andreas Al Faragih Dwi Putra  <https://orcid.org/0009-0000-0702-357X>
Herpandi Herpandi  <https://orcid.org/0000-0002-2186-7653>
Indah Widiastuti  <https://orcid.org/0000-0003-1492-2463>
Susi Lestari  <https://orcid.org/0000-0002-9984-7118>
Sherly Ridhowati  <https://orcid.org/0000-0002-1124-1657>
Miftahul Janna  <https://orcid.org/0000-0002-8919-8556>

REFERENCES

- Andrés, C.M.C., Pérez de la Lastra, J.M., Juan, C.A., Plou, F.J., & Pérez-Lebeña, E. (2023). Polyphenols as antioxidant/pro-oxidant compounds and donors of reducing species: relationship with human antioxidant metabolism. *Processes*, 11(9), 2771. <https://doi.org/10.3390/pr11092771>
- Balaky, H.H., KhalīD, K., Hasan, A., TahīR, S., Ubur, S., & KhedīR, A. (2021). Estimation of total tannin and total phenolic content in plant (*Crataegus azarolus* L.) by orbital shaker technique. *International Journal of Agriculture, Environment and Food Sciences*, 1-6. <https://doi.org/10.31015/jaefs.2021.1.1>
- Bambang, B.S., Kumalaningsih, S., Susinggih, W., & Hardoko. (2013). Polyphenol content and antioxidant activities of crude extract from Brown Algae by various solvents. *Journal of Life Science and Biomedicine*, 3(6), 439-443.
- Baron, G., Ferrario, G., Marinello, C., Carini, M., Morazzoni, P., & Aldini, G. (2021). Effect of extraction solvent and temperature on polyphenol profiles, antioxidant and anti-

- inflammatory effects of Red Grape Skin by-product. *Molecules*, 26(18), 5454. <https://doi.org/10.3390/molecules26185454>
- Bhateja, P.K., Kajal, A., & Singh, R. (2020). Amelioration of Diabetes mellitus by modulation of GLP-1 via targeting alpha-glucosidase using *Acacia tortilis* polysaccharide in Streptozotocin-Nicotinamide induced diabetes in rats. *Journal of Ayurveda and Integrative Medicine*, 11(4), 405-413. <https://doi.org/10.1016/j.jaim.2019.06.003>
- Catarino, M.D., Silva-Reis, R., Chouh, A., Silva, S., Braga, S.S., Silva, A.M.S., & Cardoso, S.M. (2023). Applications of antioxidant secondary metabolites of *Sargassum* spp. *Marine Drugs*, 21(3), 172. <https://doi.org/10.3390/md21030172>
- Chandra, S., Khan, S., Avula, B., Lata, H., Yang, M.H., Elsohly, M.A., & Khan, I.A. (2014). Assessment of total phenolic and flavonoid content, antioxidant properties, and yield of aeroponically and conventionally grown leafy vegetables and fruit crops: a comparative study. *Evidence-Based Complementary and Alternative Medicine*, 2014, 253875. <https://doi.org/10.1155/2014/253875>
- Das, D., Arulkumar, A., Paramasivam, S., Lopez-Santamarina, A., del Carmen Mondragon, A., & Miranda Lopez, J.M. (2023). Phytochemical constituents, antimicrobial properties and bioactivity of Marine Red Seaweed (*Kappaphycus alvarezii*) and Seagrass (*Cymodocea serrulata*). *Foods*, 12(14), 2811. <https://doi.org/10.3390/foods12142811>
- Farasat, M., Khavari-Nejad, R.A., Nabavi, S.M., & Namjooyan, F. (2014, Winter). Antioxidant activity, total phenolics and flavonoid contents of some Edible Green Seaweeds from Northern Coasts of the Persian Gulf. *Iran J Pharm Res.*, 13(1), 163-170. <https://www.ncbi.nlm.nih.gov/pubmed/24734068>
- Fauzi, A., Lamma, S., & Ruslin, M. (2018). Total tannin levels analysis of brown algae (*Sargassum* sp. and *Padina* sp.) to prevent blood loss in a surgery. *Journal of Dentomaxillofacial Science*, 3(1). <https://doi.org/10.15562/jdmfs.v3i1.621>
- Gao, N., Si, X., Han, W., Gong, E., Shu, C., Tian, J., Wang, Y., Zhang, J., Li, B., & Li, B. (2023). The contribution of different polyphenol compositions from chokeberry produced in China to cellular antioxidant and antiproliferative activities. *Food Science and Human Wellness*, 12(5), 1590-1600. <https://doi.org/10.1016/j.fshw.2023.02.018>
- Herpandi, Lestari, S.D., Bastian, & Sudirman, S. (2021). Antioxidant activity of the fractions from water lettuce (*Pistia stratiotes*) extract. *Food Research*, 5(2), 451-455. [https://doi.org/10.26656/fr.2017.5\(2\).578](https://doi.org/10.26656/fr.2017.5(2).578)
- Hwang, E.-S., & Thi, D.N. (2014). Effects of Extraction and Processing Methods on Antioxidant Compound Contents and Radical Scavenging Activities of Laver (*Porphyra tenera*). *Preventive Nutrition and Food Science*, 19(1), 40-48. <https://doi.org/10.3746/pnf.2014.19.1.040>
- Ismail, G.A., Gheda, S.F., Abo-Shady, A.M., & Abdel-Karim, O.H. (2020). In vitro potential activity of some seaweeds as antioxidants and inhibitors of diabetic enzymes. *Food Science and Technology*, 40(3), 681-691. <https://doi.org/10.1590/fst.15619>
- Ismail, M.M., El Zokm, G.M., & Miranda Lopez, J.M. (2023). Nutritional, bioactive compounds content, and antioxidant activity of brown seaweeds from the Red Sea. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1210934>
- Jin, J.-O., Zhang, W., Du, J.-Y., Wong, K.-W., Oda, T., & Yu, Q. (2014). Fucoidan Can function as an adjuvant in vivo to enhance dendritic cell maturation and function and promote antigen-specific t cell immune responses. *Plos One*, 9(6), e99396. <https://doi.org/10.1371/journal.pone.0099396>
- Kumar, Y., Tarafdar, A., Badgujar, P.C., & El-Sohaimy, S. (2021). Seaweed as a source of natural antioxidants: Therapeutic activity and food applications. *Journal of Food Quality*, 2021, 1-17. <https://doi.org/10.1155/2021/5753391>
- Lobo, V., Patil, A., Phatak, A., & Chandra, N. (2010). Free radicals, antioxidants and functional foods: Impact on human health. *Pharmacognosy Reviews*, 4(8), 118-126. <https://doi.org/10.4103/0973-7847.70902>

- Lourenço, S.C., Moldão-Martins, M., & Alves, V.D. (2019). Antioxidants of natural plant origins: From sources to food industry applications. *Molecules*, 24(22), 4132. <https://doi.org/10.3390/molecules24224132>
- Mehdinezhad, N., Ghannadi, A., & Yegdaneh, A. (2016). Phytochemical and biological evaluation of some *Sargassum* species from Persian Gulf. *Research in Pharmaceutical Sciences*, 11(3), 243-249.
- Mohammed, E.A., Abdalla, I.G., Alfawaz, M.A., Mohammed, M.A., Al Maiman, S.A., Osman, M.A., Yagoub, A.E.A., & Hassan, A.B. (2022). Effects of extraction solvents on the total phenolic content, total flavonoid content, and antioxidant activity in the aerial part of root vegetables. *Agriculture*, 12(11), 1820. <https://doi.org/10.3390/agriculture12111820>
- Nandiyanto, A.B.D., Oktiani, R., & Ragadhita, R. (2019). How to read and interpret FTIR spectroscopy of organic material. *Indonesian Journal of Science and Technology*, 4(1). <https://doi.org/10.17509/ijost.v4i1.15806>
- Prajapati, A.B., & Parmar, R. (2024). "Ftir analysis of natural herbal preservative Lavanga (clove 1%, 2% oil and powder 1%, 2%) under freezer conditions". *African Journal of Biomedical Research*, 4376-4385. <https://doi.org/10.53555/AJBR.v27i3S.3166>
- Rad, M.S., Anil Kumar, N.V., Zucca, P., Varoni, E.M., Dini, L., Panzarini, E., Rajkovic, J., Tsouh Fokou, P.V., Azzini, E., Peluso, I., Prakash Mishra, A., Nigam, M., El Rayess, Y., Beyrouthy, M.E., Polito, L., Iriti, M., Martins, N., Martorell, M., Docea, A.O., Setzer, W. N., Calina, D., Cho, W.C., & Sharifi-Rad, J. (2020). Lifestyle, oxidative stress, and antioxidants: Back and forth in the pathophysiology of chronic diseases. *Frontiers in Physiology*, 11. <https://doi.org/10.3389/fphys.2020.00694>
- Sadeghi, A., Rajabiyan, A., Nabizade, N., Meygoli Nezhad, N., & Zarei-Ahmady, A. (2024). Seaweed-derived phenolic compounds as diverse bioactive molecules: A review on identification, application, extraction and purification strategies. *International Journal of Biological Macromolecules*, 266, 131147. <https://doi.org/10.1016/j.ijbiomac.2024.131147>
- Sadowska, U., Armenta Villavicencio, R., Dziadek, K., Skoczylas, J., Sadowski, S.K., & Kopeć, A. (2024). The identification of polyphenolic compounds and the determination of antioxidant activity in extracts and infusions of Peppermint, Lemon Balm and Lavender. *Applied Sciences*, 14(2), 699. <https://doi.org/10.3390/app14020699>
- Subbiah, V., Ebrahimi, F., Agar, O.T., Dunshea, F.R., Barrow, C.J., & Suleria, H.A.R. (2023). comparative study on the effect of phenolics and their antioxidant potential of freeze-dried Australian Beach-Cast Seaweed species upon different extraction methodologies. *Pharmaceuticals*, 16(5). <https://doi.org/10.3390/ph16050773>
- Sudirman, S., Herpandi, Rinto, Lestari, S., Harma, M., & Aprilia, C. (2024). Effects of extraction temperature on bioactive compounds and antioxidant activity of yellow velvetleaf (*Limnocharis flava*) and water lettuce (*Pistia stratiotes*) leaf extract. *Food Research*, 8(1), 136-139. [https://doi.org/10.26656/fr.2017.8\(1\).113](https://doi.org/10.26656/fr.2017.8(1).113)
- Sudirman, S., Herpandi, Safitri, E., Apriani, E.F., & Taqwa, F.H. (2022). Total polyphenol and flavonoid contents and antioxidant activities of water lettuce (*Pistia stratiotes*) leave extracts. *Food Research*, 6(4), 205-210. [https://doi.org/10.26656/fr.2017.6\(4\).484](https://doi.org/10.26656/fr.2017.6(4).484)
- Sudirman, S., Wardana, A.K., Herpandi, Widiastuti, I., Sari, D.I., & Janna, M. (2024). Antioxidant activity of polyphenol compounds extracted from Nipa Palm (*Nypa fruticans*) fruit husk with different ethanol concentrations. *International Journal of Secondary Metabolite*, 11(2), 355-363. <https://doi.org/https://doi.org/10.21448/ijsm.1360736>
- Uddin, N., Muhammad, N., Nisar, M., Aisha, Ali, N., Ullah, R., Ali, E.A., Khan, A.A., Rahman, I.U., Khan, A., & Zeb, A. (2022). Distribution of polyphenolic compounds, antioxidant potential, and free amino acids in *Ziziphus* fruits extract; a study for determining the influence of wider geography. *Food Science & Nutrition*, 10(5), 1414-1430. <https://doi.org/10.1002/fsn3.2726>
- Vergun, O., Svydenko, L., Sedlačková, V.H., Shymanska, O., Ivanišová, E., Hlushchenko, L., & Brindza, J. (2024). Accumulation of total content of polyphenol compounds and

- antioxidant activity of Echinacea Moench species. *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, 8(1), 48–57. <https://doi.org/10.15414/ainhlq.2024.0006>
- Widyartini, D.S., Widodo, P., & Susanto, A.B. (2017). Thallus variation of *Sargassum polycystum* from Central Java, Indonesia. *Biodiversitas Journal of Biological Diversity*, 18(3), 1004-1011. <https://doi.org/10.13057/biodiv/d180319>
- Wongsa, P., Phatikulrungsun, P., & Prathumthong, S. (2022). FT-IR characteristics, phenolic profiles and inhibitory potential against digestive enzymes of 25 herbal infusions. *Scientific Reports*, 12(1). <https://doi.org/10.1038/s41598-022-10669-z>
- Wu, Y., Gao, H., Wang, Y., Peng, Z., Guo, Z., Ma, Y., Zhang, R., Zhang, M., Wu, Q., Xiao, J., & Zhong, Q. (2022). Effects of different extraction methods on contents, profiles, and antioxidant abilities of free and bound phenolics of *Sargassum polycystum* from the South China Sea. *Journal of Food Science*, 87(3), 968-981. <https://doi.org/10.1111/1750-3841.16051>
- Xu, D.-P., Li, Y., Meng, X., Zhou, T., Zhou, Y., Zheng, J., Zhang, J.-J., & Li, H.-B. (2017). Natural antioxidants in foods and medicinal plants: Extraction, assessment and resources. *International Journal of Molecular Sciences*, 18(1), 96. <https://doi.org/10.3390/ijms18010096>
- Zhang, Q.-W., Lin, L.-G., & Ye, W.-C. (2018). Techniques for extraction and isolation of natural products: a comprehensive review. *Chinese Medicine*, 13(1), 20. <https://doi.org/10.1186/s13020-018-0177-x>