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Evaluation of proximate composition, antioxidant and antimicrobial activities of some seaweeds from the Red Sea coast, Egypt.

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ABSTRACT

Nutritional composition, total Phenolic content, antioxidant and antimicrobial activities were assessed in the crude extracts of six seaweed species selected from the Red Sea coast, Hurghada, Egypt. These species are *Caulerpa racemosa* var. *gracilis* from Chlorophyta; *Padina boergesenii*, *Polycladia myrica*, *Hormophysa cuneiformis* and *Sargassum aquifolium* from Phaeophyta and *Digenea simplex* from Rhodophyta. The results of nutritional content revealed that, the tested seaweeds have high values of fibers (27.6-36.2% dry wt.), ash (24.7–35.8% dry wt.), and carbohydrates (23.4-35.7% dry wt.), medium values of moisture (2.4-10.8% dry wt.) and protein (4.8-7.1% dry wt.), while low values of total lipids (0.8-5.2% dry wt.) were detected. The highest total phenolic content (129.9 ± 1.8 mg GAE/g dry wt.) was detected in the brown seaweed, *H. cuneiformis*, and the lowest (31.3 ± 0.6 mg GAE/g dry wt.) was observed in the green seaweed *C. racemosa*. The antioxidant activity was detected using DPPH (2, 2-Diphenyl-2-picrylhydrazyl) radical scavenging activity and the highest activity was recorded in the brown seaweed *H. cuneiformis*, while the lowest activity was observed in the green seaweed *C. racemosa*. All the algal extracts were effective against *Pseudomonas aeruginosa* and *Candida albicans*, while the extract of *H. cuneiformis* is the only one that effective against *Enterococcus faecalis* and *Staphylococcus aureus*. None of the tested extracts was effective against *Aspergillus niger*. Overall, the results of this study indicated that the Red Sea seaweeds could be introduced as raw materials or some of their contents for nutrient supplementation in various food products.

INTRODUCTION

Marine macroalgae represent a source of potential bioactive compounds for a variety of applications in cosmetics, pharmaceutical industries, agro-food industry and more recently, in the field of functional food and chemistry (Gressler *et al.*, 2010 and Holdt and Kraa, 2011).

In Egypt, the coasts of the Mediterranean, Suez Canal, and the Red Sea are rich in seaweeds (El-Manawy, 2001 and 2008a), yet none is commercially utilized; and the scientific research for their potency as functional food and source of bioactive compounds is scarce (El-Manawy *et al*., 2000, 2005; El-Manawy, 2008b; Shanab, 2007 and Osman *et al*., 2011).The use of seaweeds as a food dates back to the fourth

century and some countries such as Japan, China and Korea have become the largest seaweed consumers (Bixler and Porse, 2010).

It has been reported that seaweeds have a high amount of polysaccharides, essential and non-essential amino acids, minerals, polyunsaturated fatty acids, polyphenolic compounds, vitamins and dietary fibers (non-starch polysaccharides) that are important for normal growth (Garcia-vaquero and Hayes, 2016 and Garcia-Vaquero *et al.*, 2017), which could be used as preservatives, nutrition enhancers, and healthy food source (Syad *et al.*, 2013 and Barba, 2016). Besides, phenolic compounds which are aromatic secondary metabolites of marine algae play a significant role in color and nutritional qualities of food (Peinado *et al.*, 2014 and Fleurence and Levine, 2016).

In addition to the unusual content of polysaccharides, amino acids, fatty acids, carotenoids, phycobiliproteins and phycocolloides, seaweeds contain many active compounds including polyphenols, alkaloids, terpenes and phlorotannins (Hayes, 2012). These constituents possess a potent activity as antioxidants, anti-proliferative, anti-inflammatory, anticoagulant, anti-diabetic, and anti-hepatitis (Kim and Li, 2011). Furthermore, many compounds of marine algae show antimicrobial activities such as polyhydroxylated fucophlorethol (Sandsdalen *et al*., 2003), polysaccharide (Laurienzo, 2010), bromophenols (Oh *et al*., 2008) and polyphenolic compounds (Devi *et al*., 2008). Therefore, this study was carried out to study the content of some Red Sea seaweeds in terms of nutritional composition as well as antimicrobial and antioxidant properties and evaluate their potential use for the production of alternative food with acceptable nutritional content for diets.

MATERIALS AND METHODS

Algae selection, collection and preparation

Algal samples were collected from the Red Sea coast at Hurghada, in front of the National Institute of Oceanography and Fisheries (NIOF) between latitudes 27 ^{o} 17\13\\ N and longitudes 33^{o} 46\ 21\\ E in August 2017. Six seaweed species were randomly selected from the intertidal zone. These species were *Caulerpa racemosa* var. *gracilis* from Chlorophyta, *Padina boergesenii*, *Polycladia myrica*, *Hormophysa cuneiformis* and *Sargassum aquifolium* from Phaeophyta and *Digenea simplex* from Rhodophyta. The seaweeds were identified on the basis of morphological characteristics according to taxonomic references (Børgesen, 1957; Dawson, 1962; Jaasund, 1977; Aleem, 1978; Coppejans and Beeckman, 1990; Oza and Zaidi, 2001 and Sahoo, 2001).The collected seaweeds were washed with seawater to remove epiphytes, animal castings, sand, and other adhering detritus matters, followed by another wash with fresh water to remove excess salt. The algal materials were then shade dried under an air jet to prevent photolysis and thermal degradation. The completely dried materials were weighed and ground coarsely in a mechanical grinder and then stored in sealed plastic pages for further use.

Determination of proximate nutritional composition

Moisture and ash were measured by AOAC (1995), total carbohydrates including soluble and fibers by Hedge and Hofreiter (1962), total soluble proteins by Lowry *et al*. (1951), crude fibers by AOAC (1990) and total lipids by AOAC (2000). All measurements were recorded as g.100g^{-1} of dry weight.

Evaluation of antioxidant activity

Preparation of extracts

According to Moubayed *et al.,* 2016 with some modification, 20 grams of each grinded algal species was mixed with 200 ml of 70% ethyl alcohol and placed in a shaking incubator at 25^{o}C overnight. The extract was then harvested and the extraction process was repeated several times till the ethanolic extract became clear. All alcoholic extracts of each algal sample were combined together, filtered through Whatman No.4 filter paper and concentrated up to 5-10 ml in a rotary vacuum evaporator. The residue was evaporated to complete dryness in a vacuum desicator and stored in the refrigerator

DPPH radical scavenging assay

The DPPH (2, 2-Di Phenyl-1-Picryl Hydrazyl) free-radical scavenging assay was carried out in triplicate according to Viturro *et al*., (1999).The EC_{50} value (the amount of antioxidant necessary to decrease the initial DPPH radical concentration by 50 %.) was determined from the plotted graph of scavenging activity versus the concentration of seaweed extracts.

Total Phenolic contents

The phenolic content of the algal extracts was determined according to Folin–Ciocalteau method (Singleton *et al.*, 1999) and it was expressed as Gallic acid equivalent (mg GAE/g).

Antimicrobial activity tests

Preparation of seaweed extracts for antimicrobial activity

Ten grams of each dried sample was extracted in 100 ml of 100% methyl alcohol and placed in a shaking incubator (50 rpm) for 7 days at room temperature. The solution was filtered through Whatman No.1 filter paper and evaporated till dryness under reduced pressure vacuum. The crude extract was dissolved in DMSO to prepare 200 mg/ml stock solution and stored in airtight bottles in a refrigerator before testing (Moubayed *et al.,* 2016).

Microorganisms and culture conditions

The bacterial strains that used during this study were *Enterococcus faecalis* ATCC 29212, *Staphylococcus aureus* ATCC 29213 and *Pseudomonas aeruginosa* ATCC 278223.These bacterial strains were supplied from NCIMB (National Collections of Industrial Food and Marine Bacteria) company and College of Veterinary Medicine, South Valley University. The fungal strains that used during this study included: *Candida albicans* ATCC 10231 and *Aspergillus niger*. These microbial strains were kindly provided by staff members of microbiology Lab., National Institute of Oceanography and Fisheries, Alexandria, Egypt.

Agar well diffusion assay

The crude extracts were screened for antimicrobial activity using the agar well diffusion method as described by Krishnaraj and Mathivanan (2011). A control experiment was carried out by loading sterile DMSO into control well against each test microorganism to ensure that it does not have activity against the tested microorganisms. Chloramphenicol (C) and Streptomycin (S) were used as positive control at a concentration of 30µg/disc to determine the sensitivity of each tested microbial species.

Statistical analysis

All the data were expressed as average ± standard deviation (SD). Statistical analysis was calculated by one way ANOVA followed by Fisher's grouping test. A number of replicate experiments carried out were, n=3. All statistical tests were performed using Minitab® (Version 16) software.

RESULTS

Nutritional composition

The proximate nutritional compositions of the six studied species are presented in Table 1. The results indicated high values of fibers (27.6-36.2 % dry wt.), ash (24.7–35.8 % dry wt.), and carbohydrates (23.4-35.7 % dry wt.), medium values of moisture (2.4-10.8 % dry wt.) and protein (4.8-7.1 % dry wt.), while showed low values of total lipids (0.8-5.2 % dry wt.).As shown in Table 1, the total carbohydrate content was a highly significant difference between species (F= 918.8, P= 0.001). It was varied from 23.4±0.2 in the brown alga *H. cuneiformis* to 35.7±0.5 % dry wt. in the red seaweed *D. simplex.* Results of total soluble protein content showed a highly significant difference among species (F= 37.3, P= 0.001). The highest average was recorded in the brown seaweed *P. myrica* (7.1±0.25 % dry wt.), while the lowest average (4.8±0.4 % dry wt.) was found in the green seaweed *C. racemosa*.

Table 1: Nutritional composition (% dry wt.) of the investigated seaweeds.

Nutritional composition	ANOVA		Fisher's test for species grouping					
	F	P	*Caulerpa racemosa*	*Digenea simplex*	*Hormophysa cuneiformis*	*Padina boergesenii*	*Polycladia myrica*	*Sargassum aquifolium*
Carbohydrates	918.8	0.001	35.5±0.3 A	35.7±0.5 A	23.4±0.2 E	24.7±0.1 D	30.4±0.2 B	29.3±0.15 C
Proteins	37.3	0.001	4.8±0.4 D	5.3±0.05 C	4.8±0.6 D	5.9±0.25 B	7.1±0.25 A	5.4±0.2 C
Lipids	128.3	0.001	5.2±0.4 A	0.8±0.05 D	0.92±0.02 D	3.8±0.5 B	1.3±0.1 D	3.1±0.2 C
Moistures	164.7	0.001	6.1±0.4 C	2.4±0.35 D	10.8±0.65 A	9±0.2 B	9.7±0.4 B	9.1±0.4 B
Ash	560.2	0.001	31.5±0.3 B	24.7±0.3 E	27.5±0.1 D	35.8±0.05 A	27.8±0.4 D	30.8±0.3 C
Fibers	9.1	0.001	31.9±1.5 BC	28.4±0.4 CD	27.6±1.6 D	36.2±2.7 A	34.7±2.2 AB	33.1±2.4 AB

Values are expressed as average ± standard deviation. Different letters (A, B, C & D) indicate significant difference at the level of $p \leq 0.05$.

The lipid content of investigated seaweeds showed a highly significant difference between species (F= 128.3, P=0.001). It was varied from 0.8±0.05 % dry wt. in the red alga *D. simplex* to 5.2±0.4 % dry wt. in the green seaweed *C. racemosa.*

The moisture content of the air dried algal materials was highly significant varied among species (F= 146.7, P= 0.001). The highest average (10.8±0.65% dry wt.) was observed in the brown seaweed *H. cuneiformis*, while the lowest average (2.4±0.35% dry wt.) was found in the red seaweed *D. simplex.*

Ash was the most abundant component of dried materials in all species. Results showed a highly significant difference between species (F= 560.2, P=0.001). It was varied from 24.7±0.3 % dry wt. in the red alga *D. simplex* to 35.8±0.05 % dry wt. in the brown seaweed *P. boergesenii.*

Finally, results of crude fibers showed highly significant differences between species (F=9.1, P= 0.001). The highest average of 36.2±2.7 % dry wt. was observed in the brown seaweed *P. boergesenii*, while the lowest average of 27.6±1.6 was found in the brown seaweed *H. cuneiformis.*

Antioxidant Activity of the investigated algae

The DPPH radical scavenging activity

The antioxidant activities of the crude extracts of seaweeds were evaluated by the measuring the DPPH radical scavenging activity at different concentrations of the crude extract (0.5, 1, 1.5, 2 and 2.5 mg/ ml) as shown in, and the EC_{50} value of each of the seaweed extracts was calculated as presented in. It was evident that the DPPH radical scavenging activities of all the extracts tested follow a dose-dependent manner and increased with the increase in extract concentration. Furthermore, the extracts of different seaweeds exhibited varied antioxidant activities as indicated by the percentage of scavenging activity obtained at the highest concentration tested of each of the crude extracts (Fig. 1).

Among the tested extracts, the crude extract of the brown seaweed, *H. cuneiformis* exhibited the highest antioxidant activity and the lowest EC_{50} value. The percentage of DPPH scavenging activity and the EC_{50} value were 97.2± 2.6 % and 0.86 ±0.07 mg/ ml respectively, followed by the brown seaweed *S. aquifolium* (DPPH scavenging activity was 62.5± 2.6% and EC_{50} was 1.77± 0.07 mg/ ml). The lowest activity was obtained with the green seaweed, *C. racemosa* (DPPH activity 30.8 ± 3.5% and EC_{50} value 4.87 ±0.12). In general, DPPH scavenging activity was significantly different between seaweed species (Table 2).

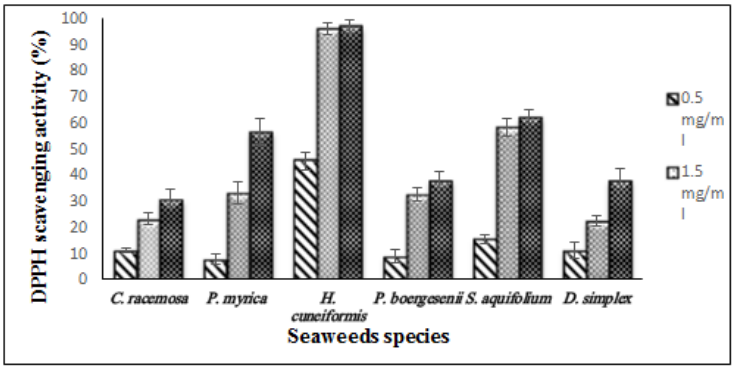


Fig. 1: DPPH radical scavenging activity (%) of macroalgal extracts at different concentrations (0.5, 1.5 and 2.5 mg/mL) expressed as inhibition percentage. Values are expressed as average ± standard deviation.

Total phenolic content (TPC)

The total phenolic content of the six selected algae was analyzed. As shown in Table 2, the crude extract of *H. cuneiformis* had the highest average of TPC (129.9 ± 1.8 mg GAE/g dry wt.). While the lowest average of 31.3 ± 0.6 mg GAE/g dry wt., was observed in the red algae *D. simplex*. In general, ANOVA (F=54.2 and P=0.001) and Fisher's grouping test results indicate significant difference among species.

Table 2: Total phenolic content and EC_{50} values of DPPH free radical scavenging activity of investigated seaweeds.

Species	Total phenolic content mg (GAE)/g dry wt.		EC_{50} mg/ml extract	
ANOVA	F	P	F	P
	54.2	0.001	8.1	0.001
Caulerpa racemosa	41.7 ±0.56 ^{C}		4.87 ±0.12 ^{D}	
Digenea simplex	31.3 ± 0.6 ^{D}		3.27 ±0.09 ^{C}	
Hormophysa cuneiformis	129.9 ± 1.8 ^{A}		0.86 ±0.07 ^{A}	
Padina boergesenii	46.3 ± 0.2 ^{C}		3.16 ±0.13^{C}	
Polycladia myrica	50.2 ± 16.5^{C}		2.01± 0.10^{BC}	
Sargassum aquifolium	96.03 ± 0.3 ^{B}		1.77± 0.07^{B}	

Values are expressed as average ± standard deviation. Different letters indicate significant difference at the level of $p \leq 0.05$.

Correlations between total phenolic content and antioxidant activity

The total phenolic content in tested seaweed extracts displayed a significant (P-Value = 0.001) and strong positive correlation with DPPH free radical scavenging activity (r= 0.850) at 2.5 mg/ml concentration.

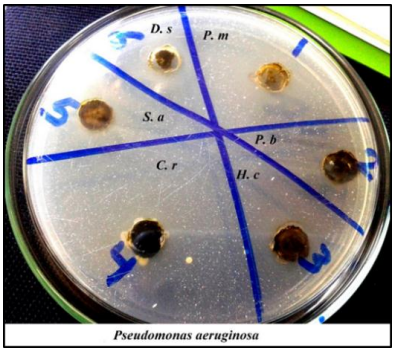
Antimicrobial activity of the investigated seaweeds

The antimicrobial activities of the crude extracts of the selected seaweeds (200 mg/ ml) were evaluated by agar well diffusion methods and the results were expressed as the diameter of inhibition zone (Table 3). All the algal extracts were effective against *Pseudomonas aeruginosa* (Fig. 2a) and *Candida albicans* (Fig. 2b), whereas, only the extract *H. cuneiformis* inhibited the growth of *Enterococcus faecalis* and *Staphylococcus aureus* (Fig. 2c). However, none of the tested extracts was active against *Aspergillus niger* (Table 3). In general, the antimicrobial activity of investigated seaweeds showed highly significant differences between species.

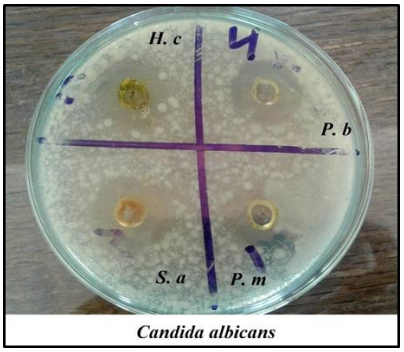
Table 3: Inhibition halo diameter (mm) of extracts of the tested seaweeds and 30 µg/disc of two commercial controls (C and S) against the tested microorganism

Tested microorganism	ANOVA		Control		*Caulerpa racemosa*	*Digenea simplex*	*Hormophysa cuneiformis*	*Padina boergesenii*	Polycladia myrica	*Sargassum aquifolium*
	F	P	C	S						
E. faecalis	932.3	0.001	10±0.32	13±0.5	0 ^{b}	0 ^{b}	20.1±0.3^{a}	0 ^{b}	0 ^{b}	0 ^{b}
S. aureus	952.8	0.001	16±0.3	19±0.3	0 ^{b}	0 ^{b}	27.3±0.3^{a}	0 ^{b}	0 ^{b}	0 ^{b}
P. aeruginosa	128.4	0.001	8.5±0.5	20.4±0.4	15±0.5^{de}	14.5.±0.3^{e}	19±0.3^{b}	16.4±0.4^{c}	20.3±0.2^{a}	15.2±0.2^{d}
C. albicans	6.09	0.002	-	-	12.6±0.9 ^{ab}	13.8±3.4 ^{a}	12.9±4 ^{b}	12.4±2.1 ^{ab}	13±1.6 ^{ab}	12.3±2.2^{b}
A. niger	0	0	-	-	0	0	0	0	0	0

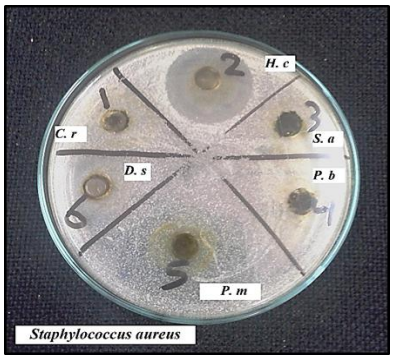
Each value is the average of the inhibition zone (mm) ±SD. Each average carrying different superscripts is significantly different from each other at P =0.001. C refers to Chloramphenicol antibiotic-and S to Streptomycin.



a. *Pseudomonas aeruginosa.*



b. *Candida albicans*



c. *Staphylococcus aureus*

Fig. 2: Inhibition halo zone of seaweed extracts against the tested microorganisms. *S. a* (*Sargassum aquifolium*), *P. m* (*Polycladia myrica*), *H. c* (*Hormophysa cuneiformis*), *P. b* (*Padina boergesenii*), *D. s* (*Digenea simplex*) and *C. r* (*Caulerpa racemosa*).

Comparing the potency of the antimicrobial activity of the crude extracts with two commercial antibiotics, Streptomycin and chloramphenicol, indicated that, all of the tested extracts exhibited higher antimicrobial activity than chloramphenicol against *P. aeruginosa*, however, streptomycin was more active against the same microorganism. Moreover, the extract of *H. cuneiformis* was more active than streptomycin and chloramphenicol against *E. faecalis* (Table 3).

DISCUSSION

Nutritional composition of investigated seaweeds

Seaweeds are considered as highly nutritive food having proteins, fibers, vitamins, minerals and essential fatty acids (Ortiz *et al*., 2006). Carbohydrates are considered the most important biochemical constituent in algae since they represent the main energy source for the metabolic process (Wells *et al*., 2017). The total carbohydrates content of the six studied seaweeds ranged from 23.4 - 35.7% of dry wt. However, El-Manawy (2008b) found the carbohydrates range to be 7.07- 14.77% of dry weight and Osman *et al.* (2011) reported a carbohydrate content of (14.6 - 45.6%) of the dry weight of some seaweeds collected from the same site. This difference in content could be due to the difference of harvested seaweed species, season and methods of measurement. According to Ahmed *et al.* (2015), the higher content of carbohydrate in the red alga *D. simplex* might be due to the high phycocolloid content in its cell wall.

Results of total soluble protein content showed a highly significant difference among species. The highest average was recorded in the brown seaweed *P. myrica*, while the lowest average was found in the green seaweed *C. racemosa.* Similarly, Dinesh *et al.* (2007) and Ahmed *et al.* (2015) reported higher protein content in brown than green seaweeds. Contrary, El-Manawy (2008b) and Osman *et al.* (2011) reported more protein content in red than brown seaweeds. In general, the protein content of macroalgae differs greatly from species to another in different taxonomic group or even within species of the same genus (Fathy, 2007 and Ahmed *et al.*, 2015).

Seaweeds contain low levels of lipids, varying from 0.92 to 5 % dry wt. (Schmid *et al.*, 2014). The lipid content of investigated seaweeds showed a highly significant difference between species, it was varied from 0.8±0.05 % dry wt., in the red alga *D. simplex* to 5.2±0.4 % dry wt. in the green seaweed *C. racemosa*. However, Kumar *et al*. (2011) reported relatively lower lipids values (2.64 ± 0.20% dry wt.) for *C. racemosa* collected from Veraval Coast in India. In general, the variation in lipid content among species could be related to the taxonomic entity, seasonality of sampling, location and macroalgae growth conditions (Khotimchenko, 2005) in addition to extraction processing and solvent polarity (Li *et al.*, 2013).

The moisture content of food is a critical factor to improve food quality and preservation (Nielsen, 2010). For successful marketing and preservation of commercially dried seaweeds, the moisture content should be maintained between 15 and 35% and remain stable even below 15% (Blakemore, 1990). Accordingly, the moisture content of the studied seaweeds (2.4±0.35- 10.8±0.65%) suggests their stability during storage and marketing.

Ash content was among the most abundant constituents of the studied algal species (24.7-35.8), with the highest value obtained in the brown seaweed *P. boergesenii* and the minimum content was observed at the red seaweed *D. simplex*. These results are in agreement with previous reports on seaweeds (Wong and

Cheung, 2001; Zubia *et al*., 2003; McDermid and Stuercke, 2003; Marsham *et al.*, 2007 Kasimala*et al.*, 2017). According to Kasimala *et al.*, (2017), the high ash content could be due to the presence of salt in fronds and the mineral accumulation induced by the high salinity of the Red Sea.

It has been reported that the average content of dietary fiber in seaweeds ranged from 30 to 40% of dry weight (Rasmussen and Morrissey, 2007). However, our results reported the highest average of dietary fiber content in the brown seaweed *P. boergesenii* to be 36.2±2.7 % dry wt. and the lowest average in the brown seaweed *H. cuneiformis* to be 27.6±1.6. These results are in agreement with Gómez-Ordóñez *et al*. (2010). These results of nutritional composition of the studied seaweeds suggest that, they could be an excellent source of Ash, carbohydrates andfibers.

Antioxidant activity of the investigated seaweeds

Total phenolic content (TPC)

In the present study, the total phenolic content was highly significant varied among species. The crude extract of the brown seaweed *H. cuneiformis* had the highest average of TPC (129.9 ± 1.8 mg GAE/g dry wt.). While the lowest average of 31.3 ± 0.6 mg GAE/g dry wt., was observed in the red seaweed *D. simplex*. Similarly, Li *et al*., 2011 reported that phenolic content was higher in brown seaweeds and in lower amounts in some red algae. Furthermore, Machu *et al*., 2015 stated that variations in total phenolic contents among seaweed species due to many influencing factors, such as geographical origin, seasonal, physiological, and environmental variations.

The DPPH radical scavenging activity

The crude extract of the brown seaweed, *H. cuneiformis* exhibited the highest antioxidant activity where the percentage of DPPH scavenging activity was high (97.2± 2.6 %) as compared to other seaweeds. On the other hand, the lowest activity was observed in the green seaweed *C. racemosa* (30.8± 3.5%). These findings are in agreement with the results obtained by Wang *et al*. (2009), Cox *et al*., 2010 and Sarojini, *et al*., 2016. They concluded that high amounts of polyphenols and DPPH radical scavenging activity are found in the brown seaweeds than red and green species. The highest antioxidant activity of brown algae in the present study could be due to the highest phenolic content in these algae, which agrees with the studies of Indu and Seenivasan, 2013. Furthermore, the total phenolic in the studied seaweed extracts showed a significant (P= 0.001) and a strong positive correlation (r= 0.85) with DPPH free radical scavenging activity. These observations are in accordance with those of Matanjun *et al*. (2008) and Wang *et al*. (2009). The high activities observed in this work suggest that the studied macroalgae could also be used as food preservative, preventing lipid peroxidation, which can cause deterioration in food (Gupta and Abu- Ghannam, 2011).

Antimicrobial activity of the investigated seaweeds

Antimicrobial activity of the Red Sea seaweeds against both bacteria and fungi has been established by several workers (Shanab, 2007; Salem *et al*, 2011; Selim, 2012 and Sheikh *et al*., 2018). But there was variation in the antibacterial activities which may be due to the method and solvent used in the extraction and season at which samples were collected (Kandhasamy and Arunachalam, 2008).

In the present study, all the algal extracts were effective against *Pseudomonas aeruginosa;* while the extract of *H. cuneiformis* is the only one that effective against the *Enterococcus faecalis* and *Staphylococcus aureus* at the concentration of 200 mg/ml of extract. The results showed that Gram-negative organisms were more

susceptible to the methanolic extract of the algae used. In contrast, Salem *et al.* (2011) reported that Gram-positive bacteria were more efficiently controlled by the extracts of the algae used in their study compared to Gram-negative bacteria. Furthermore, the present results are in agreement with El-Sheikh *et al.* (2014). The more susceptibility of a specific group of bacteria was due to the variance in their cell wall structure and their composition (Demirel *et al*., 2009). While the outer membrane of Gram-negative bacteria acts as a barrier to many environmental elements including antibiotics (Tortora *et al.,* 2007). In general, the capacity of antimicrobial activities was considered to be an indicator of the seaweeds capability to synthesize bioactive secondary metabolites. Many bioactive compounds from marine seaweeds were confirmed to possess antimicrobial activity. Demirel *et al*. (2009) identified different groups of compounds with antimicrobial activity including hydrocarbons, terpenes, acids, phenols, a sulfur-containing compound, aldehydes, naphthalene skeleton and alcohols. Phenolic compounds have been identified in several seaweed species as biologically active compounds with antimicrobial activity (Bansemir *et al*., 2006). This agrees with the results of the present study that revealed the presence of phenolic compounds in considerable amounts, especially in some brown seaweeds.

All of the tested extracts exhibited antimicrobial activity against *Candida albicans*, while, had no effect against *Aspergillus niger*. Similarly, El-Sheikh *et al.* (2014) investigated the antimicrobial activity of four macroalgae and observed the antifungal activity only against *Candida albicans*. The antimicrobial activity of the algal extracts tested during the present investigation against the tested pathogens suggests that these seaweeds could be a promising source of antibiotic substances useful in the treatment of diseases caused by these pathogens.

CONCLUSION

The six studied Red Sea seaweeds demonstrated a good source of carbohydrate, fibers, minerals, phenols, antioxidant and antimicrobial activities. However, the nutritional values of these seaweeds were based on chemical analyses only. Biological evaluation using human and animal feeding studies would be required to establish the nutritional value of these seaweeds. Among the tested species; *Hormophysa cuneiformis* has been shown to possess a specific phenolic content, antioxidant and antimicrobial activities, thus could be used as a potential source for biologically active compounds.

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