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Research Article

Biochemical composition and antioxidant properties of some seaweeds from Red Sea coast, Egypt

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ABSTRACT

The current study investigated the biochemical composition and antioxidant properties of four seaweeds: *Laurencia* sp. (Rhodophyta), *Cystoseira myrica*, *Hydroclathrus clathratus* and *Padina pavonica* (Ochrophyta). The highest amount of carbohydrates was (215.78 mg/g dry wt.) in *Laurencia* sp. and proteins content was maximum (50 mg/g dry wt.) in *Laurencia* sp. and *Cystoseira myrica*. The highest values of free amino acid content were recorded in the brown seaweed species *Cystoseira myrica* (4.01 mg/g dry wt.). The pressurized hot water extract of *Cystoseira myrica* has the highest total phenolic content (1.61 mg GAE/g dry wt.). Cy*stoseira myrica* contained the highest amounts of flavonoids (3.35 mg/g dry wt.), ascorbic acid (9.07 mg/g dry wt.) and α-tocopherol (27.25±0.00 abs. at 520 nm/g dry wt.). Furthermore, the ethyl alcohol extract of *Cystoseira myrica* showed high antioxidant capacities (541.6 µg/g dry wt.) and achieved the most powerful reducing ability among all of the different extracts of algal species. Statistical evaluation by Spearman correlation between the TAC assay and the total phenolic contents was found to be significant, but the correlation was nonsignificant between FRAP assay and the total phenolic contents. The composition of elements of the studied seaweed species was also analyzed. The most significant macro-elements present in the studied seaweeds were K, Na and Ca, representing that the seaweeds are good sources of these elements. Since, these seaweeds are widespread in the Egyptian waters, their biochemical composition and antioxidant capacities made them promising candidates for industrial, nutritional and pharmaceutical applications.

Keywords: Seaweeds; Biochemical composition; Phenolic compounds; Ascorbic acids; Antioxidant activity; Elemental analysis.

1. INTRODUCTION

Seaweeds belong to a group of plants known as algae. Seaweeds are classified as Chlorophyta, Phaeophyta and Rhodophyta based on their chemical and nutrient composition. Seaweeds, besides their very significant ecological role in the nature, have come up step by step starting with using them as food, later as raw material for cosmetic, pharmaceutical, medicinal and industrial purposes [1], related to their high contents of vitamins, carotenoids, essential fatty acids, minerals, polysaccharides and proteins [2, 3]. Polysaccharides are generally the main component of brown, green and red algae [4, 5]. Several polysaccharides constitute the major structure of the algal cell walls. The major

polysaccharides in the algae include fucoidan, ulvans, laminarans, carrageenans, galactans, alginates and agar. Therefore, polysaccharides play the role of storage function and structural support in algae. Generally, macromolecules of algae are formed with several monosaccharides linked by glucosidic bonds, as well as some have linear backbones that contain repeating disaccharide units [6]. The total amounts of polysaccharides in the seaweeds ranged between 4% and 76% of the dry weight [7] where fucoidans, carrageenans, aligns and agar are some of the polysaccharides usually used by man, some with different biological activities [8, 9]. Protein contents are also variable and the highest amounts are commonly found in red and green seaweeds (10-30% of the dry weight) compared to the brown seaweeds (5-15% of the dry weight) [7, 10]. Moreover, seaweeds are considered as a source of the bioactive components, whereas they can produce a high variety of secondary metabolites such as alkaloids, terpenoids, phenolic compounds and flavonoids characterized by a wide spectrum of biological activities [11]. Compounds with antimicrobial, antifungal, antiviral and antioxidant activities have been observed in green, red and brown algae [12, 13]. Therefore, more attentions have been paid to their applications in nutraceuticals, cosmeceuticals, pharmaceuticals and functional foods [14]. The metabolism of seaweeds can be influenced by several factors such as nutrients, light, salinity and water temperature, being forced to rapidly adapt to the new environmental conditions and to survive, they produce a high variety of biologically active secondary metabolites as previously mentioned [15]. These conditions, as well can lead to the production of free radicals and other oxidizing agents, however seaweeds rarely suffer any severe photodynamic damage through the metabolism. This fact suggests that the cells of seaweed have protective mechanisms. Reactive oxygen species such as superoxide, hydroxyl and peroxyl radicals are formed in the cells of human by endogenous factors and cause wide oxidative damage which can lead to cancer, age related degenerative conditions and a wide range of other human diseases [16]. Seaweeds are also known as sources rich in numerous elements such as Na, Mg, Ca, K and P or trace elements such as Mn, I or Zn. This elemental richness is due to their ability to preserve inorganic compounds up to 36% of dry weight in some species [17]. Marine algae comprise more than 60 trace elements in a concentration, which are greatly higher than that present in the terrestrial plants and have several pharmacological activities [18]. The Red Sea is a diverse and rich ecosystem, and more than 500 species of seaweeds have been recorded in it [19]. The studies on the antioxidant properties of the extracts of seaweed in Egypt are very scarce. Therefore, the main objective of the present investigation was to analyze the influence of the different extraction methods: cold water, boiling water, pressurized hot water and ethyl alcohol on the total phenolic content and antioxidant activity of four different edible species namely; *Laurencia* sp. (Red alga), *Cystoseira myrica*, *Hydroclathrus clathratus* and *Padina pavonica* (brown algae), to identify the new resources of natural antioxidant compounds, as well as, to evaluate the correlation between the total phenolic content and antioxidant capacities. Flavonoids, vitamin (C and E) contents and other biochemical compounds such as soluble protein, carbohydrate, free amino acids, were also determined in the algal species.

2. MATERIAL AND METHODS

2.1. Samples collection

Samples of red algae (Rhodophyta, Florideophyceae) *Laurencia* sp. (Ceramiales), brown algae (Ochrophyta, Phaeophyceae) *Cystoseira myrica* (Fucales), *Hydroclathrus clathratus* (Ectocarpales) and *Padina pavonica* (Dictyotales), were harvested in April 2013 from Hurghada and Al-Quseir (Red Sea coast of Egypt). The classification of these seaweeds was based on Algae Base [20]. Identification of seaweeds at least to the genus level followed the keys and descriptions adapted from Meñez and Mathieson [21], Nizamuddin [22], Aleem [23] and Jha et al. [24]. The seaweeds were first washed with tap water and deionized water to remove the residues from the surface of thalli and then dried in an oven at 60^{o}C. Lastly, the seaweeds were ground and kept in the polyethylene bags at room temperature.

2.2. Extraction methods of compounds from seaweeds

Some extraction methods were achieved by using different solvents. Conventional cold and hot water extraction besides extraction with ethanol was used. In addition, pressurized hot water extraction (PHWE) was tested also as extraction method. PHWE is a technique of extraction that uses water as extractant (extraction solvent) at temperatures above the boiling point of the water (100°C/273 K, 0.1 MPa), but below the critical point of water (374°C/647 K, 22.1 MPa).

2.2.1. Extract preparation

Cold water: a known algal tissue weight (0.1 g) was homogenized and suspended in 5 ml cold water for 2 h.

Boiling water: a known algal weight (0.1 g) was boiled in 5 ml distilled water for 2 h.

Pressurized hot water: a known algal weight (0.1 g) was suspended in 15 ml distilled water and autoclaved for 2 h at 121^{o}C.

Ethyl alcohol: a known weight of algal tissue (0.1 g) was homogenized in 20 ml ethyl alcohol 80% and shaken for 2 h.

The resultant extracts from each extraction process was separately filtered through a Whatman No. 1 filter paper, then it was stored in a closed bottle away from the light. The extracts were used for determination of total phenolic contents, total antioxidant activity and reducing power.

2.3. Determination of soluble carbohydrates

The contents of soluble carbohydrate in the crude extract of boiling water were determined by the anthrone sulphuric acid method [25, 26].

2.4. Determination of soluble proteins

The determination of soluble protein in the crude extract of boiling water was performed by Folin reagent according to Lowry et al. [27]. A calibration curve was made by bovine serum albumin (BSA) and the results were expressed as mg BSA/g dry wt.

2.5. Determination of free amino acids

Free amino acid content in the crude extract of boiling water was estimated according to the method of Moore and Stein [28]. A calibration curve was made by glycine, and free amino acid concentration was calculated as mg/g dry wt.

2.6. Determination of total phenolics

Total phenolics were estimated according to Kofalvi and Nassuth [29]. Free phenolics were estimated by the Folin-Ciocalteu's phenol reagent by using gallic acid as a standard.

2.7. Total flavonoid content

The measurement of total flavonoid content in the crude extract of ethanol was made according to the method described by Moreno et al. [30] and the results are expressed as quercetin equivalents.

2.8. Determination of ascorbate (vitamin C) content

The ascorbic acid content in the crude extract of trichloroacetic acid was estimated according to Jagota and Dani [31].

2.9. Determination of α-tocopherol (vitamin E) content

α-tocopherol content in the crude extract of petroleum ether was determined by the method of Pearson [32].

2.10. Antioxidant assay

2.10.1. Determination of the total antioxidant activity

The total antioxidant activity was determined by the method of Prieto et al. [33]. The method was based on the reduction of Mo^{6+} to Mo^{5+} and following production of a green phosphate/ Mo^{5+} complex at acidic pH.

2.10.2. Reducing power assay

The reducing power of the algal samples was estimated according to the methods described by Oyaizu [34] and the results were expressed as µg/g dry wt.

2.11. Estimation of mineral content

2.11.1. Total phosphorus

It was estimated using a Unico UV-2100 spectrophotometer by the chlorostannus-phosphomolybdic acid method in a sulfuric acid system [35].

2.11.2. Total potassium and sodium

They were determined by the flame photometer methods (Dr Lange Flame Photometer M 71 D type Nr/ LPG 075) according to Page et al. [36].

2.11.3. Total calcium and magnesium

They were determined by the flame photometer methods described by Page et al. [36].

2.12. Statistical analysis

All results obtained were subjected to one-way analysis variance (ANOVA), by using the SPSS statistical package. For comparison of the means, the Duncan's multiple range tests ($p < 0.05$) were used. Analysis of correlation (Spearman correlation) was performed to obtain the relation between the phenolic compounds, total antioxidants and the reducing power.

3. RESULTS AND DISCUSSION

Carbohydrates, proteins and amino acids are the most vital biochemical components of algae. Carbohydrates are considered the major significant biochemical component in algae since they represent the main source of energy for the metabolic activities. In the current study, the red seaweed; *Laurencia* sp. appeared to be the highest (215.78 mg/g dry wt.) in the soluble carbohydrate content compared to the brown algae, *Cystoseira myrica* (47.45 mg/g dry wt.), *Hydroclathrus clathratus* (39.55 mg/g dw.) and *Padina pavonica* (28.40 mg/g dry wt.) (Fig. 1). The amount obtained from *Laurencia* sp. was much higher than that present in another red alga, *Grateloupia turuturu* (41.57 ± 0.66 mg/g dry wt.) [37]. Rhodophycean species presented high content of carbohydrate than the Phaeophycean members. The high carbohydrate content in the red algae might be due to the higher content of phycocolloid in their cell walls [18]. Seaweeds contain high contents of polysaccharides as cell wall structural components that were already captured by the industry of hydrocolloid. Water soluble polysaccharides of seaweeds were related to hypoglycemic activities and hypocholesterolemia, however insoluble polysaccharides were related to digestive tract transit time reduction [38].

Proteins content, one of the most biochemical components of seaweeds, ranged from 50 mg/g dry wt. in *Laurencia* sp. and *Cystoseira myrica* to 36.35 mg/g dry wt. and 29.05 mg/g dry wt. in *Padina pavonica* and *Hydroclathrus clathratus*, respectively (Fig. 1). In this respect, Ismail [39] showed that, the protein content in *Sargassum linifolium* (Phaeophyceae) (14.89%) was higher than that of *Corallina officinalis* (Rhodophyceae) (5.91%) of dry wt. According to Ibañez and Cifuentes [40], the content of protein varies between algal species and generally, Rhodophycean and Chlorophycean species are characterized by the larger content of proteins compared with Phaeophycean species. However, differences in the content of proteins may be also related to the seasonal period, temperature values or to its consumption by seaweeds in the growth and reproduction. Also might be associated with the variances between species, the surrounding environmental conditions of seaweeds and the geographical locations [41].

The highest contents of free amino acid were present in the Phaeophycean species *Cystoseira myrica* (4.01 mg/g dry wt.) followed closely by the Rhodophycean species *Laurencia* sp. (3.99 mg/g dry wt.), while the lowest free amino content was present in *Padina pavonica* and *Hydroclathrus clathratus* (2.93 and 2.80 mg/g dry wt., respectively) (Fig. 1). Fleurence [41] indicated that the seaweeds, particularly Rhodophyceae, could be a complementary source of food proteins for the nutrition of animal and human and their content of amino acids was of nutritional interest.

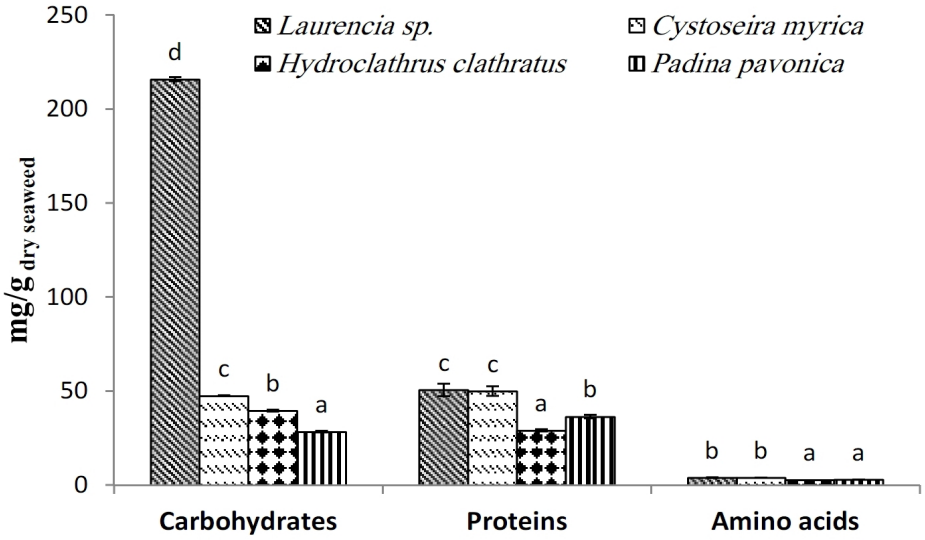

Figure 1. Soluble carbohydrates, soluble proteins and free amino acids (mg/g dry wt.) of crude extract of marine algal species with boiling water.

The studied seaweeds showed a significant content of total phenolic compounds that were significantly different at $p \leq 0.05$ (Table 1). Total phenolic content in the algal crude extracts was effected by the algal species and various extraction processes. Data in table 1 indicated that, the pressurized hot water extract of *Cystoseira myrica* has the highest total phenolic content (1.61 mg GAE/g dry wt.), followed by the pressurized hot water extract of *Laurencia* sp. and boiling water extract of *Cystoseira myrica* (1.49 and 1.40 mg GAE/g dry wt., respectively), as compared with the other algae. The pressurized hot water extract has been largely used to extract comparatively polar bioactive molecules such as phenolic compounds [42]. Moreover, PHWE was considered as an effective process for extracting the phenolic compounds in comparison with the other applied extraction methods. In general, the crude extract of cold water from all algal species indicated the lowest total polyphenol content (Table 1). Various algal products provided varied total phenolic contents because of many influencing conditions, such as algal species and, geographical origin or the region of cultivation, environmental, physiological, and seasonal variations [43]. According to Chakraborty et al. [44] phenolic compounds can chelate the metal ions and inhibit the formation of free radical, thus improving the antioxidant intrinsic coordination. In this respect, phenols transfer hydrogen atoms to peroxyl in the lipid peroxidation cycle to form the aryloxyls that are unable to act as chain carriers for free radicals and therefore delaying the peroxidation process. Based on the research papers dealing with the phenolic contents in fresh algae, the obtained algal product results cannot be suitably compared because of the different extraction methods used; just for clarification, the ethanol extract of *Eisenia bicyclis* contained about 319 $mg.g^{-1}$ GAE [45], aqueous extract of *Porphyra tenera* 10.1 mg/g GAE [46], ethanol extract of *Palmaria palmata* 10.3 mg/g GAE [47], aqueous extract of *Undaria pinnatifida* contained 3.8 mg/g GAE [48], methanol-chloroform extract of *Laminaria japonica* 0.3 mg/g GAE [49] and aqueous extract of *Hizikia fusiformis* contained 4.1 mg/g GAE [48].

The content of flavonoids, ascorbic acid and α-tocopherol of the different algal species are presented in Fig. 2. Flavonoids content ranged between 2.21 mg/g dry wt. in *Laurencia* sp. (red algae) and 3.35 mg/g dry wt. in Cy*stoseira myrica* (brown algae). This variation in the content of flavonoid may be because of the difference in algal species and the variation in physicochemical factors such as salinity between the selected sites. Depending on the molecular structure of flavonoids, they showed a wide spectrum of biological and chemical activities including inhibitors of lipid peroxidation, antioxidants and as therapeutic agents for various diseases [50]. Flavonoid revealed anti-inflammatory, antiulcer and antihepatotoxic effects in addition protecting against cardiovascular mortality [51].

Table 1. Total phenolic contents (mg GAE/g dry wt.) of crude extract of marine algal species with various extraction processes.

Algal species	Different extraction processes			
	Pressurized hot water	Cold water	Boiling water	Ethyl alcohol
Laurencia sp.	1.49±0.00^{c}	0.97±0.02^{b}	1.11±0.07^{b}	0.92±0.01^{b}
Cystoseira myrica	1.61±0.03^{c}	0.90±0.04^{b}	1.40±0.07^{c}	1.06±0.02^{c}
Hydroclathrus clathratus	0.75±0.02^{a}	0.61±0.05^{a}	0.65±0.04^{a}	0.82±0.01^{a}
Padina pavonica	1.17±0.08^{b}	0.67±0.01^{a}	0.80±0.02^{a}	1.13±0.02^{d}

For each treatment the means within the column by different letters are significantly different at $P < 0.05$ Each value is expressed as the means ±SE (n=3).

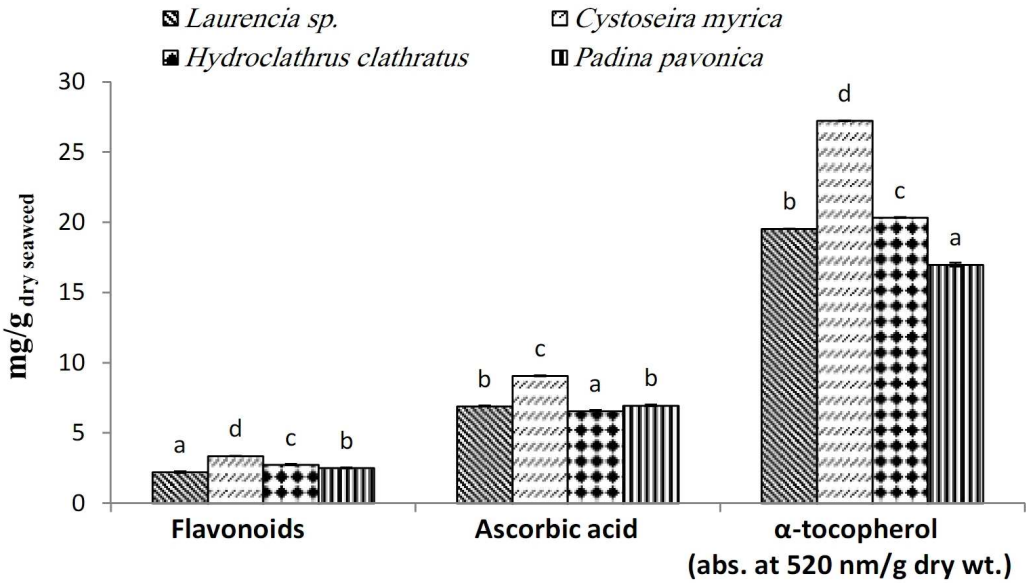

Figure 2. Flavonoids, ascorbic acid (mg/g dry wt.) and α-tocopherol (abs. at 520 nm/g dry wt.) of marine algal species.

Ascorbic acid was also significantly different between algal species at $p \leq 0.05$, whereas, it ranged between 6.57 mg/g dry wt. in *Hydroclathrus clathratus* and 9.07 mg/g dry wt. in *Cystoseira myrica* (Fig. 2). α-tocopherol content varied from 27.25± 0.00 (Cy*stoseira myrica*) to 16.99±0.14 (*Padina pavonica*) abs. at 520 nm/g dry wt. seaweed (Fig. 2). The α-tocopherol content in the Cy*stoseira myrica* extract was significantly different ($p < 0.05$) compared to those of the other algal species. Natural antioxidants such as polyphenols and vitamins in the higher plants were used to capture the reactive oxygen species that lead to lipid peroxidation. Thus, these compounds became used in the food industry to protect human body from the free radicals and prevent expansion of various chronic diseases. Several studies strongly suggested natural sources of polyphenols and vitamins to inhibit the free radical-damage that lead to aging progression and to prevent initiations of cancer [38, 52].

As a result of the variation of the oxidation methods, the use of one antioxidant process to assess the antioxidant capacity cannot reveal a clear view of their actual antioxidant activities. Thus, the antioxidant capacity of various algal extracts was estimated by two antioxidant methods: ferric reducing antioxidant power, and total antioxidant capacity.

The phosphomolybdenum assay has been used to assess the total antioxidant activity of the extracts [33]. In the presence of any antioxidants, Mo^{6+} is reduced to Mo^{5+} and forms a green color from phosphomolybdenum complex. The type and conditions through the extraction have a crucial effect on the total antioxidant potential, which is evident from Table 2. From these data, it was clear

that, the ethyl alcohol extract of *Cystoseira myrica* showed high antioxidant capacities (541.6 µg/g dry wt.) followed by an ethyl alcohol extract of *Hydroclathrus clathratus* and *Padina pavonica* (383.02 and 339.92 µg/g dry wt., respectively). On the other hand, the cold water extract of all tested algae showed absolutely the lowest values among all different extraction methods, followed by the boiling water extract.

The determination of reducing power of compounds may serve as an important indicator for their potential antioxidant capacity. In the ferric reducing antioxidant power method, the antioxidants reduce Fe^{3+}-ferricyanide complex to its Fe^{2+} form. Thus, Fe^{2+} can be checked by determining the formation of Perl's Prussian blue. The ethyl alcohol extract from *Cystoseira myrica* followed by *Hydroclathrus clathratus* achieved the most powerful reducing capacity among all of the different extracts of algal species (Table 3). In contrast, the cold water extract showed the lowest activity for all algal species except in the case of *Laurencia* sp. These results showed that the ethyl alcohol extract may contain most of the antioxidative substances in these algae.

Statistical evaluation by Spearman correlation between the total antioxidant capacity assay and the total phenolic contents was found to be significant ($r = 0.60$, $p = 0.014$). On the other hand, nonsignificant correlation was found between ferric reducing antioxidant power assay and the total phenolic contents ($r = 0.23$, $p = 0.39$). This shows that phenolic compounds might be a major contributor to the antioxidant abilities for either of these macroalgae. A high correlation between the total phenolic content and antioxidant capacity has been described by several authors [13]. However, other reports showed that this correlation doesn't occur and it was concluded that the phenolic compounds are not responsible for the antioxidant capacity [53]. Although phenolic compounds are found to be the most important contributor to the antioxidant capacities in various higher-order species as plants, this might hold real for macroalgae. Dixon and Palva [54] revealed that the antioxidants such as phenolic compounds are in plants part of a complex defense mechanism against a broad range of stresses, and therefore accumulate as a result to these stresses. The macroalgae in this investigation might not have been exposed to stresses, causing less phenolic compounds to be formed, as compared to the plants.

Table 2. Total antioxidants (µg/g dry wt.) of crude extract of marine algal species with various extraction processes.

Algal species	Different extraction processes			
	Pressurized hot water	Cold water	Boiling water	Ethyl alcohol
Laurencia sp.	335.3±8.5^{d}	167.4±3.7^{c}	229.7±2.8^{d}	338.2±2.6^{a}
Cystoseira myrica	212.9±8.4^{c}	111.9±2.5^{b}	159.1±1.2^{c}	541.6±38.7^{b}
Hydroclathrus clathratus	139.9±3.6^{a}	73.1±2.3^{a}	88.3±0.2^{a}	383.1±10.7^{a}
Padina pavonica	170.1±0.7^{b}	69.4±0.8^{a}	98.3±1.1^{b}	339.9±12.5^{a}

For each treatment the means within the column by different letters are significantly different at $P < 0.05$ Each value is expressed as the means ±SE (n=3).

Table 3. Reducing power (µg /g dry wt.) of crude extract of marine algal species with various extraction processes.

Algal species	Different extraction processes			
	Pressurized hot water	Cold water	Boiling water	Ethyl alcohol
Laurencia sp.	185.8±1.7^{a}	501.5±9.8^{b}	116.6±0.7^{a}	629.2±6.0^{a}
Cystoseira myrica	1181.4±16.4^{c}	688.5±22.7^{c}	803.6±10.7^{d}	3208.3±135.8^{c}
Hydroclathrus clathratus	245.2±5.6^{b}	225.9±22.6^{a}	526.7±14.1^{c}	1194.9±162.9^{b}
Padina pavonica	264.9±3.5^{b}	231.4±6.7^{a}	428.8±13.0^{b}	886.1±54^{ab}

For each treatment the means within the column by different letters are significantly different at $P < 0.05$ Each value is expressed as the means ±SE (n=3).

Seaweeds are rich in macroelements with some content in trace elements. The macroelements such as Na, Ca, K and Mg are among the elements which are found in significant quantities in seaweeds [55]. The composition of elements of the four studied species was evaluated and is shown in Fig. 3. The most important macro-elements found in the studied seaweeds were K, Na and Ca, representing that the seaweeds are a good source of these elements. Phosphorous was present in a slightly fairly constant value (between 1.771 and 2.791 mg/g dry seaweed) among all studied seaweeds, but of a much lower order of magnitude than the three other minerals that previously mentioned (Fig. 3). In what concerns the distribution of mineral per species, the differences were detected between all algal species. For instance, potassium was the most dominant element present in all the four studied species with amounts ranging from 21.00 mg/g dry seaweed in *Cystoseira myrica* to 34.45 mg/g dry seaweed in *Laurencia* sp. being statistically different ($p < 0.05$) among all the four studied species (Fig. 3). Potassium, the macro element preserves the ionic exchange, osmotic gradients and normal neural functions. Potassium is a very significant element for the appropriate function of all cells, tissues, and organs in the human body. It has a significant role in regulation of water balance of the body [56].

Slight variations were detected among the four studied species for total nitrogen (Fig. 3). *Laurencia* sp. and *Hydroclathrus clathratus* tended to indicate higher amounts of nitrogen (2.93 and 2.02 mg/g, respectively), while *Cystoseira myrica* showed lower values (1.6 mg/g) followed by *Padina pavonica* (0.933 mg/g). The nitrogen contents varied maybe due to the algal species, site, season and environment [57]. Sodium content also varied significantly between the different algal species. The high value of sodium was recorded by *Hydroclathrus clathratus* (24.81 mg/g dry seaweed) (Fig. 3).

Calcium was the most significant element that accumulated in the seaweeds at much higher content than in the terrestrial food stuffs [58]. Calcium values ranged from 5.9 mg/g dry seaweed in *Laurencia* sp. to 18.18 mg/g dry seaweed in *Padina pavonica* (Fig. 3). The content of seaweeds mineral differs according to species, seasons, wave exposure, physiological and environmental conditions, type of processing and method of mineralization [59]. Exogenous and endogenous factors have contributed to the variability of the composition of seaweeds mineral. The variations in mineral in seaweed tissues were detected also with the same seaweed species influenced by the stage of the living cycle and the age of seaweed [60].

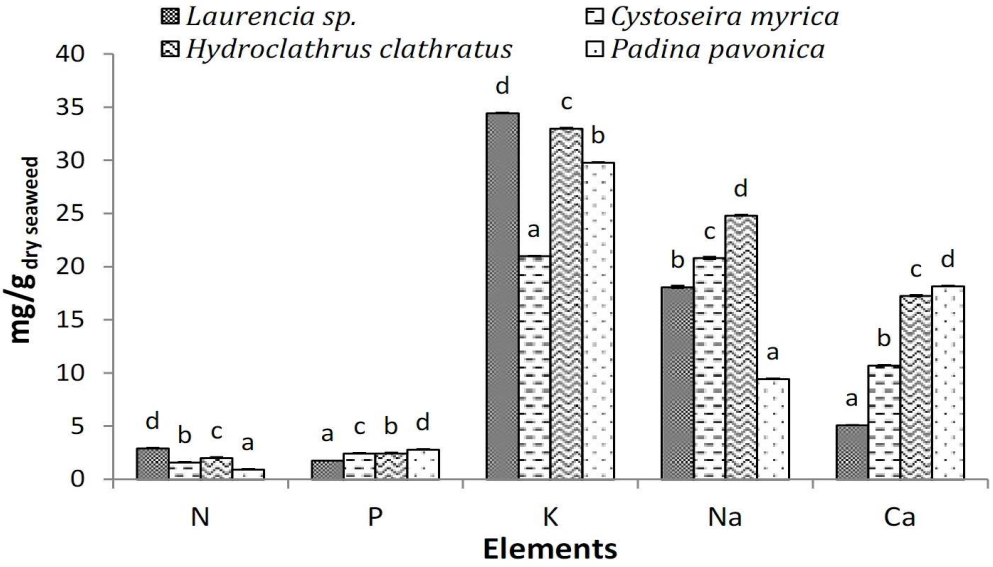

Figure 3. Elemental composition of marine algal species. For each treatment the means within the column by different letters are significantly different at $P < 0.05$. Each value is expressed as the means ±SE (n=3).

4. CONCLUSION

Seaweeds: *Laurencia* sp., *Cystoseira myrica*, *Hydroclathrus clathratus* and *Padina pavonica*, have high contents of proteins, carbohydrates, vitamins and minerals suggesting a promising role in pharmaceutical and nutritional applications. Moreover, these seaweeds offer new potential sources of bioactive compounds such as flavonoids, phenols, α-tocopherol and ascorbic acid. These compounds showed a high antioxidant capacities with wide nutraceutical, pharmaceutical, biomedical and prospected applications. Thus, intensive future studies should be made to develop these naturally economical resources.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

RME-S and MAF: designed research, analyzed the data, wrote and revised the manuscript, performed the extraction methods of compounds from seaweeds and determined the different parameters, carried out the research point by point. MAF: collected and identified the seaweeds. Both authors read and approved the final manuscript.

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