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Antioxidant activity and mineral composition of three Mediterranean common seaweeds from Abu-Qir Bay, Egypt



Hanan M. Khairy ^a, Mohamed A. El-Sheikh ^{b,c,*}

^a Hydrobiology Lab., National Institute of Oceanography and Fisheries, Alexandria, Egypt

^b Botany and Microbiology Department, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia

^c Botany Department, Faculty of Science, Damanhour University, Damanhour, Egypt

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Abstract Antioxidant activity and mineral composition were evaluated seasonally from spring to autumn 2010 in the three common seaweeds *Ulva lactuca* Linnaeus (Chlorophyta), *Jania rubens* (Linnaeus) J.V. Lamouroux and *Pterocladia capillacea* (S.G. Gmelin) Bornet (Rhodophyta). The antioxidant activity was measured with β -carotene, total phenol content and DPPH (2,2-diphenyl-1-picrylhydrazyl). Seaweeds were collected from the rocky site near Boughaz El-Maadya Abu-Qir Bay of Alexandria, Egypt. The results showed maximum increase of β -carotene in *P. capillacea* during summer. A significant increase in total phenolic content at $P \leq 0.05$ was found in the red alga (*J. rubens*) during summer. Also, *U. lactuca* showed the maximum antioxidant scavenging activity especially during summer. Minerals in all investigated samples were higher than those in conventional edible vegetables. Na/K ratio ranged between 0.78 and 2.4 mg/100 g, which is a favorable value. All trace metals exceeded the recommended doses by Reference Nutrient Intake (RNI). During summer season, it was found that $\text{Cu} = 2.02 \pm 0.13$ and $\text{Cr} = 0.46 \pm 0.14$ mg/100 g in *U. lactuca* and Fe had a suitable concentration (18.37 ± 0.5 mg/100 g) in *P. capillacea*. The studied species were rich in carotenoids, phenolic compounds, DPPH free radicals and minerals, therefore, they can be used as potential source of health food in human diets and may be of use to food industry. © 2015 Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

* Corresponding author at: Botany and Microbiology Department, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia.

E-mail addresses: hanan_khairy@yahoo.com (H.M. Khairy), el_sheikh_eg@yahoo.co.uk (M.A. El-Sheikh).

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1. Introduction

Seaweeds are widely used in the life science as source of compounds with diverse structural forms and biological activities, therefore, potential source of novel antioxidants. The nutrient compositions of seaweeds are different depending on species, habitats, maturity and environmental conditions (Ito and Hori, 1989). Antioxidants play an important role in inhibiting

and scavenging radicals and thus providing protection to humans against infections and degenerative diseases. A number of marine algae were reported to possess antioxidant properties (Yasantha et al., 2006).

Antioxidant activities are attributed to various reactions and mechanisms: prevention of chain initiation, binding of transition metal ion catalysts, reductive capacity and radical scavenging (Huang and Wang, 2004). Nowadays, there is an increasing interest in natural antioxidants because of the safety and toxicity problems of synthetic antioxidants, for example, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) that are commonly used in lipid containing food (Li et al., 2007). Natural antioxidants such as α -tocopherol, phenols and β -carotene found in higher plants are being used in the food industry to inhibit lipid peroxidation and they can protect the human body from free radicals and retard the progress of many chronic diseases (Qi et al., 2005). Antioxidants, in particular carotenoids, help to prevent the free radical-damage associated with the aging process.

A review by the National Research Council (NRC, 1982) concluded that “the epidemiological evidences sufficient to suggest that food rich in carotenes or vitamin A are associated with a reduced risk of cancer”. Natural β -carotene is chemically and physically different from the synthetic form and although there is evidence that the body absorbs natural β -carotene ten times more easily than it absorbs the synthetic form (Ben-Amotz et al., 1989). Thus foods rich in carotenoids, particularly here β -carotene, may not only be able to prevent but also reverse cancers (Wolf, 1992).

Among natural antioxidants, phenolic antioxidants are commonly found in plants, including seaweeds (Duan et al., 2006). Phenolic antioxidants act by chelating metal ions, preventing radical formation and improving the antioxidant endogenous system (Rodrigo and Bosco, 2006). A study by Yamaguchi et al. (1998) showed that antioxidant substances which scavenge free radicals play an important role in prevention of free radical-induced diseases. By donating hydrogen radicals, the primary radicals are reduced to non-radical chemical compounds and are then converted to oxidized antioxidant radicals. This action helps in protecting the body from degenerative diseases. An antioxidant is generally defined as any substance that effectively prevents or delays the adverse effects caused by free radicals, even when the amount of the antioxidant substance is less than the substance to be oxidized (Halliwell, 1999). Recently, several studies reported that *Ulva* can be of potential interest for food, development of novel drugs and functional foods, pharmaceutical and agricultural applications (Costa et al., 2010; Wijesekara et al., 2011).

Mineral content is generally high and varies from 8% to 40%, and the essential minerals and trace elements needed for human nutrition are present in seaweeds (Rupérez, 2002). The wide range in mineral content is related to factors such as geographical distribution, seasons, environmental and physiological variations (Mabeau and Fleurence, 1993). Thus, seaweeds are important sources of elements vital for the metabolic reactions in the human health (Insel et al., 2007). Rupérez et al., 2002 determined various mineral contents in several brown and red edible marine sea vegetables. Various chemical constituents of the *Grateloupia turuturu* were determined by Ke et al. (2008) and that of *Kappaphycus alvarezii* determined by Rajasulochana et al. (2012).

In Abu-Qir Bay which is located along the Mediterranean coast of Alexandria, Egypt, several seaweed species are common as (*Ulva lactuca* Linnaeus – Division Chlorophyta; *Jania rubens* (Linnaeus) J.V. Lamouroux and *Pterocladia capillacea* (S.G. Gmelin) Bornet – Division Rhodophyta). The biochemical composition of the three studied seaweed species was previously evaluated elsewhere (Khairy and El-Shafay, 2013). Up to now, the information about the influence of environmental factors on antioxidant activity of seaweeds still is rare. The present study aimed to evaluate the antioxidants and mineral ion contents of the three seaweeds species.

2. Materials and methods

2.1. Seaweed sampling

Three seaweed species were collected during April, August and October 2010, representing spring, summer and autumn respectively. The algae were collected from submerged rocks on the coast of Abu Qir Bay Boughaz El-Maadya (Fig. 1), where they are usually abundant during the relevant collected periods. All samples were brought to laboratory in plastic bags containing sea water to prevent evaporation. Epiphytic and extraneous matter were removed by washing first in sea water and then with distilled water to separate potential contaminants. The dry samples were prepared by drying the fresh seaweeds in air at room temperature until dry and kept in plastic bag for further analysis. Algae were identified following Aleem (1993), they belonged to two families: *U. lactuca* Linnaeus of Chlorophyta and *J. rubens* (Linnaeus) J.V. Lamouroux and *P. capillacea* (S.G. Gmelin) Bornet of Rhodophyta.

2.2. Water analysis

Surface water sample was collected from coastal area of Abu-Qir Bay near Boughaz El-Maadya from spring to autumn (Fig. 1). Surface water temperature was measured at the time of sampling by using a pocket thermometer. Water salinity was determined by an Induction Salinometer (Beckman model RS-10). The pH of water samples was measured using a digital portable pH meter. Nitrate was determined as described by Strickland and Parsons (1972). Total dissolved phosphorus was determined according to Valderrama (1981) in filtered water sample.

2.3. Estimation of β -carotene

Total carotenes were extracted by the method of Beadle and Zscheile (1942). β -Carotene was extracted in diethyl ether and determined at 440 nm following Neeld and Pearson (1963) and expressed as mg/100 g dry wt.

2.4. Total phenols

Total content of phenolic compounds of algal extracts was determined spectrophotometrically at 725 nm using Folin-Ciocalteu reagent according to the method described in Lim et al. (2002). The total content of phenolic compounds was calculated based on a standard curve of phloroglucinol and expressed in % of dry weight.

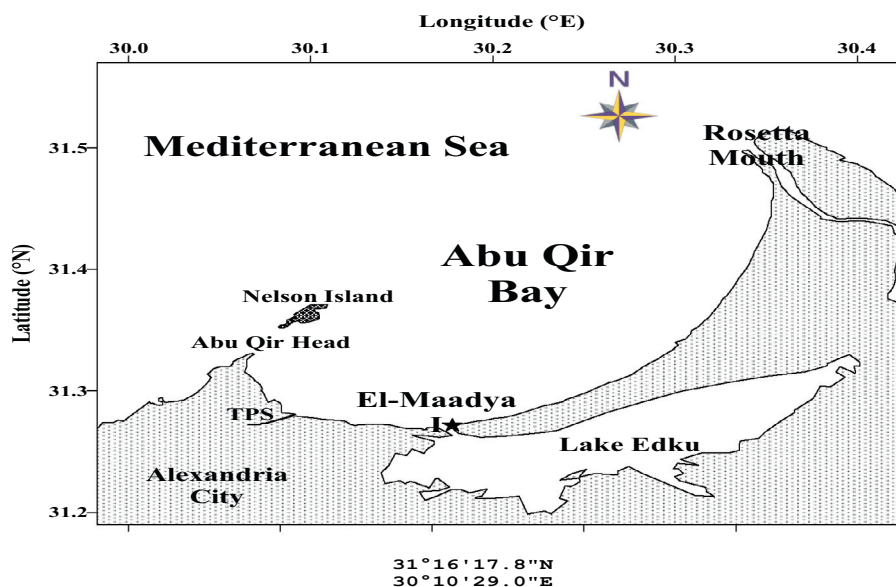


Figure 1 Map showing the rocky site near Boughaz El-Maadya (I) at Abu Qir Bay of Alexandria Egypt ($31^{\circ} 16' 17.8$ N and $30^{\circ} 10' 29.0$ E) where samples are collected.

2.5. Free radical scavenging activity (DPPH-decolorization assay)

Free radical scavenging activity of algal extracts of different concentrations (25 , 50 and $100 \mu\text{g ml}^{-1}$) was evaluated spectrophotometrically (at 517 nm) against the absorbance of the indicator 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution (20 mg l^{-1}). All reactions were carried out in triplicates and the degree of decolorization indicated the free radical scavenging activities of the algal extracts (Viturro et al., 1999). Silymarin was used as reference of free radical scavenger and percentage of DPPH-decolorization was calculated as follows:

$$\text{Free radical scavenging \%} = 1 - (\text{Ac} - \text{As}) / \text{Ac} \times 100$$

where Ac = Absorbance of control and As = Absorbance of algal sample.

2.6. Mineral analysis

Dry seaweed (0.5 g) was digested in 6 ml of HNO_3 ($65\% \text{ v/v}$) by using advanced microwave digestion system (ETHOS 1). Total contents of different elements were determined in the digested solution by using an Inductively Coupled Plasma Spectrometer (PERKEN ELEMER EMISSION SPECTROPHOTOMETER-6000 Series, Thermo Scientific) following Allen et al. (1997) in the Central Laboratory of Faculty of Agricultural, Cairo University, Egypt.

2.7. Statistical analysis

The results were expressed as mean of four replicates \pm SD and the data of β -carotene, phenolic compounds, and DPPH were statistically analyzed by using a one way analysis of variance (ANOVA) followed by LSD comparison test. Significance of differences is determined for the same species at different seasons at $P \leq 0.05$. Statistical analysis was carried out by SAS program (1989–1996) version 6.12.

3. Results and discussion

3.1. Water analysis

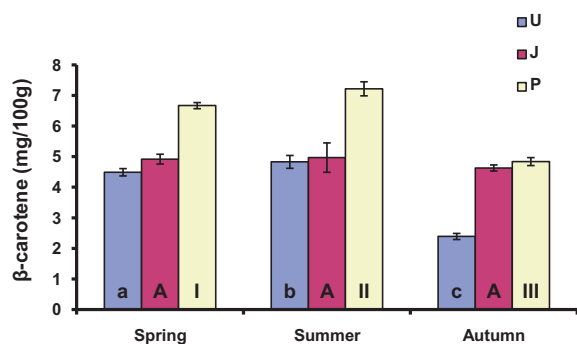
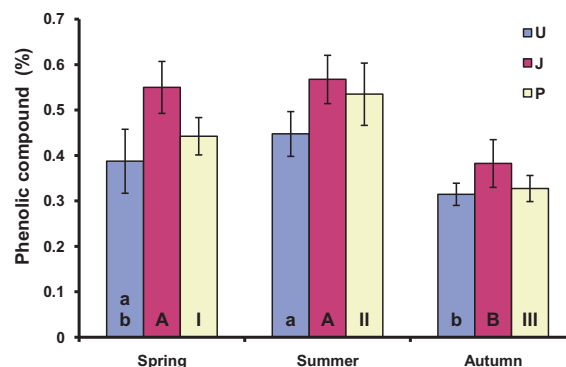
During the summer season, the environmental conditions such as temperature, salinity and pH exhibit high values ($27.1 \pm 0.2 \text{ }^{\circ}\text{C}$, $37.4 \pm 0.3\text{‰}$ and 8.3 ± 0.2 , respectively) than those observed during spring ($20.2 \pm 0.2 \text{ }^{\circ}\text{C}$, $34.4 \pm 0.4\text{‰}$ and 7.94 ± 0.01 , respectively) and autumn ($25.3 \text{ }^{\circ}\text{C} \pm 0.2$, $35.3 \pm 0.4\text{‰}$ and 7.9 ± 0.1 , respectively) (Table 1). On the other hand, nitrate and total dissolved phosphorus are higher during autumn (9.3 ± 0.8 and $1.8 \pm 0.1 \mu\text{M}$, respectively) than during spring (4.8 ± 0.7 and $0.86 \pm 0.1 \mu\text{M}$) and summer (2.6 ± 0.4 and $1.39 \pm 0.1 \mu\text{M}$). The nutrient contents of seaweeds were strongly related to nutrient regimes in the surrounding water (Murakami et al., 2011; Benjama and Masniyom, 2011). Most of these environmental parameters can influence the biosynthesis of several nutrients due to seasonal changes in ecological conditions (Lobban et al., 1985).

3.2. Estimation of β -carotene

β -Carotene content increased in the studied species to optimize and maximize the harvesting of light, and consequently increase the photosynthetic rates (Fig. 2). With regard to species, the significant increase in β -carotene content at $P \leq 0.05$ was observed in the red alga (*P. capillacea*) with a maximum value during summer ($7.2 \pm 0.1 \text{ mg/100 g}$), and this might have resulted in enhanced photosynthetic performance at sub saturating light intensities with increasing temperature during summer seasons. Obviously, variation in β -carotene content depends on the species, seasons, and environmental conditions. According to Lapointe and Ryther (1978), the alterations in pigment concentration are determined by the interaction between two factors, light intensity and nutrient availability. The main source of β -carotene was red and brown algae (Schubert et al., 2006; Sachindra et al., 2007).

Table 1 Environmental conditions (mean \pm SD) of aquatic environment of the selected station in Abu-Qir Bay of Alexandria, Egypt during spring to autumn 2010.

Variable	Season		
	Spring	Summer	Autumn
Temperature ($^{\circ}$ C)	20.2 \pm 0.2	27.1 \pm 0.2	25.3 \pm 0.2
Salinity (‰)	34.4 \pm 0.4	37.4 \pm 0.3	35.3 \pm 0.4
pH value	7.94 \pm 0.01	8.3 \pm 0.2	7.9 \pm 0.1
Nitrate (μ M)	4.8 \pm 0.7	2.6 \pm 0.4	9.3 \pm 0.8
Total dissolved phosphorus (μ M)	0.86 \pm 0.1	1.39 \pm 0.1	1.8 \pm 0.1

**Figure 2** β -Carotene contents of *Ulva lactuca* (U), *Jania rubens* (J) and *Pterocladia capillacea* (P) at different seasons. The vertical bars represent the standard deviation; different letters above the bars indicate a significant level for the same alga in different seasons at $P \leq 0.05$.**Figure 3** Total phenolic compound of *Ulva lactuca* (U), *Jania rubens* (J) and *Pterocladia capillacea* (P) at different seasons. The vertical bars represent the standard deviation; different letters above the bars indicate a significant level for the same alga in different seasons at $P \leq 0.05$.

The values of β -carotene are less than that of the previous studies (0.431 mg/g) in *Gracilaria corticata* (Thinakaran and Sivakumar, 2012) and (5.4 mg/100 g) in *Gracilaria* spp. (MacArtain et al., 2007). As reported by USDA (2010), the amount of β -carotene in some vegetables such as Spinach was 5.63 mg/100 g; Red chilli (0.534 mg/100 g) and Broccoli (0.361 mg/100 g). The average dietary intake of natural β -carotene from natural sources was estimated to be about 2–5 mg day⁻¹ (Omenn et al., 1996; Woodall et al., 1996). The antioxidant properties of the algal carotenoids have also been shown to play a role in preventing human pathogens linked to oxidative stress (Okuzumi et al., 1993; Mitra et al., 2006). Furthermore, experimental studies strongly suggest that β -carotene could prevent the onset of cancers, especially lung cancer (Astorg, 1997). However, other studies suggest that β -carotene could induce lung cancer in smokers. However, natural source of β -carotene is highly recommended as they protect against the development of cancer (NRC, 1982).

3.3. Total phenols

The present study indicated that the total phenolic content was influenced by seasons and algal species (Fig. 3). A significant increase in total phenolic content at $P \leq 0.05$ was found in the red alga (*J. rubens*) during summer season (0.75 \pm 0.05 mg/100 g). Therefore, our results showed that seasonal variations in phenolic compounds of brown algae are species specific; where maximum values are generally observed during the summer and minimum values during fall and winter. These results agreed with study of Budhiyanti

et al. (2012). Jung et al. (2009) suggested that polyphenolic extracts of *Laurencia undulata* possess therapeutic potential for combating bronchial asthma associated with allergic diseases.

Algal phenolic compounds are effective antioxidant to delay peroxidation, that phenols easily transfer a hydrogen atom to lipid peroxy cycle and form the aryloxy, which being incapable of acting as a chain carrier, couples with another radical, thus, quenching the radical process (Ruberto et al., 2001).

3.4. Free radical scavenging activity (DPPH-decolorization assay)

In the present study the seaweed extracts have high DPPH scavenging capacity, and significantly increased with increasing their concentration in different species and different seasons at $P \leq 0.05$ (Table 2). These findings are in agreement with the results obtained by Lai et al. (2001). *U. lactuca* showed the maximum antioxidant activity especially during summer (Table 2). The present study found significant differences in seaweed extracts at $P \leq 0.05$ of the studied samples to show varying degrees of free radical scavenging activity. Natural antioxidants are not limited to terrestrial sources and reports have revealed seaweeds to be rich sources of natural antioxidant compounds (Lim et al., 2002; Duan et al., 2006). Free radicals can be produced during every step in a chain reaction; thus, it is important for an antioxidant to prevent the chain initiation step by scavenging the initiator radical

Table 2 DPPH radical scavenging activity (%DPPH) of 25, 50 and 100 $\mu\text{g ml}^{-1}$ extracts on *Ulva lactuca*, *Jania rubens* and *Pterocladia capillacea* at different seasons. Data were presented as the average of four replicates \pm standard deviation (SD).

	Concentration ($\mu\text{g ml}^{-1}$)	Species		
		<i>Ulva lactuca</i>	<i>Jania rubens</i>	<i>Pterocladia capillacea</i>
Spring	25	14.1 \pm 0.3 ^a	22.8 \pm 0.4 ^a	24.2 \pm 0.6 ^a
	50	19.8 \pm 0.8 ^b	24.2 \pm 0.3 ^{bd}	26.02 \pm 0.4 ^b
	100	26.7 \pm 0.3 ^c	27.96 \pm 0.2 ^c	29.1 \pm 0.2 ^{cd}
Summer	25	25.4 \pm 0.5 ^d	23.95 \pm 0.2 ^b	22.4 \pm 0.5 ^e
	50	29.4 \pm 0.4 ^e	27.2 \pm 0.7 ^e	27.4 \pm 0.5 ^f
	100	33.2 \pm 0.1 ^f	29.1 \pm 0.1 ^f	29.6 \pm 0.2 ^c
Autumn	25	15.9 \pm 0.1 ^g	17.7 \pm 0.6 ^g	22.2 \pm 0.2 ^e
	50	16.7 \pm 0.5 ^h	19.8 \pm 0.2 ^h	25.3 \pm 0.2 ^g
	100	22.8 \pm 0.1 ⁱ	24.6 \pm 0.2 ^d	28.8 \pm 0.2 ^d

Values are expressed as mean \pm SD, $n = 4$. Values of the same species at different seasons and different concentrations with the same letter are not significant ($p \leq 0.05$).

(Saha et al., 2004). In contrast to our study, Wang et al. (2009) found that brown algae contained higher amounts of polyphenols and DPPH radical scavenging activity than red and green algae. However, Chandini et al. (2008) reported low levels of DPPH radical scavenging activity in brown seaweeds, in the range of 17.79–23.16% at an extract concentration of 1000 $\mu\text{g ml}^{-1}$. As reported by Abd El-Baky et al. (2008), decolonization of DPPH radical suggested the presence of electron and hydrogen donors' constituent in *Ulva* organic extracts. Thus, potential antioxidant properties of *Ulva* extracts could be due to their extracts containing some substances such as carotenoid and phenolic compounds.

3.5. Minerals composition

The macromolecules such Sodium (Na), Calcium (Ca), Potassium (K) and Magnesium (Mg) are among the minerals which are present in significant amounts in marine algae (Nisizawa, 2006). Among these elements, the results showed that, Ca was the most abundant in Chlorophycean species (*U. lactuca*), especially during summer season (Table 3), it was amounted to 97.8 \pm 0.56 mg/100 g. MacArtain et al. (2007) showed that Calcium was the most important element, and accumulated in seaweeds at much higher levels than in terrestrial foodstuffs. Mineral contents are shown to vary according to species, wave exposure, seasons, environmental factors, physiological

factors, type of processing and method of mineralization (Mabeau and Fleurence, 1993). As reported by MacArtain et al. (2007), 8 g dry weight of *U. lactuca* (sea lettuce) produces 260 mg of Calcium, which equals to approximately 37% of the Reference Nutrient Intake (RNI) values in adult male as recommended by Committee on Medical Aspects of Food and Nutrition Policy (1991).

In comparison, the same portion of cheddar cheese provides just 5% of the RNI (McCance et al., 1993), and by the DGE (2000) for the intake of Na, K, Ca, Mg, and the contents of these macro elements in algae products tested were relatively small. The Na/K ratio in the studied species ranged between 0.78 and 2.4, which is a favorable value and also agreed with the previous reports (Rupérez, 2002; Matanjun et al., 2009). In contrast to our results, in traditional European food products, such as meat and sausage, the Na/K ratio is 2.9–7.5 (Elmadfa et al., 2001). As reported by Insel et al. (2007), these findings suggested that the intake of both species can help to balance Na/K ratio diets. Na, Cl, and K are responsible for the maintenance of body fluid balance, and the consumption of foods with a high Na level may relate to the risk of hypertension.

For the trace elements (Table 3), Copper (Cu) contents of the tested seaweeds were found in the range of 0.17 \pm 0.03 to 2.02 \pm 0.13 mg/100 g. The maximum Cu value was present in the green alga *U. lactuca* during summer. This value was

Table 3 Minerals composition of different seaweeds *Ulva lactuca* (U), *Jania rubens* (J) and *Pterocladia capillacea* (P) at different seasons. Data were presented as the average of four replicates \pm standard deviation (SD).

Element (mg/100 g)	Spring			Summer			Autumn		
	U	J	P	U	J	P	U	J	P
Calcium	71.2 \pm 0.36	62.6 \pm 0.61	26.5 \pm 0.78	97.8 \pm 0.56	75.7 \pm 0.68	74.4 \pm 0.49	47.3 \pm 0.92	41.4 \pm 0.35	32.1 \pm 0.87
Sodium	8.9 \pm 0.58	49 \pm 1.04	59.2 \pm 0.61	11 \pm 0.36	46.6 \pm 0.52	68.4 \pm 1.2	4.6 \pm 0.61	25.7 \pm 0.87	38.8 \pm 0.85
Potassium	7.5 \pm 0.62	25 \pm 0.95	29.5 \pm 0.35	5.34 \pm 0.37	42.33 \pm 0.99	50.9 \pm 0.7	4.6 \pm 0.35	12.9 \pm 0.72	30.9 \pm 0.39
Magnesium	14.6 \pm 0.71	30 \pm 1.01	15.9 \pm 0.45	9 \pm 0.22	52 \pm 0.24	22.1 \pm 1.04	12 \pm 0.27	36 \pm 0.58	15.7 \pm 0.32
Copper	0.56 \pm 0.08	0.6 \pm 0.07	0.54 \pm 0.07	2.02 \pm 0.13	0.23 \pm 0.05	0.5 \pm 0.07	0.54 \pm 0.04	0.17 \pm 0.03	0.4 \pm 0.05
Zinc	0.17 \pm 0.03	0.2 \pm 0.04	0.3 \pm 0.04	0.31 \pm 0.05	0.13 \pm 0.03	0.19 \pm 0.03	0.2 \pm 0.03	0.3 \pm 0.04	0.16 \pm 0.01
Ferrous	2.35 \pm 0.1	2.98 \pm 0.2	4.94 \pm 0.17	1.43 \pm 0.05	5.3 \pm 0.08	18.37 \pm 0.5	0.95 \pm 0.02	1.7 \pm 0.14	16.55 \pm 0.17
Chromium	0.1 \pm 0.02	0.28 \pm 0.02	0.1 \pm 0.01	0.46 \pm 0.14	0.05 \pm 0.002	0.05 \pm 0.003	0.18 \pm 0.003	0.10 \pm 0.003	0.07 \pm 0.005
Lead	0.04 \pm 0.01	0.05 \pm 0.01	0.04 \pm 0.004	0.05 \pm 0.01	0.03 \pm 0.004	0.05 \pm 0.004	0.04 \pm 0.005	0.02 \pm 0.003	0.03 \pm 0.004

considerably higher than that reported by Norziah and Ching (2000) in *Gracilaria changgi* (0.8 mg/100 g), and Karthikai Devi et al. (2009), which amounted to 1.51 ± 0.03 mg/100 g in brown seaweed *Sargassum wightii* and 0.39 ± 0.01 mg/100 g in red alga *Acanthophora spicifera*. According to PSSICA (2009) the dietary intake of copper should not exceed 12,000 mg/100 g for males and 10,000 mg/100 g for females. The levels of the detected elements fit within the ranges observed in previous reports on seaweeds (Mabeau and Fleurence, 1993; Rupérez, 2002).

Ferrous is a vital constituent of plant and animal life and appears in hemoglobin. The results of this study showed that the tested species contain relatively high amounts of Fe. The maximum amount of Fe (18.37 ± 0.5 mg/100 g) was present in *P. capillacea* during summer (Table 3). Ferrous was present in seaweeds at higher levels than in many well-known terrestrial sources of minerals, such as meats and spinach. As compared to data for other vegetables reported by Tee et al. (1988), this value is considerably high due to its metabolic system in which it is capable of directly absorbing elements from the seawater. According to Nutrition Division (2001) the Dietary Recommended Intake (DRI) for Thai males and females of age between 19 and 50 years were in the range of 10.2 and 24.7 mg/100 g, respectively for males and females.

The chromium (Cr) content in the studied seaweeds varied from 0.05 ± 0.002 to 0.46 ± 0.14 mg/100 g (Table 3), the higher level of concentration was obtained from green alga *U. lactuca* during summer. In contrast to our study, Karthikai Devi et al. (2009) showed that Cr content varied (0.38 ± 0.02 to 4.16 ± 0.28 mg/100 g) in the red alga *A. spicifera* and the brown seaweed *S. wightii*, respectively. Chromium is present in the diet both as the inorganic form and organic complexes. The rate of absorption of inorganic Cr is low, from 0.4% to 3%, and is a function of daily dose supplied. According to Anderson (1987) ingestion of daily dose of 10 µg, up to 2% is absorbed, while at the dose of 40 µg, absorption decreases to 0.5%, and at the higher doses, it remains constant at 0.4%.

The maximum value of lead (Pb) in the tested seaweeds was 0.05 mg/100 g (Table 3), this value exceeded the values recorded by Real (1978) which amounted to ≤ 5 mg/100 g, and Almela et al. (2006) which amounted to 1 mg/100 g. The relatively high levels of some heavy metals in the alga reflect firstly the high concentration of the metals in the study area and secondly the capacity of the alga to take them up (Karez et al., 1994).

4. Conclusion

This study can be considered as a preliminary investigation of antioxidants in some Egyptian seaweed. The *U. lactuca*, *J. rubens* and *P. capillacea* were rich in antioxidants [β -carotenoids (7.2 ± 1.2 mg/100 g), phenolic compounds (0.75 ± 0.05 mg/100 g) and DPPH (33.2 ± 0.1 µg ml⁻¹)] and minerals. The production of these components in red algae may be enhanced by changing the culture conditions in large scale for overproduction of the targeted molecules. Therefore, these species can be used as potential source of health food in human diets and may be of use to food industry.

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