



Nutritional values of some Seaweeds from Iraqi coast of North – West Arabian Gulf

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Abstract

In this study, 6 taxa from the *Chlorophyta*, *Phaeophyta* and *Rhodophyta* collected from different stations at north – west of Arabian Gulf, Iraqi coast. A total of 120 samples from these seaweeds were used to measure the proteins, carbohydrates, lipids, vitamins, chlorophylls, total phenols and total carotenoids. In addition to lipid-soluble and water-soluble antioxidant. The red seaweeds *B.fuscopurpura* and *E.carnea* were showed high moisture content (85 % and 87 %), low ash (18.88 % and 20.45 %), low carbohydrate (22.12% and 20.22%), low lipids (2.55% and 2.48%) and low vitamins E and C. *E.carnea*, showed the lowest pigments contents as well as phenolic content (2.5 ppm), lipid-soluble antioxidant (78.34 μM BHT/g) and total antioxidant capacities (33.5 μM AAE/g). While *E. carnea* contained more protein (7.26%) than the other studied seaweeds. The highest ash contains (31.1%), vitamin E (20.12 IU) and phenolic content were recorded in the green seaweed *E. Compressa*, while Highest carbohydrate (38.77%), vitamin C (4.92 IU) and water soluble (52.12 μM AAE/g) were recorded by the brown seaweed *G. mitchellae*. The green seaweed *C.glumerata* showed highest lipid contents (7.63%), chlorophyll a (0.721 mg/g), lipid soluble (1.25.66 μM AAE/g) and total antioxidant capacities (77.8 μM AAE/g), in the same time the highest carotenoides contents were found in the brown seaweed *E. cofervoidex*. There are no previous records on the chemical composition or nutritional values of Iraqi seaweeds so far, so this research focused on this side for the first time and open opportunities for further investigations of other seaweeds to evaluate their consumption as nutritional valuable food and medicinal products.

Introduction

Seaweeds are important sources of macronutrients such as protein, fibre, carbohydrates, lipids, minerals and vitamins, beside that they are important bioactive compounds [1,2]. Seaweeds have been showed as being important for human and animal health [3]. Seaweed is use as humane food in most Asian countries especially

Japan. Approximately 25% of all food consumed as sushi wrappings, seasonings, condiments and vegetables and has considered a main income source for the fisherman [4]. Seaweeds are also sources of thickening and gelling agents for various food and pharmaceutical industries. Seaweeds are also used in animal feed, cosmetics, medicine and fertilizers [5,6]. 221 seaweed species are being used throughout the world [7] 66% of them are used for food in far East. In Western countries the consumption of seaweed are increasing, approximately 15- 20 of the seaweeds are being marketed for consumption. Many workers were studied the biochemical and nutritional composition of various seaweeds from different parts of the world such as [5,6,8,9,10,11,12,13,14,15].

FAO has announced that the annual global aquaculture production of marine algae is around 6.5×10^6 tons [3]. Microalgae culture has been replaced by macroalgae as food for fish larvae. In Iraq, seaweeds are not cultured for nutrition, and commercial harvesting or as animal foods. However, no published report on the chemical composition of the seaweeds in Iraq has been made. As the chemical compositions of seaweeds showed different respond to different geological and environmental factors [7], so it is important to investigate on nutrient composition of some seaweeds of the Iraqi coast of Arabian Gulf to evaluate them to be used as highly nutritious food sources for human, animal and medical applications.

Material and Method

Algal samples preparation

Six seaweeds species (2 *Chlorophyta*, (2) *Phaeophyta* and (2) *Rhodophyta* were collected from six stations along the coastal area of north-west Arabian Gulf, Iraqi side Map 1. The species collected are: *Chladophora glomerata*(L.) Kg., *Enteromorpha clatherata*(L.) Kg., *Ectocarpus cofrcoidex* (Roth) Leyotis., *Griffordia mitchellae*(Harv.) Hamel., *Bangia fuscopurpurea* (Dillw.) Lyngbye., and *Erythrotrichia carnea* (Dillw.) J.Ag. After collection, the seaweeds samples were cleaned with seawater to remove epiphytes and transported directly to the laboratory in an ice cooler box to maintain low temperature and moisture. The samples were identified, clean with distilled water and dried to remove excess water. The moisture and ash of the fresh samples were dried in the oven at 40 °c. The dried samples were grounded into fine powder for(5 min.) reaching a constant weight before being stored in a freezer at -20°C for further analysis.

Biochemical composition

Seaweeds total protein was determined by the Lowry method [16] described by Ozyilmaz. The total carbohydrate was measured as mg g-1dw. by the Phenol-Sulphuric acid method described by [17] using extraction with hot ethanol [18]. Total phenolic was determined by the Folin-Clocalteu method. Pigments extraction was extracted in methanol, at 4°C, for 20 h. Chlorophyll *a*, *b* and total carotenoid were determinate as described by Durmaz [19]. lipid was measured according to Kumari[20]. Vitamine E was calculated by the method described by Celikler [21]. Vitamin C was extracted with 10% trichloro acetic acid and measured according to Sauer *et al*[22].

The lipid and water-soluble were extracted as described by Celickler [21]. [23] procedure were used to extract lipid – soluble antioxidant, which expressed as standard butyl hydroxyl toluene equivalents (BHT), while the water-soluble antioxidant of the seaweeds samples were measured by using phosphor molybdenum reagent. The

antioxidant activity is expressed as L-ascorbic acid equivalents (AAE) [23]. Total antioxidant was measured by extraction with methanol using molybdenum reagent and expressed as L-ascorbic acid equivalents (AAE) [23].

Statistical analysis

The data are recorded as mean \pm standard deviation (SD). Correlation and regression analysis were carried using Microsoft Excel 2003 to analyze significant relationship between the biochemical compositions. According to Mahmoud *et al*, 2009 the *P*-Values < 0.05 were considered statistically significant.

Results and discussion

Moisture and ash contents of different seaweeds samples are shown in Table 1 and illustrated in Fig1. The moisture content ranged from 80.3 % in the green algae *C.glumerata* to 87.1 % in the red algae *E.carnea*. Ash contents percentage were different in different seaweeds species (Table 1). The highest ash contents of 35.1% and 32.2 % were recorded in the green algae *E.compressa* and *C.glumerata* respectively, while the lowest ash contents were recorded in the red algae *B.fuscopurpurea*.

[24] were reported 88.5% moisture contents in the brown algae *Colpominea sinuosa* from Iran. In the present work moisture contents ranging from 81.8 to 83.8 % in the brown algae *E.confervoides* and *G.mitchellae* which is lower than the amount recorded by these workers for other brown algae. [25] had recorded moisture content up to 91.53 % in his study on the green alga *Caulerpa racemosa*, from India, compared with 80.2 to 82.8% in the present study. [26] explained the high level of ash contains in the marine algae to the presence of inorganic compounds especially mineral elements such as Ca, Mg, P, Na, and K or trace elements such as Zn, I and Mn. [27] showed that the cell wall of marine macroalgae composes of polysaccharides and proteins containing anionic carboxyl, sulfate, and phosphate groups which are regarded as available binding sites for metal. Ash content was in the range of 28.1 - 39.28 % in *C.sinuosa* from Iran [24]. In *P. pavonia* the ash contents was 33.08 % [27]. Ash content of the studied seaweeds (18.88-35.1%) was found higher than *C. racemosa* from India with 15.51% [9] and less than what was found by Renaud and [5], for *C. racemosa* from Australia which was in the range of (42.2 – 47.0 %). [28] explained The differences in ash content by the types of processing and mineralization methods as well as to species differences because of geographical locations, and environmental conditions.

Table 1 represented the carbohydrates contents of the selected seaweeds studied and are illustrated in Fig1. A wide range in carbohydrate contents was observed (20.22 – 38.77 %) with the highest values recorded in the brown algae *G.mitchella* and the lowest in the green algae *E.carnea*

(Fig.1). The carbohydrate levels in this study are higher than those reported by Shams El Din and [29] for Egypt, recording 6.93 %; [32] for *C. racemosa* of India (9.4 %) and for *C. racemosa* from Australia (14.7 to 16.6 %) [5]. The carbohydrate contents of *C. racemosa* were found to be 41 % by [6] and 48.95 % by [27], which is relatively in the range of this study for the brown algae.

Lipid contents are presented in Table 1 and shown in Fig.1. In the present study, the highest values were found in the green algae *C.glumera* with 7.63 % which is in the range for *Laurencia pipillosa* (6.73%) from Egypt [30] and the lowest value were in the red algae *E.carnea* (2.48 %). [8] found that the lipid content of the red alga *P. capillacea* from

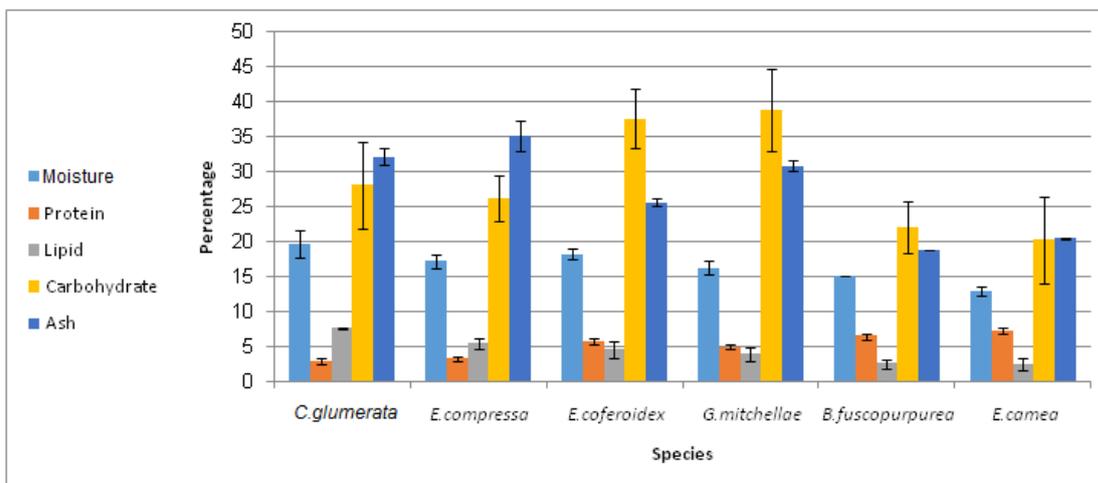


Fig.1 : Moisture, Ash, Carbohydrate, Lipids and protein of the studied seaweeds

Egypt were in the range of 1.76 - 2.71 % which is in agreement with the values for the red algae in this study and higher than the amount given by Shams El Din and [8] for *C.simosa*. Nirmal Kumar [27] recorded lipid contents in the range of 2-15% for Phaeophyta followed by 0.8-3-5% for chlorophyta and 0.45-0.85% for Rhodophyta which is in disagreement with the present study.

Protein contents of the studied algae are shown in Table (1) and illustrated in Fig. 1. The protein contents ranged from 2.8 % in the green algae *C.glumerata* to 7.26 % in the red algae *E.glumerata* (Fig.1).. protein content of *P. pavonia* were studied by some workers from different places as Red sea of Egypt [8] who recorded a value of (8.35%) and Iranian side of Arabian Gulf (11.83 %) [28], from India by Manivannan [31] who recorded (13.63) while a values of 35.4 % was recorded in *P. pavonia* from northeastern Mediterranean Coast of Egypt (Polat and Ozogul, 2009), (14.37 - 23.72 %) for *P.capillacea* from Alexandria Coast [9], and (24.8 %) for *C.racemosa* from India [32]. The protein contents showed different values with different species and groups of macroalgae. According to the work of [33] , the seaweeds were rich in protein in the order of Rhodophyta>Chlorophyta>Phaeophyta , while the order of protein richness in the present study showed the following pattern Rhodophyta> Phaeophyta> Chlorophyta.

Seaweeds are rich in vitamins such as vitamins A, B1, B12, C, D, and E, riboflavin, niacin, pantothenic acid, and folic acid. Their amounts varies according to seasons and environmental conditions [34]. As shown in Fig2, vitamin E content of *E.compressa* (20.02µM/g) was the highest among the studies algae and higher than values given by Santos *et al.*, (2015) for the green alga *Codium tomentosum* (0.051µM/g) from Portuguese Coast. Vitamin C contents were in the range of 1.77µM/g for the red alga *E.carnea* and 4.92µM/g for brown alga . *G.mitchellae*. Chakraborty and Bhattacharya (2012) recorded vitamin C value of 1.70µM/g for *C. racemosa* which is in agreement with this study for red algae and lower than vitamin C level in the brown algae (Table.1).

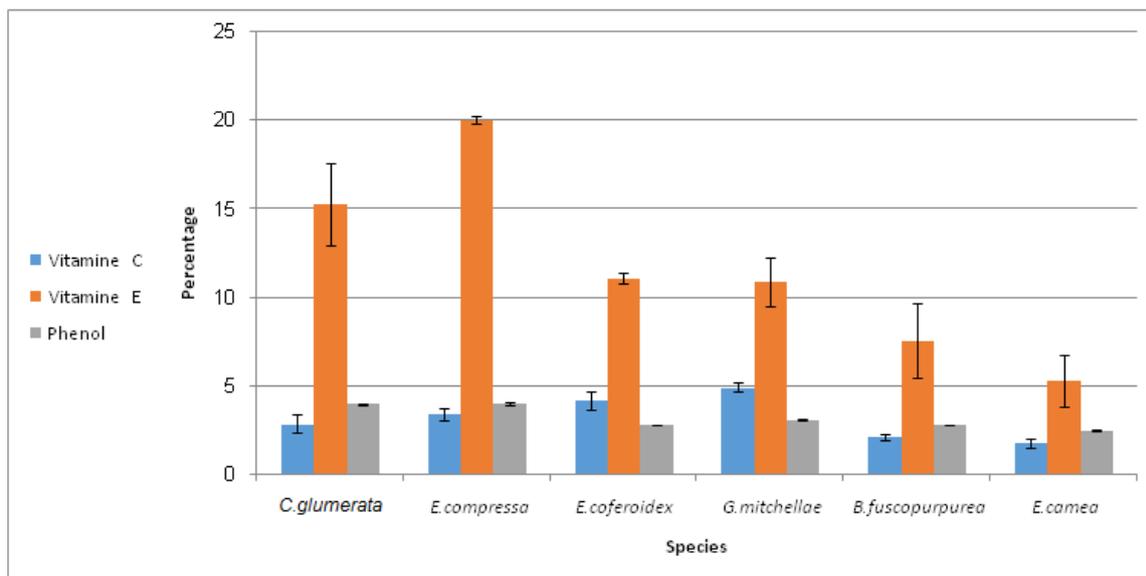


Fig.2 : Vitamin C , vitamin E and phenol of the studied seaweeds

Phenolic compounds is one of the stress compounds that inter in protective mechanisms of biotic and abiotic factors and antioxidant to delay peroxidation by transfer a hydrogen atom to lipid peroxy cycle [11]. The phenolic contents of the studied algae varied among the algal groups, the highest values were recorded in green algae (4.0 and 4.2 mg GAE/g), and the lowest values in the brown algae *E.camea* (2.5 mg GAE/g) (Fig.2). These results are in agreement with the study of [19] for *C. sinuosa* from Turkey, which showed phenolic content of 3.4 mg GAE/g, however it is higher than what was observed for the brown alga

Sargassum muticum (0.499 mg) by Rodrigues. [35] Martins reported higher Phenolic values of 85.30, and 18.80 mg GAE/g for *C. sinuosa* and *P. capillacea*, respectively from Brazilian Coast. Khairy and El-Sheikh, recorded 7.5 mg GAE/ g of phenolic contents in the red alga *P. capillacea* from Alexandria which is three times the amount of this study. Phenolic contents of 61.69 mg PGE/g were recorded by Kumar for *C. racemosa* from India, while 19.8 mg GAE/g were reported for *C. racemosa* from Malaysia [10] which are regarded higher than the present study values (Table 1).

The pigments contents are shown in Table 1, Fig3. The chlorophyll a contents ranged from 0.222 to 0.721 mg/g dry weight and chlorophyll b from 0.037 to 0.194 mg/g . Total carotenoids varied between 1.332 to 5.711 mg/g . The highest chlorophyll a and chlorophyll b contents were found in the green alga *C. glomerata* (Table1), while the highest carotenoids were found in the brown alga *E.covervoides*. Carotenoids have been reported as effective antioxidants in a number of ways. [36,24]Shams El Din and El-Sherif had reported chlorophyll a (0.487mg/g) for *C.racemosa* from Egypt. Indian *C. racemosa* showed values of 2.50 mg/g for chlorophyll a, 0.73 mg/g for chlorophyll b, and 0.017 mg/g for carotenoids[33].

Ragonese *et al.*(2014) recorded high carotenoids contents of 121.4 mg/g and 60.9 mg/g in *P. sinuosa* (12.1 mg/g) from Iranian side of the Arabian Gulf than test algae.

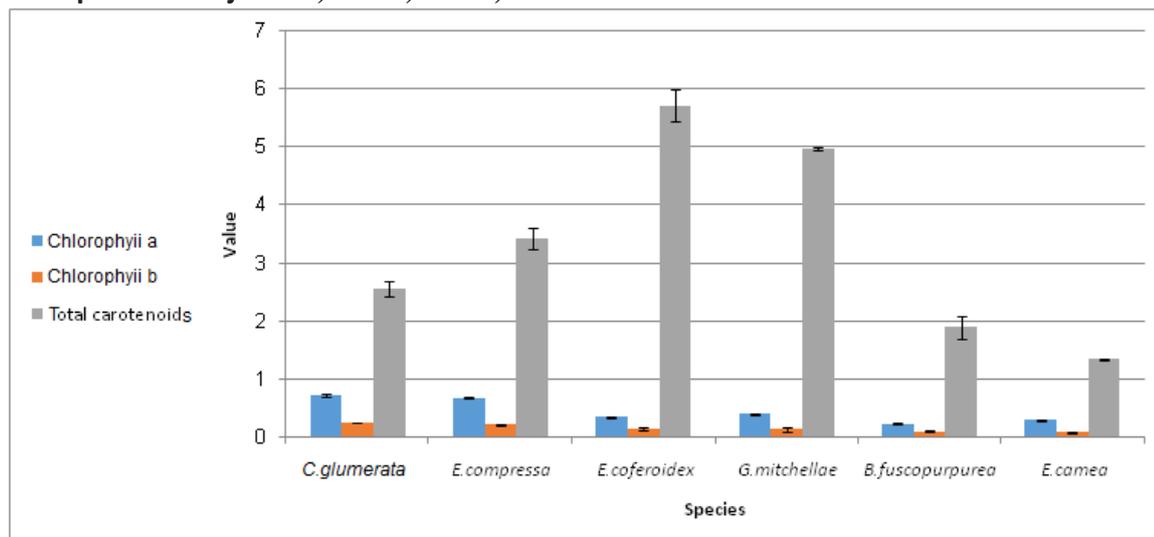


Fig.3 : Chlorophyll a , chlorophyll b and total carotenoids

Antioxidants are compounds used as protectors against oxidation in food and cosmetics and they have potential to counteract several diseases[4]. powerful antioxidants are many, such as Proteins, chlorophyll derivatives, carotenoids, nitrogen-containing compounds, vitamin E, phenolic compounds, vitamin C, glutathione, uric acid, and sulfated polysaccharides [16]. Table 1, Fig 4 showed the antioxidant capacity of the studied algae. As indicated from the results, the lipid-soluble compounds showed higher antioxidant capacity (78.34 - 120.66 $\mu\text{M/g}$) than that of the water-soluble ranging between 23.38-52.02 $\mu\text{M/g}$.

The antioxidant capacity of *C. glumerata* with high Lipid-soluble and low water-soluble (Table1) may be related to the high lipid content [22]. Same finding was recorded for *Sargassum vulgare* from Lebanese Coast [22].The brown alga *G. mitchellae* exhibited relatively low antioxidant activity for lipid-soluble extract while showed the high activity (52.02 $\mu\text{M/g}$) for water-soluble compounds. These findings could be explained by the existence of quantity of water-soluble constituents such as sugars, glycosides, phenolics and tannins in the seaweed [15]. The water-soluble showed no correlation with Total oxidant ($r^2=0.17$).

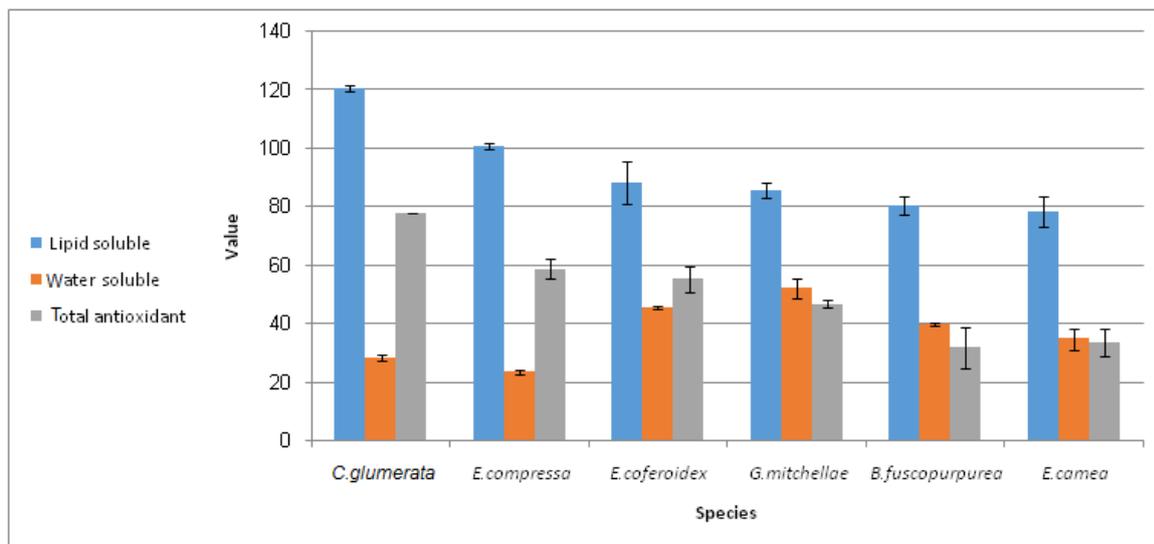


Fig.4: Lipid soluble , water soluble and total antioxidant of the studied seaweeds.

The marine seaweeds are surrounded by a lot of stress factors such as high irradiance, temperature, and salinity which encourage them to produce antioxidants to resist these factors [11]. The total antioxidant activity found in this study, ranged between (31.7 μ M AAE/g and 77.8 μ M AAE/g) (Table 1, Fig4). The green alga *C. glumerata* showed highest total antioxidant value while the red alga *B. fuscopurpurea* showed the lowest one. [21] indicated that the total antioxidant of the different species of *Caulerpa* was between 2.38 and 4.20 which is very low comparing with this study. On the other hand Ganesan indicated wide range of total antioxidant (1.76-181.75 μ M AAE/g) found in the red algae *Euchema kappaphycus*, *Gracilaria edulis* and *Acanthophora spicifera* compared with the present results of the red algae. There is a good correlation between the total antioxidant of the studied seaweeds and the phenolic contents ($r^2 = 0.679$) (Table 2). Similar findings were recorded for the brown algae *Stypocaulon scoparium* [37], *Sargassum pallidum* [38], *P. Pavonia* [22], and red alga *Rhodomela confervoides* [39]. Different findings were recorded by [40] for the brown algae; *Sargassum siliquastrum*, *Sargassum vulgare* and Pangestuti and [41] for the green algae; *Enteromorpha prolifera*, *Enteromorpha intestinalis*, *Cladophora vagabunda*. It has been proved by many workers that there are many constituents, which may affect the antioxidant capacity like chlorophyll a, carotenoids, flavonoids and Lipids [41,40]. The strong positive correlation ($r^2 = 0.90$) obtained between total antioxidant capacity and lipid content agreed with the finding of Khaled [42] for *S. vulgare* extract. [36] proved that lipid-soluble compounds are the most antioxidant material recorded and the water-soluble antioxidants assist their lipid-soluble. Chlorophyll a besides phenolic compounds were showed as a strong antioxidant in the green alga, *E. prolifera* [42], which is in agreement with the results obtained in this study. The correlation between total antioxidant activity and chlorophyll a ($r^2=0.79$), and chlorophyll b ($r^2=0.92$), were significant, while total carotenoids showed no correlation with total antioxidant ($r^2=0.09$) (Table 2).

Table. 1: Biochemical composition of the studied seaweed

<i>E.carnea</i>	<i>B.fuscopurpurea</i>	<i>G.mitchellae</i>	<i>E.coferoidex</i>	<i>E.compressa</i>	<i>C.glumerata</i>	
87.1±0.67	85.0±0.01	83.8±0.97	81.8±0.82	82.8±0.99	80.3±1.92	Moisture %
20.45±0.04	18.88±0.01	30.8±0.76	25.6±0.51	35.1±2.21	32.2±1.2	Ash%
20.22±6.11	22.12±3.66	38.77±5.87	37.6±4.28	26.22±3.32	28.12±6.18	Carbohydrate %
2.48±0.78	2.55±0.66	3.89±0.99	4.51±1.22	5.45±0.79	7.63±0.08	Lipid %
2.5±0.01	6.45±0.44	4.88±0.33	5.76±0.43	3.22±0.33	2.81±0.42	Protein %
7.26±0.41	2.8±0.01	3.1±0.02	2.8±0.01	4.02±0.06	4.0±0.05	Phenol (ppm)
1.77±0.29	2.11±0.17	4.92±0.26	4.22±0.52	3.44±0.34	2.87±0.52	Vitamine C (IU)
5.29±1.43	7.58±2.12	10.88±1.41	11.12±0.31	20.02±0.19	2.87±0.52	Vitamine E (IU)
0.277 ± 0.02	0.222 ± 0.01	0.382 ± 0.01	0.333 ± 0.01	0.671 ± 0.01	0.721 ± 0.03	Chlorophyll a (mg/g)
0.079 ± 0.01	0.088 ± 0.01	0.119 ± 0.03	0.136 ± 0.02	0.198 ± 0.02	0.24 ± 0.01	Chlorophyll b (mg/g)
1.332 ± 0.02	1.882 ± 0.19	4.971 ± 0.03	5.711 ± 0.27	3.422 ± 0.19	2.55 ± 0.13	Total carotenoid (mg/g)
78.34 ± 5.22	80.67 ± 3.13	85.59 ± 2.63	88.18 ± 7.25	100.75 ± 1.23	120.66 ± 0.91	Lipid soluble (µMAAE/g)
34.82 ± 3.66	39.82 ± 0.67	52.02 ± 3.45	45.51 ± 0.53	23.38 ± 0.77	28.44 ± 0.94	Water soluble (µMAAE/g)
33.5 ± 4.9	31.7 ± 7.0	46.6 ± 1.3	55.2 ± 4.2	58.7 ± 3.4	77.8 ± 0.2	Total antioxidant (µMBHT/g)

Table. 2: The relations between Chlorophyll a, Chlorophyll b, Total carotenoids, Lipid soluble, Water soluble and Phenolic contents with Total antioxidant components of the studied seaweeds.

Linear equations R ²	Variances
Ch1a = 0.0108(TA) - 0.1135 R ² = 0.7918	Chlorophyll a and Total antioxidant (TA)
0Ch1b = 0.0035(TA) - 0.0357 R ² = 0.9264	Chlorophyll b and Total antioxidant (TA)
TC = 0.0305(TA) + 1.7707 R ² = 0.0919	Total carotenoid (TC) and Total antioxidant (TA)
LS = 0.8754(TA) + 48.086 R ² = 0.9019	Lipid soluble (LS) and Total antioxidant (TA)
WS = -0.2547(TA) + 50.215 R ² = 0.1702	water soluble (Ws) and Total antioxidant (TA)
P = 0.0312(TA) + 1.6273 R ² = 0.6793	Phenol (P) and Total antioxidant (TA)

Map 1: Sampling stations of the studied area.



References

- [1] Ortiz, J., Romero, N., Robert, P., Araya, J., Lopez-Hernández, J., Bozzo, C. E., Navarrete, C. E., Osorio, A., and Rios, A. Dietary fiber, amino acid, fatty acid and tocopherol contents of the edible seaweeds *Ulva lactuca* and *Durvillaea antarctica*. *Food Chemistry*, 99: 98-104, 2006.
- [2] Yaich, H., Garna, H., Bchir, B., Besbes, S., Paquot, M., Richel, A., and Attia, H. Chemical composition and functional properties of dietary fibre extracted by Englyst and Prosky methods from the alga *Ulva lactuca* collected in Tunisia. *Algal Research*, 9:, 65-73, 2015.
- [3] Frings, C.S., Fendly, T.W., Dunn, R.T. and Queen, C.A. Improved determination of total serum lipids by the sulfo-phospho-vanillin reaction. *Clinical Chemistry*, 18: 673-674, 1972.
- [4] Balboa, E.M., Conde, E., Moure, A., Falque, E. and Dominguez, H. *In vitro* antioxidant properties of crude extracts and compounds from brown algae. *Food Chemistry*, 138: 1764-1785, 2013.
- [4] Anantharaman, P., Parthiban, C., Saranya, C., Girija, K., Hemalatha, A., and Suresh, M. Biochemical composition of some selected seaweeds from Tuticorin coast. *Advances in Applied Science Research*, 4(3):362-366, 2013
- [5] Lordan, S., Ross, R. P., and Stanton, C. Marine bioactives as functional food ingredients: Potential to Reduce the Incidence of Chronic Diseases. *Marine Drugs*, 9: 1056-1100, 2011.
- [7] Renaud, S.M. and Luong-Van, J.T. Seasonal variation in the chemical composition of tropical Australian marine macroalgae. *Journal of Applied Phycology*, 18: 381-387, 2006.
- [8] Gressler, V., Yokoya, N.S., Fujii, M.T., Colepicolo, P., Mancini Filho, J., Torres, R.P. and Pinto, E. Lipid, Fatty Acid, Protein, Amino Acid and Ash Contents in Four Brazilian Red Algae Species. *Food Chemistry*, 12:, 585-59, 2010.

- [9] **Rahul, M., Suresh, N. and Anil, T.** Evaluation of physicochemical properties of seaweed, *Caulerpa racemosa*. Int. J. Res. Ayurveda Pharm., 5: 540-546, 2014.
- [10] **Chia, Y.Y., Kanthimathi, M.S., Khoo, K.S., Rajarajeswaran, J., Cheng, H.M. and Yap, W.S.** Antioxidant and cytotoxic activities of three species of tropical seaweeds, 2015.
- [8] **Khairy, H.M. and El-Shafay, S.M.** Biochemical composition of some common seaweed species from the coast of Abu Qir Bay, Alexandria, Egypt. Oceanologia, 55: 435-452, 2013.
- [11] **Khairy, H.M. and El-Sheikh, M.A.** Antioxidant activity and mineral composition of three Mediterranean common seaweeds from Abu-Qir Bay, Egypt. Saudi Journal of Biological Sciences, 22: 623-630, 2015.
- [12] **Ragonese, C., Tedone, L., Beccaria, M., Torre, G., Cichello, F., Cacciola, F., Dugo, P. and Mondello, L.** Characterisation of lipid fraction of marine macroalgae by means of chromatography techniques coupled to mass spectrometry. Food Chemistry, 145: 932-940, 2014.
- [13] **Santos, S.A.O., Vilella, C., Freire, C.S.R., Abreu, M.H., Rocha, S.M. and Silvestre, A.J.D.** Chlorophyta and rhodophyta macroalgae: a source of health promoting phytochemicals. Food Chemistry, 183: 122-128, 2015.
- [14] **Mahmoud, M.G., Tadros, A.B., Goma, R.H. and Moawad, M.N.** Some physicochemical investigations on water resources used in feeding ponds of El-Max fish farm, Egypt. World Journal of Fish and Marine Sciences, 1: 230-238, 2009.
- [16] **Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J.** Protein measurement with the folin phenol reagent. J. Biol. Chem., 193: 265-275, 1951.
- [17] **DuBois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F.** Colorimetric method for determination of sugars and related substances. Analytical Chemistry, 28, 350-356, 1956.
- [18] **Nielsen, S.S.** Food analysis. Food Science Texts Series, Springer Science dia, LLC, 2010.
- [19] **Demirel, Z., Yilmaz-Koz, F.F., Karabay-Yavasoglu, U.N., Ozdemir, G. and Sukatar, A.** Antimicrobial and antioxidant activity of brown algae from the Aegean Sea. J. Serb. Chem. Soc, 74: 619-628, 2009.
- [20] **Kumar, M., Gupta, V., Kumari, P., Reddy, C.R.K. and Jha, B.** Assessment of nutrient composition and antioxidant potential of Caulerpaceae seaweeds. Journal of Food Composition and Analysis, 24: 270-278, 2011.
- [21] **Celikler, S., Vatan, O., Yildiz, G. and Bilaloglu, R.** Evolution of anti-oxidative, genotoxic and antigenotoxic potency of *Codium tamentosum* Stackhouse ethanolic extract in human lymphocytes *in vitro*. Food and Chemical Toxicology, 47: 796-801, 2009.
- [22] **Sauer, M., Branduardi, P., Valli, M. & Porro, D.** Production of L-Ascorbic acid by metabolically engineered *Saccharomyces cerevisiae* and *Zygosaccharomyces bailii*. Appl. Environ. Microbiol., 70: 6086-6091, 2004.
- [23] **Prieto, P., Pineda, M. and Aguilar, M.** Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. Analytical Biochemistry, 269: 337-341, 1999.
- [24] **Rohani-Ghadikolaei, K., Abdulalian, E. and Ng, W.** Evaluation of the proximate, fatty acid and mineral composition of representative green, brown and red seaweeds from the Persian Gulf of Iran as potential food and feed resources. J. Food Sci. Technol., 49: 774-780, 2012.

- [25] **Kumari, P., Reddy, C.R.K. and Jha, B.** Comparative evaluation and selection of a method for lipid and fatty acid extraction from macroalgae. *Analytical Biotechnology*, 415: 134-144, 2011.
- [26] **Rodrigues, D., Freitas, A.C., Pereira, L., Rocha-Santos, T.A.P., Vasconcelos, M.W., Roriz, M., Rodriguez-Alcala, L.M., Gomes, A.M.P. and Duarte, A.C.** Chemical composition of red, brown and green macroalgae from Buarcos Bay in Central West Coast of Portugal. *Food Chemistry*, 183: 197-207, 2015.
- [27] Tabarsa, M., Rezaei, M., Ramezanpour, Z., Waaland, J.R. and Rabiei, R, (2012) . Fatty acids, amino acids, mineral contents, and proximate composition of some brown seaweeds. *J. Phycol.*, 48: 285-292.
- [29] **El-Shafay, S.M.** Biochemical composition of some seaweed from Hurghada coastal along Red Sea coastal, Egypt. *International Journal of Basic and Applied Sciences*, 14: 29-35, 2014.
- [30] **Polat, S. and Ozogul, Y.** Fatty acid, mineral and proximate composition of some seaweeds from the northeastern Mediterranean coast. *Italian Journal of Food Science*, 21, 317-324, 2009.
- [31] **Manivannan, K., Thirumaran, G., Devi, G.K., Anantharaman, P. and Balasubramanian, T.** Proximate composition of different group of seaweeds from Vedalai coastal waters (Gulf of Mannar): southeast coast of India. *Middle-East Journal of Scientific Research*, 4: 72-77, 2009.
- [32] **Chakraborty, S. and Bhattacharya, T.** Nutrient composition of marine benthic algae found in the Gulf of Kutch coastline, Gujarat. India. *J. Algal Biomass Utiln.*, 3: 32-38, 2012.
- [33] **Nirmal Kumar, J.I., Kumar, R.N., Amb, M.K., Bora, A. and Chakraborty, S.** Variation of biochemical composition of eighteen marine macroalgae collected from Okha Coast, Gulf of Kutch, India. *EJEAFChe*, 9: 404-410, 2014.
- [34] **Nor Salmi, A., Shamsul, M., Ibrahim, C.O. and Hasmah, A.** Proximate composition of Red seaweed, *Gracilaria manilaensis*. UMT 11th International Annual Symposium on Sustainability Science and Management, 2012.
- [35] **Martins, C.D.L., Ramlov, F., Carneiro, N.P.N., Gestinari, L.M., Santos, B.F., Bento, L.M., Lhullier, C., Gouvea, L., Bastos, E., Horta, P.A. and Soares AR** , Antioxidant properties and total phenolic contents of some tropical seaweeds of the Brazilian coast. *J. Appl. Phycol.*, 25, 1179-1187, 2013.
- [36] **Shams El Din, N.G. and El-Sherif, Z.M.** Nutritional value of some algae from the north-western Mediterranean coast of Egypt. *J. Appl. Phycol.*, 24: 613-626, 2012.
- [37] **Lopez, A., Rico, M., Rivero, A. and Tangil, M.S.** The effects of solvents on the phenolic contents and antioxidant activity of *Stypocaulon scoparium* algae extracts. *Food Chemistry*, 125: 1104-1109, 2011.
- [38] **Ye, H., Zhou, C., Sun, Y., Zhang, X., Liu, J., Hu, Q. and Zeng, X.** Antioxidant activities *in vitro* of ethanol extract from brown seaweed *Sargassum pallidum*. *European Food Research and Technology*, 23:, 101-109, 2009.
- [39] **Wang, B., Zhang, W., Duan, X. and Li, X.** *In vitro* antioxidive activities of extract and semi-purified fractions of the marine red alga, *Rhodomela confervoides* (Rhodomelaceae). *Food Chemistry*, 113: 1101-1105, 2009.
- [40] **Cho, M., Lee, H., Kang, I., Won, M. & You, S.** Antioxidant properties of extract and fractions from *Enteromorpha prolifera*, a type of green seaweed. *Food Chemistry*, 127: 999-1006, 2011.

[41] **Kim, S., Woo, S., Yun, H., Yum, S., Choi, E., Do, J., Jo, J., Kim, D., Lee, S. and Lee, T.K.** Total phenolic contents and biological activities of Korean seaweed extracts. *Food Science Biotechnology*, 14:1-6, 2005.

[42] **Khaled, N., Hiba, M. and Asma, C.** Antioxidant and antifungal activities of *Padina pavonica* and *Sargassum vulgare* from the Lebanese Mediterranean coast. *Advances in Environmental Biology*, 6: 42-48, 2012.

[42] **Sokolova, E.V., Barabanova, A.O., Bogdanovich, R.N., Khomenko, V.A., Solov'eva, T.F. and Yermak, I.M.** *In vitro* antioxidant properties of red algal polysaccharides. *Biomedicine and Preventive Nutrition*, 1: 161-167, 2011.