EVALUATION OF FUCOIDAN, POLYSACCHARIDE, AND POLYPHENOL CONTENT IN SELECTED BROWN SEAWEED SPECIES FROM LY SON ISLAND

ĐÁNH GIÁ HÀM LƯỢNG FUCOIDAN, POLYSACCHARIDE VÀ POLYPHENOL TRONG MỘT SỐ LOÀI RONG NÂU Ở HUYỆN ĐẢO LÝ SƠN

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Abstract - This study evaluates the fucoidan, polysaccharide, and polyphenol contents in five species of brown seaweed collected from Ly Son island, aiming to determine their potential for sustainable exploitation and aquaculture. The chemical analyses revealed that, *Sargassum sp.* exhibited the highest fucoidan content (5.66 ± 1.60%), whereas *Turbinaria ornata* had the highest polyphenol concentration (431.81 ± 115.46 mg GAE/100g dry weight). Polysaccharide content varied among species, with *T. ornata* reaching the highest value (26.57 ± 8.37%). The observed differences in biochemical composition may be attributed to genetic factors, environmental conditions, and the developmental stage of the seaweed. These findings provide a scientific basis for the sustainable utilization and industrial application of brown seaweed in food, pharmaceuticals, and marine ecosystem conservation.

Key words - Brown seaweed; fucoidan; polysaccharide; polyphenol

Tóm tắt - Nghiên cứu này đánh giá hàm lượng fucoidan, polysaccharide và polyphenol trong năm loài rong nâu thu thập tại huyện đảo Lý Sơn, nhằm xác định tiềm năng khai thác và nuôi trồng bền vững. Kết quả phân tích cho thấy, *Sargassum sp.* có hàm lượng fucoidan cao nhất (5,66 ± 1,60%), trong khi *Turbinaria ornata* có hàm lượng polyphenol cao nhất (431,81 ± 115,46 mgGAE/100g rong khô). Hàm lượng polysaccharide chênh lệch không đáng kể giữa các loài, trong đó, *T. ornata* đạt giá trị cao nhất (26,57 ± 8,37%). Sự khác biệt về hàm lượng các hợp chất sinh học có thể do yếu tố di truyền, môi trường sống và giai đoạn phát triển của rong. Những kết quả này góp phần cung cấp cơ sở khoa học cho việc khai thác hợp lý và phát triển nguồn lợi rong biển, hướng tới sử dụng bền vững trong công nghiệp thực phẩm, dược phẩm và bảo tồn hệ sinh thái ven biển.

Từ khóa - Rong nâu; fucoidan; polysaccharide; polyphenol

1. Introduction

Ly Son island possesses a rich seaweed ecosystem, comprising 143 species across four main phyla: Rhodophyta (67 species), Ochrophyta (39 species), Chlorophyta (36 species), and Cyanobacteria (1 species) [1]. Among these, 60 species have economic value, including 16 species of green seaweed, 22 species of red seaweed, and 22 species of brown seaweed. However, seaweed harvesting activities are mainly focused on several genera such as *Gracilaria* (*Gracilaria tenuistipitata* - "rong Câu chỉ vàng", *Gracilariopsis bailinae* - "rong Câu cước"), *Sargassum* ("rong Mơ"), and *Ulva* (*Ulva lactuca*, *Ulva conglobata*) [1]. Commercial products are primarily produced in the form of dried seaweed with a low selling price (2,000-5,000 VND/kg), and spontaneous exploitation methods have led to the decline of certain seaweed populations, including three species now listed as rare and in need of conservation (*Hydropuntia eucheumatoides* - "rong câu chân vịt"; *Betaphycus gelatinus* - "rong hồng vân"; *Sargassum congkinhii* - "rong mơ công kinh") [1]. Therefore, research on economically valuable seaweed species and their potential for sustainable cultivation is essential for genetic resource conservation and the development of the local seaweed industry.

In Ly Son, brown seaweed-especially the genus *Sargassum*-has the highest biomass (942 ± 417 g/m²) and contains significant nutritional components, including carbohydrates (6-17%), protein (3-15%), fiber (10-58%), polysaccharides (20-76%), and polyphenols (140-1000 mg GAE/100g dry seaweed) [2]. Notably, polysaccharides, fucoidan, and polyphenols are recognized for their high antioxidant activity and effects such as anticoagulation, anti-inflammatory, antiviral, antitumor, and immunomodulation [2].

Despite their biological and economic potential, studies on seaweed in Vietnam have mainly focused on species distribution surveys, particularly in areas such as Ly Son Archipelago, Quang Ngai [1]; Thi Nai lagoon, Binh Dinh province [3]; the Spratly Islands [4]; and Nam Du Archipelago, Kien Giang [5]. In contrast, in-depth research on the content of bioactive compounds and the application potential of seaweed in Vietnam remains limited [2], [6].

Given these circumstances, this study was conducted to investigate the chemical composition of several brown seaweed species in Ly Son island, thereby identifying species with potential for cultivation and application in production, contributing to economic and social benefits as well as the conservation and development of local seaweed genetic resources.

2. Materials and methods

2.1. Research materials

Brown seaweed samples were collected from Lý Sơn Island in April 2024. Sampling was conducted in areas with distinct environmental characteristics as described in Table 1. The collected samples included five species: *Palisada perforata* (Bory) K. W. Nam, 2007; *Sargassum aquifolium*; *Turbinaria ornata*; *Hormophysa cuneiformis*; and *Sargassum sp*. After collection, the seaweed was cleaned to remove large debris, repeatedly washed with distilled water, and dried to constant weight at 4°C. Dried seaweed was stored in PE bags at -21°C for subsequent experiments [7].

Table 1. *Coordinates of sampling sites and characteristic environmental conditions*

Site name	GPS Coordinates	Description of characteristic environment
Chua Hang	15.392381°N, 109.125309°E	Rocky shore near the beach, clear water, moderate waves, located in the northwest of the island
Mu Cu lighthouse	15.379063°N, 109.145398°E	Tidal flat in the southeast of the island, medium waves, sandy substrate
Thon Tay	15.369180°N, 109.121940°E	Coastal area in the west of the island, gentle waves, near residential area, rubble substrate

2.2. Species identification method

Species identification was performed using morphological methods. Seaweed samples were analyzed at the Laboratory of Algal Technology and Secondary Compounds, Faculty of Biology - Agriculture - Environment, The University of Danang - University of Science and Education. The identification process was based on references by Do Anh Duy et al. [8], Pham Hoang Ho [9], Pham Hoang Ho [10], Nguyen Huu Dinh [11], T. Isao [12], Nguyen Huu Dai [13], Nguyen Huu Dai [14], and Nguyen Van Tu [15].

2.3. Extraction and quantification of fucoidan

Fucoidan was extracted and quantified according to the modified method of Hanjabam et al. [16]. Specifically, 1 g of dried seaweed was incubated in 25 mL of HCl at pH 2, at a ratio of 1:25 (seaweed:acid solution). The mixture was sonicated for 30 minutes at 30-35°C, and the extract was collected through a 25 µm mesh filter. The filtrate was centrifuged at 3,500 rpm for 15 minutes, and the supernatant was dried at 40°C to obtain the extract. The extract was precipitated in absolute ethanol until the final concentration reached 70%. The precipitate was then dried to constant weight at 35°C for 2 hours. Fucoidan content (%) was calculated as the ratio of the precipitate mass to the analyzed seaweed mass.

$$\text{Fucoidan content (\%)} = \frac{m_1}{m_0} \times 100\%$$

Where: m_1(g) is the mass of the precipitate obtained, m_0 is the mass of analyzed seaweed.

2.4. Extraction and quantification of polyphenols

Total polyphenol content was determined following the method of Singleton et al. [17]. A 0.1 g sample was extracted and diluted to 50 mL with distilled water, then precisely 0.1 mL of the extract was mixed with 0.9 mL of distilled water. Subsequently, 1 mL of 10% Folin-Ciocalteu reagent and 2.5 mL of 7.5% Na_2CO_3 were added. The mixture was vortexed for 30 seconds, kept in the dark at room temperature for 30 minutes, and then measured at 760 nm. Gallic acid was used to construct the calibration curve, and results were expressed in mg gallic acid equivalents (mg GAE/g dry seaweed).

$$\text{TPC (mg/g)} = \frac{C_M \times V}{m}$$

Where: C_M is the polyphenol content according to the calibration curve; V is the volume of water; m (g) is the mass of analyzed seaweed.

2.5. Extraction and quantification of polysaccharides

Polysaccharide content was analyzed according to the method of Tran Trung Giang et al. [18]. Specifically, 10 g of seaweed powder was soaked in 600 mL of distilled water at 100°C for 6 hours. The supernatant was collected by filtration and centrifuged for 10 minutes at 4,000 rpm. The mixture was evaporated to remove water, yielding dry polysaccharides. The polysaccharide powder was stored at 4°C for subsequent studies. Polysaccharide content (%) was calculated as the ratio of the precipitate mass to the analyzed seaweed mass.

$$\text{Polysaccharide content (\%)} = \frac{m_1}{m_0} \times 100\%$$

Where: m_1(g) is the mass of the precipitate obtained, $m_0$is the mass of the analyzed seaweed.

2.6. Data analysis

Collected data were statistically analyzed using Excel and R software [18]. Significant differences between experimental groups were assessed using analysis of variance (ANOVA) and Tukey's Honestly Significant Difference post-hoc test. Statistical significance was determined at $p \leq 0.05$.

3. Research results

3.1. Fucoidan content in selected brown seaweed species from Ly Son island

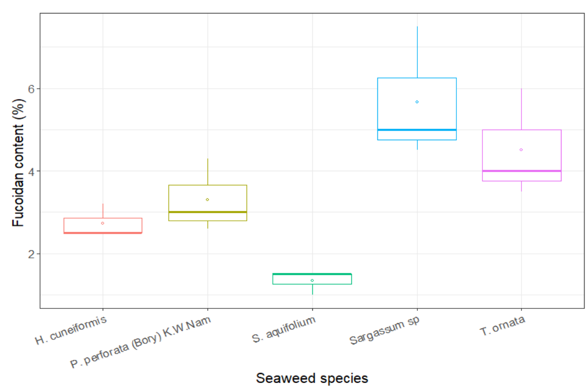

Figure 1. *Fucoidan content in five brown seaweed species collected from Ly Son island*

Fucoidan content varied among the five brown seaweed species from Ly Son island (p-value = 0.004 < 0.05) (Figure 1). *Sargassum* sp. exhibited the highest fucoidan content, reaching 5.67 ± 1.61%, which was twice as high as that of other species. In contrast, *Sargassum aquifolium* showed the lowest fucoidan content at only 1.33 ± 0.28%, 4.3 times lower than *Sargassum* sp. *Hormophysa cuneiformis* and *Palisada perforata* (Bory) K.W.Nam, 2007 had intermediate fucoidan contents, around 3.01%. These results indicate that *Sargassum* sp. is the most promising species for fucoidan extraction and product development.

3.2. Polyphenol content in selected brown seaweed species from Lý Sơn island

Analysis revealed significant differences in polyphenol content among the five brown seaweed species (p-value = 0.003 < 0.05) (Figure 2). Notably, *T. ornata* and *Sargassum* sp. had the highest polyphenol content, approximately 411 mg GAE/100g dry seaweed, which was three times higher than the other species. Conversely, *Palisada perforata* (Bory) K.W.Nam, 2007 and *Sargassum aquifolium* had the lowest polyphenol content, with average values of only 86 mg GAE/100g dry seaweed, about 3.1 times lower than the other species. Remarkably, the polyphenol content of *Hormophysa cuneiformis* was about 50% of that in *T. ornata* and *Sargassum* sp., indicating marked differences in polyphenol accumulation capacity among species and highlighting the potential of certain species as valuable sources of natural antioxidants.

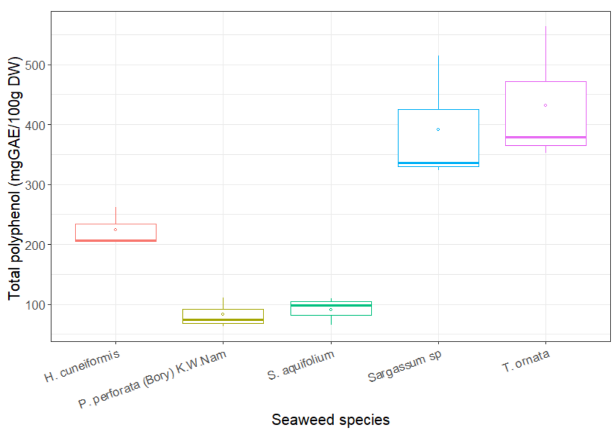

Figure 2. *Total polyphenol content in five brown seaweed species collected from Ly Son island*

3.3. Polysaccharide content in selected brown seaweed species from Ly Son island

Table 2. *Polysaccharide content (%) in selected brown seaweed species analyzed in this study*

Species	Polysaccharide content
Hormophysa cuneiformis	10.77 ± 2.45^a
Palisada perforata (Bory) K.W.Nam, 2007	12.2 ± 3.36^a
Sargassum aquifolium	21.9 ± 4.75^a
Sargassum sp.	18.83 ± 10.37^a
Turbinaria ornata	26.57 ± 8.37^a

Note: *Data are presented as % dry weight (dehydrated). Superscript letters a, b, c indicate statistically significant differences (p-value < 0.05) between pairwise values from each seaweed species.*

According to the analysis, there were no significant differences in polysaccharide content among the five samples collected from Ly Son (p-value = 0.07 > 0.05) (Table 2). Nevertheless, polysaccharide content exhibited some fluctuations among species. Specifically, *Turbinaria ornata* had the highest polysaccharide content, reaching 26.57 ± 8.37%, while *Hormophysa cuneiformis* had the lowest at about 10.77 ± 2.45%. Compared to previous studies, there is still limited data on polysaccharide content in brown seaweed species from Ly Son waters. These results contribute to the scientific database on bioactive compound contents in brown seaweed and suggest the potential for polysaccharide exploitation from certain high-content species for applications in food, pharmaceutical, and biological industries.

4. Discussion

The results indicate significant differences in fucoidan, polysaccharide, and polyphenol content among brown seaweed species from Ly Son island. Specifically, *Sargassum* sp. showed the highest fucoidan content (5.66 ± 1.60%), while *Sargassum aquifolium* had the lowest (1.33 ± 0.28%). Compared to previous studies, fucoidan content in *Sargassum* sp. from Ly Son was lower than reported in Egypt (19%) but higher than in studies from the Philippines (2.17%) and Thailand (0.16%) [19] - [21] (Table 3). Regarding polysaccharides, this study recorded the highest content in *Turbinaria ornata* (26.57 ± 8.37%), with *Hormophysa cuneiformis* showing the lowest value (10.77 ± 2.45%). Compared to previous data, polysaccharide content in *Sargassum* sp. (18.83 ± 10.37%) from Ly Son was lower than in some species of this genus from Khanh Hoa (20-76%) [22]. Polyphenol content also varied greatly among species in this study (Table 4). *Turbinaria ornata* had the highest polyphenol content (431.81 ± 115.46 mg GAE/100g dry seaweed), about three times higher than *Sargassum aquifolium* (91.08 ± 23.20 mg GAE/100g dry seaweed). These findings are consistent with previous studies (Table 5), where polyphenol content in *Sargassum* species ranged from 4.26 mg phloroglucinol/g dry seaweed (*S. angustifolium*) to 6.77 mg phloroglucinol/g dry seaweed (*S. binderi*) [23].

Differences in fucoidan, polysaccharide, and polyphenol content among species may be attributed to various biological and environmental factors. Firstly, the sampling period in April 2024 at Ly Son, during the transition between the dry and rainy seasons, may affect fucoidan, polysaccharide, and polyphenol levels in brown seaweed. *Sargassum* sp. achieved high fucoidan content (5.66 ± 1.60%) due to favorable light and salinity conditions at that time, surpassing *Turbinaria ornata* (4.50 ± 1.32%) in Nam Du during the rainy season. Polyphenol content in *T. ornata* (431.81 ± 115.46 mg GAE/100g dry seaweed) was high due to strong UV radiation at the end of the dry season, while the rainy season may reduce this content. Polysaccharide content in *T. ornata* (26.57 ± 8.37%) was high due to slightly increased nutrient levels, but lower than during the rainy season in Khanh Hoa. Additionally, genetic differences among species play an important role in their ability to synthesize bioactive compounds [1]. Environmental conditions such as light, temperature, salinity, and nutrient levels in seawater can also affect these compound contents [24], [25]. Fucoidan and polysaccharide content may increase when seaweed is exposed to heavy metals like Zn and Cd, as fucoidan and polysaccharides can bind metal ions, protecting seaweed cells [24]. Furthermore, the location of the extracted plant part significantly affects fucoidan content, with spores containing higher fucoidan than leaf blades [22]. This may be due to developmental stage-related changes in bioactive compound levels. For polyphenols, phlorotannin-a major polyphenol group in brown seaweed-tends to increase when seaweed is exposed to strong UV radiation [24]. Thus, seaweed growing in shallow waters may accumulate higher polyphenol levels than those in deeper waters [25]. Polyphenols also play a role in physical defense mechanisms, being produced more when seaweed is damaged by erosion or infection [26], [27].

Table 3. *Fucoidan content (%) in several brown seaweed species from this study and other studies*

Species	This study	Other studies
Hormophysa cuneiformis	2.73 ± 0.40^{bc}	2.17 Sampling location: Along 14 provinces of the Philippines [22]
Palisada perforata (Bory) K.W.Nam, 2007	3.30 ± 0.89^{abc}	
Sargassum aquifolium	1.33 ± 0.28^{c}	0.16 Sampling location: Eastern coastal region of Thailand [23]
Sargassum sp	5.66 ± 1.60^{a}	19 Sampling location: Intertidal zone, Hurghada City, Egypt Sampling time: summer [24]
Turbinaria ornata	4.50 ± 1.32^{ab}	2.89 Sampling location: Nam Du Islands Sampling time: - Rainy season: May, July, September 2020 - Dry season: November 2020 and January 2021 [7]

Note: *Data are presented as % dry weight (dehydrated). Superscript letters a, b, c indicate statistically significant differences (p-value < 0.05) between pairwise values from each seaweed species.*

Findings from this study highlight the potential for exploitation and application of brown seaweed in Ly Son island. With high contents of fucoidan, polysaccharides, and polyphenols, *Sargassum sp.* and *Turbinaria ornata* may serve as promising raw materials for food, pharmaceutical, and biopolymer production. However, for sustainable seaweed resource utilization, further research on brown seaweed cultivation models in Ly Son is needed, especially regarding factors affecting growth and seaweed quality. Developing controlled cultivation processes will ensure a stable supply, reduce pressure on natural exploitation, and enhance the economic value of the seaweed industry in Vietnam.

Table 4. *Polyphenol content of five brown seaweed species from Ly Son island*

Species	Polyphenol content (mgGAE/100g DW)
Hormophysa cuneiformis	223.87 ± 32.96^{bc}
Palisada perforata (Bory) K.W.Nam, 2007	82.62 ± 25.15^{c}
Sargassum aquifolium	91.08 ± 23.20^{c}
Sargassum sp.	391.50 ± 107.16^{ab}
Turbinaria ornata	431.81 ± 115.46^{a}

Note: *Data are presented as % dry weight (dehydrated). Superscript letters a, b, c indicate statistically significant differences (p-value < 0.05) between pairwise values from each seaweed species.*

Table 5. *Polyphenol content in brown seaweeds from other studies*

Species	Content	Sampling location	Sampling Time
S. Angustifolium	4.265 ± 0.1 (mg phloroglucinol/g DW) [24]	Bai Co reef, Cam Ranh, Hon Chong, Nha Phu lagoon, Khanh Hoa	June-July 2010
S. Aemulum	5.146 ± 0.09 (mg phloroglucinol/g DW) [24]		
D. Antarctica	5.146 ± 0.09 (mg phloroglucinol/g DW) [24]		
S. Brevifolium	6.229 ± 0.14 (mg phloroglucinol/g DW) [24]		
D. Antarctica	5.0 ± 0.05 (g PGE/kg DW) [34]	El Tabo sea, Chile	January 2013
L. Spicata	1.21 ± 0.11 (g PGE/kg DW) [34]		
M. Integrifolia	3.70 ± 0.14 (g PGE/kg DW) [34]		
S. mcclurei	2.057 ± 0.003 (mg phlorotannin/g DW) [4]	Nha Trang sea, Khanh Hoa	March 2012
S. polycystum	0.735 ± 0.002 (mg phlorotannin/g. DW) [4]		
S. oligocystum	2.369 ± 0.004 (mg phlorotannin/g DW) [4]		
S. aquifolium	6.770 ± 0.001 (mg phlorotannin/g DW) [4]		

5. Conclusion

This study provides a comprehensive evaluation of fucoidan, polysaccharide, and polyphenol content in five brown seaweed species from Lý Sơn Island, serving as a basis for identifying differences in bioactive compound levels among species. The results indicate that *Sargassum* sp. and *Turbinaria ornata* are the most promising species, with high contents of fucoidan, polysaccharides, and polyphenols, opening up broad application prospects in food, pharmaceutical, and biological industries. The observed differences in bioactive compound content among species are determined by the combined effects of genetic factors, habitat conditions, and developmental stages. In particular, the high fucoidan content in *Sargassum* sp. (5.66 ± 1.60%), high polysaccharide content in *T. ornata* (26.57 ± 8.37%), and high polyphenol content in *T. ornata* (431.81 ± 115.46 mg GAE/100g dry seaweed) are considered to have great potential for the exploitation of valuable bioactive compounds.

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