Indian Journal of Geo Marine Sciences
Vol. 48 (04), April 2019, pp. 484-491

Biochemical and mineral compositions of six brown seaweeds collected from Red Sea at Hurghada Coast

Wafaa A. Fouda[1], Wael M. Ibrahim[2], Ashgan M. Ellamie[1], & Gamal Ramadan[3]*
[1]Physiology of Animal and Poultry Department, Animal and Poultry Production Division, Desert Research Centre, Cairo, Egypt
[2]Department of Botany, Faculty of Science, Damanhour University, Damanhour, Egypt
[3]Zoology Department, Faculty of Science, Ain Shams University, Cairo, Egypt
*[E-mail: gramadan@sci.asu.edu.eg]

Received 08 September; revised 09 January 2018

The biochemical and mineral compositions of six brown seaweeds collected during spring season from Red Sea at Hurghada coast were determined to evaluate their significance in animal nutrition. The results suggested that the highest ash and protein contents were recorded in *Padina gymnospora* (45.48%) and *Sargassum muticum* (5.31%), respectively. The carbohydrates content was > 24.0% in the studied seaweeds, while the fat content ranged from 0.11 to 0.27%, and the essential amino acids formed 38.13-42.34% of the total amino acids. Both *Padina gymnospora* and *Turbinaria sp.* had the majority of measured phenolic compounds. Also, the studied seaweed species were rich in vitamin B_2 (> 105.0 ppm), except *Sargassum aspirofolium*. The highest/lowest vitamin C content existed in *Sargassum muticum* (11.76 ppm) and *Sargassum aspirofolium* (3.96 ppm), respectively. Moreover, the tested seaweeds exhibited high amounts of essential minerals. Therefore, Red Sea brown seaweeds are good food sources for animal nutrition.

[Keywords: Amino acids; Brown seaweeds; Minerals; Phenolic compounds; Red Sea coast; Vitamins]

Introduction

Seaweeds are one of the most important commercially renewable marine resources of the world with long life history. They have been used since ancient times as food, fodder, fertilizer and raw material for many industries and as a source of medicinal drugs[1]. More reports revealed that marine algae are rich sources of antioxidant compounds with potential free radical scavenging activity[2,3]. Therefore, algal species as alternative materials to extract natural anti-oxidative compounds have attracted much attention of biomedical scientists. Macroalgae are [illegible] defense system due to the strong UV radiation, combination of light and high oxygen concentrations as well as heavy metals and high salt concentrations in their environment, which induce the promotion of oxidative stress in their tissues[4,5]. This fact implies that seaweed cells have some protective mechanisms and compounds[6]. Generally, marine algae have higher antioxidant activity due to higher contents of non-enzymatic antioxidant components, such as ascorbic acid, phenols, and flavonoids. Several studies have demonstrated that seaweeds are excellent sources of components, such as polysaccharides, tannins, flavonoids, phenolic acids, bromophenols and carotenoids, which have exhibited different biological activities[7-10]. Brown seaweeds have higher antioxidant potential in comparison with red and green seaweeds and contain compounds not found in terrestrial plants[11].

Marine algae are often termed as super-food due to their high concentration of carbohydrates and proteins; while the lipid content is very low in seaweeds[12]. Generally, algal protein is called complete protein as it contains most of the required essential amino acids, unlike most plant foods that have lower percentage of net protein utilization[13]. Vitamins are essential nutrients [illegible]m specific and vital functions in a variety of body systems and are crucial for maintaining optimal health[14]. Marine algae are rich sources of vitamins A, B_1, B_2, B_3, B_9, C and E. Vitamins C, and E are potent antioxidants while vitamin A plays an important role in cell growth and differentiation, but vitamins B are precursors for enzyme cofactors[14]. Moreover, many of the essential minerals accumulate in marine algae at much higher levels than in terrestrial plants[8]. Compounds isolated from seaweeds especially brown algae have various functional biological activities, namely, antibacterial, antioxidant, anti-inflammatory, anti-coagulant, antiviral, antifungal, and apoptotic activities[15]. Therefore, the aim of this study was to evaluate the nutritional value of six marine brown algae collected from Red Sea at Hurghada coast (Egypt) to assess their validity towards animal consumption.

Materials and Methods

Collection and preparation of algal samples

The brown algae *Cystosira myrica, Padina gymnospora, Sargassum aspirofolium, Sargassum latifolium, Sargassum muticum and Turbinaria sp*. (Fig. 1) were collected from Red Sea at Hurghada coast, Egypt (Fig. 2), during spring season from April to June. Table 1 summarized the climatic conditions at Hurghada during spring season (obtained from Egyptian Meteorological Authority, Cairo). All samples were brought to laboratory in plastic bags containing sea water to prevent evaporation. Epiphytic and extraneous matters were removed by washing the samples several times with tap water and then distilled water to separate different impurities. The algal samples were then dried in the air at room temperature to constant weight and kept in plastic bags for biochemical analysis.

Red Sea water analysis

Sea water constituents were analyzed by using inductively coupled argon plasma (ICAP 6500, Duo Thermos scientific, England); 1000 mg/L multi-element certified standard solution (Merck, Germany) was used as stock solution for instrument standardization.

Biochemical analysis of algal samples

Moisture, ash, carbohydrates, fats and crude proteins (%) of algae species were determined according to the official methods of analysis of the Association of Official Analytical Chemists[16].

Amino acids

The amino acids composition of algae species was determined according to Pellet and Young[17], using amino acid analyzer (S-2100, Germany). Briefly, the amino acids were separated by a condition of amino acid analyzer for hydro-lysate program using citrate buffer at pH 2.2, a column temperature of 57 °C, a flow rate of 0.25 ml/min for ninhydrin pump, and a flow rate of 0.45 ml/min for quaternary pump. A photometric detection was done at 440 nm for proline and 570 nm for the other amino acids after an oxidative decarboxylation reaction to the amino acid with ninhydrin to give a Riemann's purple compound. Essential amino acids index was calculated by the equation,

$$\text{Essential amino acids index} = \frac{\text{Total essential amino acids}}{\text{Total amino acid}} \times 100$$

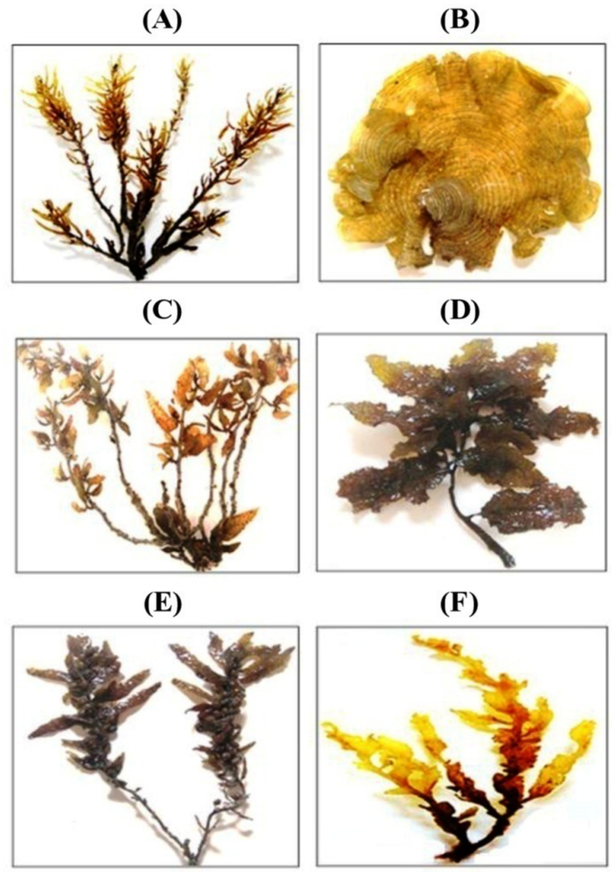

Fig 1 — Collected marine brown algal species from Red Sea at Hurghada coast during spring season from April to June. *Cystosira myrica* (**A**), *Padina gymnospora* (**B**), *Sargassum aspirofolium* (**C**), *Sargassum latifolium* (**D**), *Sargassum muticum* (**E**), *Turbinaria sp*. (**F**).

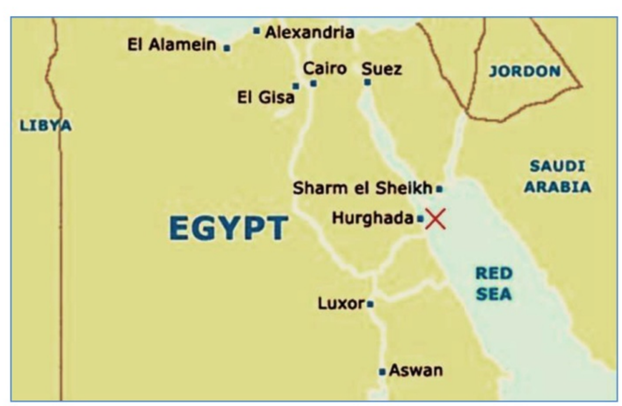

Fig 2 — Coast of Hurghada, Egypt. ×: Sample-collection area.

Phenolic compounds and vitamins

The phenolic compounds and vitamin contents of algae species were measured by high performance liquid chromatograph (HPLC, HP 3000 series, Agilent Technologies, Newtown, PA, USA), equipped with an auto sampler and a diode-array detector. The algal phenolic compounds were extracted in absolute methanol (5 g of alga in 10 ml absolute methanol). The algal vitamins were also extracted in absolute methanol, but the filtrate was extracted again with equal volume of diethyl ether after adding 2 ml KOH (90%), and the upper layer was collected and concentrated to 2 ml. Then, the algal phenolic compounds and vitamins extracts were injected into the HPLC analyzer; the analytical column was C-18 guard column. The mobile phase consisted of methanol (solvent A) and 2% acetic acid in water (v/v) (solvent B). The flow rate was kept at 1 ml/min for a total run time of 15 min. The wave lengths were 240, 245 and 250 nm. Peaks were identified by congruent retention times and UV spectra and compared with those of the standards (Sigma-Aldrich GmbH, Steinheim, Germany).

Table 1 — The climatic conditions at Hurghada during spring season (obtained from Egyptian Meteorological Authority, Cairo)

Climatic conditions	Mean ± SE
Low temperature (°C)	22.0 ± 1.3
High temperature (°C)	32.1 ± 1.4
Ambient temperature (°C)	26.9 ± 1.3
Humidity (%)	37.3 ± 2.1
THI	24.5 ± 1.1
Wind speed (m/s)	7.1 ± 0.3
Horizontal visibility (km)	9.8 ± 0.2
Dew point (°C)	10.6 ± 1.6
Atmospheric pressure (mm Hg)	758.7 ± 1.0

km: kilometer, mm Hg: Millimeter of mercury, m/s: meter per second, SE: Standard error, THI: Temperature humidity index. THI = Ambient temperature − [(0.31 − 0.31RH) × (Ambient temperature − 14.4)] Where: RH (Relative Humidity) = Humidity (%)/100.

Minerals and heavy metals

Minerals and heavy metals contents of algae species were also determined by using inductively coupled argon plasma (ICAP 6500).

Results and Discussion

Physicochemical characterization, inorganic content, and the concentration of metals and trace elements of Red Sea water at Hurghada Coast.

The results in Table 2 showed that water salinity was 41.6 g/L. The high salinity in Red Sea at Hurghada Coast is attributed to the enhancement of water evaporation in the closed areas[18,19]. The pH is one of the vital environmental characteristics for the survival, growth and physiology of aquatic organisms. It was 7.8 at Hurghada Coast (Table 2). Another study also reported that the salinity of Red Sea at Hurghada coast ranged between 40.23 and 41.43 g/L, and pH between 7.78 and 8.07, throughout the year[18]. Also the results clarified that nitrate, ammonia and total nitrogen concentrations in the Red Sea water were 3.5, 5.4 and 9.1 mg/L, respectively. The concentration of major elements such as calcium, magnesium and potassium in the Red Sea water ranged from 0.33 to 1.27 g/L, while

Table 2 — The physicochemical characterization, inorganic content, and the concentration of metals and trace elements of Red Sea water at Hurghada Coast.

Physicochemical characterization		Inorganic content		Trace elements (mg/L)	
Parameter	Amount	Parameter	Amount	Parameter	Amount
Electrical conductivity (µS/cm)	84400	Ammonia (mg/L)	5.4	Aluminum	0.0576
pH	7.8	Bicarbonate (g/L)	0.07	Barium	< 0.003
Salinity (g/L)	41.6	Carbonate (g/L)	0.03	Boron	4.514
Total dissolved solids (g/L)	48.13	Chloride (g/L)	26.6	Cadmium	< 0.0007
		Nitrate (mg/L)	3.5	Chromium	< 0.01
		Sulfate (g/L)	4.0	Cobalt	< 0.002
		Total nitrogen (mg/L)	9.1	Copper	< 0.007
		Metals (g/L)		Iron	< 0.02
		Parameter	Amount	Lead	< 0.008
		Calcium	0.82	Manganese	< 0.003
		Magnesium	1.27	Molybdenum	< 0.005
		Potassium	0.33	Nickel	0.0025
		Sodium	15.0	Vanadium	< 0.009
				Zinc	0.0072

µS/cm: Micro-Siemens per centimetre

sodium concentration was 15 g/L (Table 2). Trace elements are natural constituents in marine environment and are divided into two subclasses: (a) Cobalt, copper, iron, manganese and zinc that are necessary for the biochemical processes, but may be toxic at high concentrations and (b) Cadmium, chromium, lead and mercury that are not necessary for the biochemical processes and considered as the most important contaminates in the aquatic environment. Trace element contents of the Red Sea water at Hurghada Coast are presented in Table 2. The results showed that the concentration of trace elements in the Red Sea water decreased in the following order: Boron (4.514 mg/L) > aluminum (0.0576 mg/L) > the rest of trace elements (< 0.05 mg/L).

The nutrient compositions of the brown algal species collected from Red Sea at Hurghada coast

As shown in Table 3, the moisture and dry matter contents of the Red Sea brown algal species were 87.91-94.09% and 5.91-12.09%, respectively. The highest ash content was found in *Padina gymnospora* (45.48%), while *Sargassum aspirofolium* had the lowest ash content (19.60%), as shown in Table 3. Another study stated that the ash content of *Padina gymnospora* isolated from Malaysia coasts was 45.04% of dry weight[12]. In addition, Rupérez[20] reported that the brown seaweeds contain higher amounts of ash (21.37-45.04%) than green and red seaweeds and most terrestrial vegetables. The amount of ash content varies with environmental, geographical and physiological variations[21,22]. High invariable ash content indicates the presence of appreciable amount of diverse mineral components[23].

In the present study, the highest carbohydrates content was recorded in *Padina gymnospor*a (41.66%) followed by *Sargassum latifolium* (41.42%) and *Sargassum aspirofolium* (39.25%). While, *Sargassum muticum* had the minimum carbohydrates content (24.79%) compared with other algal species (Table 3). The fat content ranged from 0.11 to 0.27% in the collected brown seaweeds (Table 3). Typically, seaweeds are rich in carbohydrates, but they are not considered to be good source of lipid[12,23]. The ammonia content of the Red Sea brown algal species was 2.03-5.10 mg/g dry weight (Table 3). The highest protein content recorded in species *Sargassum muticum* (5.31%) followed by *Sargassum latifolium* (4.38%). On the other hand, *Cystosira myrica* had the minimum protein content (2.81%) as compared to the other algal species (Table 3). Earlier studies recorded that the protein content in seaweeds ranged from 5 to 24% of dry weight. The variation in protein content of seaweeds can be due to different species, seasonal period and geographic area[24-28]. Table 4 showed the amino acids profile of the six species of brown seaweeds studied. The results indicated that the essential amino acids forming (38.13-42.34%) of the total amino acids in all studied brown seaweed species indicating a high quality protein that could be used as a complementary source of food proteins for animal nutrition, since the essential amino acids represented about 40% of total amino acids[29,30]. Holdt and Kraan[25] and Balboa *et al.*[31] reported that seaweed species are rich sources of the acidic amino acids (aspartic acid and glutamic acid); whilst threonine, lysine, tryptophan, sulfur amino acids (cysteine and methionine) and histidine have been perceived as limiting amino acids in algal proteins, although their levels are higher than those found in terrestrial plants. Indeed, the data presented in Table 4 showed that aspartic acid and glutamine represented the most predominant amino acids in brown seaweed species, but cysteine existed in low concentration.

Table 5 showed the phenolic compounds profile of the six brown seaweeds as determined by HPLC. The

Table 3 — Amount of ammonia, dry matter, moisture, Ash, carbohydrates, proteins and fats in the brown algal species collected from Red Sea at Hurghada coast.

Parameters	*Cystosira myrica*	*Padina gymnospora*	*Sargassum aspirofolium*	*Sargassum latifolium*	*Sargassum muticum*	*Turbinaria Sp.*
Moisture (%)	90.47	94.09	88.08	88.22	87.91	91.32
Dry matter (%)	9.53	5.91	11.92	11.78	12.09	8.68
Ash (%)	27.96	45.48	19.60	26.16	20.68	23.98
Carbohydrates (%)	33.75	41.66	39.25	41.42	24.79	26.85
Proteins (%)	2.81	4.13	3.50	4.38	5.31	3.88
Ammonia (mg/g dry weight)	5.10	2.03	3.08	2.81	3.13	2.71
Fats (%)	0.11	0.13	0.17	0.27	0.12	0.20

results showed that *Turbinaria sp*. and *Padina gymnospora* had the following phenolic compounds: Coumarin, ellagic acid and resorcinol acid. Also, coumarin was detected in *Cystosira myrica*, while resorcinol acid was detected in *Sargassum latifolium*. Naphthalene was found in *Sargassum aspirofolium*, *Sargassum latifolium* and *Padina Sp*. Kaempherol and phenanthrene were detected in all studied algae, except *Cystosira myrica* and *Sargassum aspirofolium*, respectively. Such phytochemicals showed many beneficial biological effects including anticarcinogenic, antioxidant, antimicrobial, and antithrombotic activities[32,33].

Riboflavin (vitamin B_2) is needed for growth and good health[14]. It is essential for cellular aerobic respiration that completely oxidized carbohydrates, proteins and fats to produce high amounts of energy. For example, riboflavin changes pyridoxine (vitamin B_6) and folic acids, which are essential for transamination reactions and protein metabolism, into forms that the body can use[14]. Our results showed that the Red Sea brown algae are good food sources of vitamin B_2; hence it represented 105.25-232.29 ppm, except *Sargassum aspirofolium* that had only 20.9 ppm of vitamin B_2 (Table 6). Ascorbic acid (vitamin C) is one of the antioxidants molecules that scavenge free radicals and protect the body from reactive oxygen and nitrogen species[14,34]. Vitamin C content ranged from 3.96 to 11.76 ppm exhibiting

Table 4 — The amino acid composition (mg/g dry weight) of the brown algal species collected from Red Sea at Hurghada coast.

Amino acids	*Cystosira myrica*	*Padina gymnospora*	*Sargassum aspirofolium*	*Sargassum latifolium*	*Sargassum muticum*	*Turbinaria Sp.*
			Non-essential amino acids			
Alanine	1.71	0.78	1.10	1.01	1.45	1.61
Arginine	0.85	0.47	0.54	0.51	0.72	0.73
Aspartic acid	3.00	1.44	1.83	1.56	2.25	2.41
Cysteine	0.18	0.09	0.12	0.11	0.07	ND
Glutamine	3.65	1.54	2.23	1.62	2.50	2.82
Glycine	1.17	0.65	0.85	0.66	1.15	1.17
Proline	0.80	0.41	0.66	0.55	0.80	0.88
Serine	1.13	0.66	0.85	0.68	1.05	1.14
Tyrosine	0.41	0.30	0.33	0.27	0.36	0.49
Total (non-essential amino acids)	12.90	6.34	8.51	6.97	10.35	11.25
			Essential amino acids			
Histidine	0.57	0.36	0.41	0.26	0.58	0.52
Isoleucine	1.04	0.54	0.74	0.69	0.96	1.05
Leucine	1.61	0.90	1.24	1.08	1.60	1.82
Lysine	1.19	0.64	0.78	0.72	1.03	1.17
Methionine	0.33	0.18	0.30	0.25	0.36	0.44
Phenylalanine	0.91	0.58	0.77	0.59	0.96	1.00
Threonine	0.92	0.53	0.67	0.52	0.85	0.89
Valine	1.38	0.70	0.96	0.91	1.26	1.35
Total (Essential amino acids)	7.95	4.43	5.87	5.02	7.60	8.24
Total amino acids	20.85	10.77	14.38	11.99	17.95	19.49
Essential amino acids index	38.13	41.13	40.82	41.87	42.34	42.28

ND: Not detected

Table 5 — Phenolic compounds (ppm) of the brown algal species collected from Red Sea at Hurghada coast.

Phenolic compounds	*Cystosira myrica*	*Padina gymnospora*	*Sargassum aspirofolium*	*Sargassum latifolium*	*Sargassum muticum*	*Turbinaria Sp.*
Coumarin	220.6	51.8	ND	ND	ND	229.2
Ellagic acid	ND	0.354	ND	ND	ND	0.480
Kaempherol	ND	11.3	141.9	151.8	126.3	9.7
Naphthalene	ND	0.003	0.058	0.004	ND	ND
Phenanthrene	0.002	0.003	ND	0.001	0.045	0.003
Resorcinol acid	ND	16.0	ND	0.3	ND	7.3

ND: Not detected. Ferulic acid was not detected in all studied brown algal species.

different species variation. The highest/lowest vitamin C content existed in *Sargassum muticum and Sargassum aspirofolium*, respectively (Table 6). Therefore, *Sargassum muticum* is rich in both vitamins B_2 and C.

Table 7 indicated that most of the seaweeds evaluated in the present study exhibited high amounts of potassium, calcium, magnesium and iron, which were relatively higher than seaweeds collected from areas outside Red Sea[20,35,36]. Some seaweed accumulates more potassium than other elements, whereas potassium is an essential element for the growth and metabolic activities of seaweeds[37,38]. The high potassium content of all investigated seaweeds species (12-78 mg/g dry weight, Table 7) indicated that these marine algae were considered to be the major source for extraction of potash. Calcium content ranged between 9.7 and 19.4 mg/g dry weight and magnesium content ranged between 4.5 and 9.3 mg/g dry weight in Red Sea brown algal species (Table 7); their concentrations were higher than that in the seaweeds collected from Iran coasts[36]. The elements content in seaweeds may be dependent on various environmental factors, including concentrations of elements in water, interactions between elements, salinity, pH and light intensity[39,40]. Sometimes, concentrations of elements in seaweeds are regulated to a large extent by metabolic requirements[40]. Seaweeds are able to selectively absorb minerals from the surrounding sea water and accumulate them in their cells[41,42]. Iron content was higher in Cystosira *myrica* (0.993 mg/g dry weight) followed by *Padina gymnospora* (0.842 mg/g dry weight) and *Sarsassum aspirofolium* (0.802 mg/g dry weight), and the lowest iron content was found in *Turbinaria sp.* (0.48 mg/g dry weight) as shown in Table (7). The concentration of other trace elements (chromium, manganese, phosphor and zinc) in the studied brown seaweed were similar to that recorded by others in tropical and cultivated seaweeds and in seaweeds collected from northeastern Mediterranean coast and Bulgarian Black Sea Coast and were below the toxic limits[27,43-45].

Table 6 — Amount of vitamins B_2 & C (ppm) of the brown algal species collected from Red Sea at Hurghada coast.

Brown algae	Vitamin B_2 (ppm)	Vitamin C (ppm)
Cystosira myrica	105.25	7.68
0111Padina gymnospora	192.06	5.71
Sargassum aspirofolium	20.90	3.96
Sargassum latifolium	232.29	6.68
Sargassum muticum	169.46	11.76
Turbinaria sp.	140.31	8.13

Table 7 — Elements content (mg/g dry weight) of the brown algal species collected from Red Sea at Hurghada coast.

Elements	*Cystosira myrica*	*Padina gymnospora*	*Sargassum aspirofolium*	*Sargassum latifolium*	*Sargassum muticum*	*Turbinaria sp.*
Aluminum	0.569	0.707	0.502	0.288	0.366	0.167
Boron	0.131	0.234	0.088	0.107	0.013	0.285
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Calcium	14.500	19.360	15.200	15.200	15.256	9.769
Chromium	0.006	0.005	0.005	0.005	0.005	0.005
Cobalt	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Copper	0.004	0.007	0.009	0.003	0.003	0.003
Iron	0.993	0.842	0.802	0.695	0.537	0.488
Lead	< 0.005	< 0.005	0.005	< 0.001	0.001	< 0.001
Magnesium	6.409	8.204	5.778	9.264	6.777	4.513
Manganese	0.025	0.026	0.027	0.012	0.025	0.008
Molybdenum	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nickel	0.004	0.004	0.006	0.002	0.003	0.002
Phosphor	0.5422	0.6374	0.5339	0.6276	0.4528	0.3939
Potassium	49	16	12	35	13	78
Vanadium	0.006	0.008	< 0.005	0.005	< 0.005	< 0.005
Zinc	0.077	0.082	0.316	0 .323	0.128	0.038

Conclusion

The Red Sea brown seaweeds are good food sources of high quality protein that contains high amount of essential amino acids, and are rich in vitamins, minerals and phenolic compounds, which are strong antioxidants. Thus, the Red Sea brown seaweed may be used as food additives to improve feed quality, performance, productivity and health of the animals.

Acknowledgement

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. The authors have no potential financial conflict of interest. G. R., A. M. E. and W. M. I. planned the study, designed all experiments, summarized and interpreted the results, as well as drafted the manuscript. W. A. F. and W. M. I. collected and identified the species of the brown seaweeds. W. A. F. carried out all experiments with assistance from A. M. E. and G. R.

References

1 Chanda, S., Dave, R., Kaneria, M. & Nagani, K., Seaweeds: a novel, untapped source of drugs from sea to combat infectious diseases, *Curr. Res. Technol. Edu. Topics Appl. Microbial Biotechnol.*, 1 (2010) 473-480.

2 Ananthi, S., Raghavendran, H.R., Sunil, A.G., Gayathri, V., Ramakrishnan, G. & Vasanthi, H.R., *In vitro* antioxidant and *in vivo* anti-inflammatory potential of crude polysaccharide from *Turbinaria ornata* (Marine Brown Alga), *Food Chem. Toxicol.*, 48 (2010) 187-192.

3 Liu, M., Hansen, P.E. & Lin, X., Bromophenols in marine algae and their bioactivities, *Mar. Drugs*, 9 (2011) 1273-1292.

4 Matanjun, P., Mohamed, S., Mustapha, N.M., Muhammad, K. & Ming, C.H., Antioxidant activities and phenolics content of eight species of seaweeds from north Borneo, *Journal of Applied Phycology*, 20 (2008) 367-373.

5 Zubia, M., Robledo, D. & Freile-Pelegrin, Y., Antioxidant activities in tropical marine macroalgae from the Yucatan Peninsula, Mexico, *J. Appl. Phycol.*, 19 (2007) 449-458.

6 Manivannan, K., Thirumaran, G., Karthikai Devi, G., Hemalatha, A. & Anantharaman, P., Biochemical composition of seaweeds from Mandapam coastal regions along southeast coast of India, *Am-Euras. J. Bot.*, 1 (2008) 32-37.

7 Gupta, S. & Abu-Ghannam, N., Bioactive potential and possible health effects of edible brown seaweeds, *Trends in Food Science & Technology*, 22 (2011) 315-326.

8 Lordan, S., Ross, R.P. & Stanton, C., Marine bioactives as functional food ingredients: potential to reduce the incidence of chronic diseases, *Mar. Drugs*, 9 (2011) 1056-1100.

9 Rodríguez-Bernaldo de Quirós, A., Lage-Yusty, M.A. & López-Hernández, J., Determination of phenolic compounds in macroalgae for human consumption, *Food Chemistry*, 121 (2010) 634-638.

10 Wu, S.C., Wang, F.J. & Pan, C.L., The comparison of antioxidative properties of seaweed oligosaccharides fermented by two lactic acid bacteria, *J Mar. Sci. Technol.*, 18 (2010) 537-545.

11 Sudhakar, M.P., Ananthalakshmi, J.S. & Beena, B.N., Extraction, purification and study on antioxidant properties of fucoxanthin from brown seaweeds, *Journal of Chemical and Pharmaceutical Research*, 5 (2013) 169-175.

12 Ahmad, F., Sulaiman, M.R., Saimon, W., Yee, C.F. & Matanjun, P., Proximate compositions and total phenolic contents of selected edible seaweed from Semporna, Sabah, Malaysia, *Borneo Sci.*, 31 (2012) 74-83.

13 Chakraborty, S. & Bhattacharya, T., Nutrient composition of marine benthic algae found in the Gulf of Kutch coastline, Gujarat, India, *J. Algal Biomass Utln.*, 3 (2012) 32-38.

14 Bellows I & Moore R, *Water-soluble vitamins: B-complex and vitamin C*, (Colorado State University Cooperative Extension Fact Sheet No. 9.312) 2012.

15 Admassu, H., Zhao, W., Yang, R., Gasmalla, M.A.A. & Alsir, E., Development of functional foods: sea weeds (Algae) untouched potential and alternative resource - a review, *Int. J. of Sci. & Tech. Res.*, 4 (2015) 108-117.

16 AOAC, *Official methods of analysis of AOAC International*, Vol. 1, 16 Edn., (AOAC International, Arlington) 1995.

17 Pellet P L & Young V R, *Nutritional evaluation of protein feeds*, (United Nations University, Tokyo, Japan) 1980.

18 Abdelmongy, A.S. & El-Moselhy, K.M., Seasonal variations of the physical and chemical properties of seawater at the northern Red Sea, Egypt, *Open Journal of Ocean and Coastal Sciences*, 2 (2015) DOI: 10.15764/OCS.2015.01001.

19 Madkour, H.A., Impacts of human activities and natural inputs on heavy metal contents of many coral reef environments along the Egyptian Red Sea coast, *Arabian Journal of Geosciences*, 6 (2013) 1739-1752.

20 Rupérez, P., Mineral content of edible marine seaweeds, *Food Chemistry*, 79 (2002) 23-26.

21 Mendis, E. & Kim, S.K., Present and future prospects of seaweeds in developing functional foods, *Adv. Food Nutr. Res.*, 64 (2011) 1-15.

22 Sanchez-Machado, D.I., Lopez-Hernandez, J. & Paseiro-Losada, P., High-performance liquid chromatographic determination of alpha-tocopherol in macroalgae, *J Chromatogr A*, 976 (2002) 277-284.

23 EL-Shafay, S.M., Biochemical composition of some seaweed from Hurghada coastal along Red Sea coastal, Egypt, *International Journal of Basic & Applied Sciences IJBAS-IJENS*, 14 (2014) 29-35.

24 Chakraborty, S. & Santra, S.C., Biochemical composition of eight benthic algae collected from Sunderban, *Indian J. Mar. Sci.*, 37 (2008) 329-332.

25 Holdt, S.L. & Kraan, S., Bioactive compounds in seaweed: functional food applications and legislation, *Journal of Applied Phycology*, 23 (2011) 543-597.

26 Marsham, S., Scott, G.W. & Tobin, M.L., Comparison of nutritive chemistry of a range of temperate seaweeds, *Food Chemistry*, 100 (2007) 1331-1336.

27 Matanjun, P., Mohamed, S., Mustapha, N.M. & Muhammad, K., Nutrient content of tropical edible seaweeds, *Eucheuma cottonii*, *Caulerpa lentillifera* and *Sargassum polycystum*, *Journal of Applied Phycology*, 21 (2009) 75-80.

28 Renaud, S.M. & Luong-Van, J.T., Seasonal variation in the

chemical composition of tropical Australian marine macroalgae, *Journal of Applied Phycology*, 18 (2006) 381-387.

29 Vinoj Kumar, V. & Kaladharan, P., Amino acids in the seaweeds as an alternate source of protein for animal feed, *Journal of the Marine Biological Association of India*, 49 (2007) 35-40.

30 Wong, K.H. & Cheung, P.C.K., Nutritional evaluation of some subtropical red and green seaweeds: Part I - proximate composition, amino acid profiles and some physico-chemical properties, *Food Chem.*, 71 (2000) 475-482.

31 Balboa, E.M., Conde, E., Moure, A., Falque, E. & Dominguez, H., *In vitro* antioxidant properties of crude extracts and compounds from brown algae, *Food Chem.*, 138 (2013) 1764-1785.

32 Jeeva, S., Marimuthu, J., Domettila, C., Anantham, B. & Mahesh, M., Preliminary phytochemical studies on some selected seaweeds from Gulf of Mannar, India, *Asian Pacific Journal of Tropical Biomedicine*, 2 (2012) S30-S33.

33 Manchu, N., Melpha, Y., Jeeva, S. & Edwin James, J., Phytochemical analysis and antibacterial activity of *Chaetomorpha antennina* from Rasthacaud cost, Tamil Nadu, India, *World Journal of Pharmaceutical Research*, 4 (2015) 1337-1351.

34 Anantharaman, P., Karthikai Devi, G., Manivannan, K. & Balasubramanian, T., Vitamin-C content of some marine macroalgae from Gulf of mannar marine biosphere reserve, southeast coast of India, *Plant Archives*, 11 (2011) 343-346.

35 Krishnaiah, D., Sarbatly, R., Prasad, D. & Bono, A., Mineral content of some seaweeds from Sabah's South China Sea, *Asian Journal of Scientific Research*, 1 (2008) 166-170.

36 Rohani-Ghadikolaei, K., Abdulalian, E. & Ng, W.K., 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 (2012) 774-780.

37 Kuda, T. & Ikemori, T., Minerals, polysaccharides and antioxidant properties of aqueous solutions obtained from macroalgal beach-casts in the Noto Peninsula, Ishikawa, Japan, *Food Chem.*, 112 (2009) 575-581.

38 Sivakumar, S.R. & Arunkumar, K., Sodium potassium and sulphate composition in some seaweeds occurring along the coast of Gulf of Mannar, India, *Asian J. Plant Sci.*, 8 (2009) 500-504.

39 Andrade, L.R., Farina, M. & Amado Filho, G.M., Effects of copper on *Enteromorpha flexuosa* (Chlorophyta) *in vitro*, *Ecotoxicol. Environ. Saf.*, 58 (2004) 117-125.

40 Zbikowski, R., Szefer, P. & Latala, A., Distribution and relationships between selected chemical elements in green alga *Enteromorpha* sp. from the southern Baltic, *Environ. Pollut.*, 143 (2006) 435-448.

41 Azmat, R., Hayat, A., Khanum, T., Talat, R. & Uddin, F., The inhibition of bean plant metabolism by Cd metal and atrazine III: effect of seaweed *Codium iyengarii* on metal, herbicide toxicity and rhizosphere of the soil, *Biotechnology*, 5 (2006) 85-89.

42 Omar, H.H., Abdullatif, B.M., El-Kazan, M.M. & El-Gendy, A.M., Red Sea water and biochemical composition of seaweeds at southern coast of Jeddah, Saudi Arabia, *Life Science Journal*, 10 (2013) 1073-1080.

43 Panayotova, V. & Stancheva, M., Mineral composition of marine macroalgae from the Bulgarian Black Sea coast, *Scripta Scientifica Medica*, 45 (2013) 42-45.

44 Peng, Y., Xie, E., Zheng, K., Fredimoses, M., Yang, X., Zhou, X.; Wang, Y.; Yang, B.; Lin, X.; Liu, J. & Liu, Y., Nutritional and chemical composition and antiviral activity of cultivated seaweed *Sargassum naozhouense* Tseng et Lu, *Mar. Drugs*, 11 (2013) 20-32.

45 Polat, S. & Ozogul, Y., Fatty acid, mineral and proximate composition of some seaweeds from the northeastern Mediterranean coast, *Ital. J. Food Sci*, 21 (2009) 317-324.