Saudi Pharmaceutical Journal 26 (2018) 25–32

Contents lists available at ScienceDirect

Saudi Pharmaceutical Journal

journal homepage: www.sciencedirect.com

Original article

Biological activities of the red algae *Galaxaura rugosa* and *Liagora hawaiiana* butters

Nouf M. Al-Enazi [a], Amani S. Awaad [b,*], Saleh I. Alqasoumi [c], Metab F. Alwethairi [d]

[a] Biology Department, College of Science and Humanity Studies, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia
[b] Pharmacognosy Department, College of Pharmacy, Prince Sattam bin Abdulaziz University, Al-Kharj, Saudi Arabia
[c] Pharmacognosy Department, College of Pharmacy, King Saud University, Saudi Arabia
[d] Clinical Pharmacist, King Abdulaziz Medicinal City, Saudi Arabia

ARTICLE INFO

Article history:
Received 16 October 2017
Accepted 12 November 2017
Available online 13 November 2017

Keywords:
Phytochemical screening
Antitumor
Antioxidant
Antimicrobial
Extraction

ABSTRACT

The biological activities; antimicrobial, antioxidant and anticancer, of the red algae *Galaxaura rugosa* and *Liagora hawaiiana* were determined. The total ethanol, lipoidal matters, chloroform, n-butanol, aqueous extracts and powder of both algae showed and bacterial and antifungal activities. However, the chloroform extract of *Galaxaura rugosa* showed antibacterial activity against *Klebsiella pneumoniae* (24 mm, 0.15 mg/ml) higher than gentamycin (23 mm, 0.49 mg/ml). Moreover, the total ethanol, lipoidal matter and chloroform extracts showed antifungal activity (21, 22 and 25 mm, 1.25, 0.312 and 0.156 mg/ml) similar to the antibiotic Ketoconazole activity (23, 24 and 27 mm, 1.25, 0.312 and 0.156 mg/ml) against *Aspergillus fumigatus*, *A. niger* and *Candida trobicalis*, respectively. A good antioxidant activity (80.96%, IC_{50} = 27.8 μg/ml) was provided by *Galaxaura rugosa*. The anticancer activity results revealed that the lipoidal matters of *Galaxaura rugosa* and *Liagora hawaiiana* possessed antitumor activity (IC_{50} = 15 ± 1.7 and 21.2 ± 1.6, respectively) against lung carcinoma (A-549) better than vinblastine sulfate (IC_{50} = 24.6 ± 0.7). Although, the lipoidal matters of *Galaxaura rugosa* and *Liagora hawaiiana* antitumor activity against cervical carcinoma (HeLa) and intestinal carcinoma (CACO-2) (IC_{50} = 10.2 ± 0.6 and 12.2 ± 0.6, respectively) preferable than vinblastine sulfate (IC_{50} = 59.7 ± 2.1 and 30.3 ± 1.4, respectively).

1. Introduction

The interest in ancient herbal remedies has been significantly increased in the last few decades. In the worldwide, all the natural resources including medicinal plants, fungi and algae are screened for their biological activities (Awaad et al., 2013, Zain et al., 2012, Amornlerdpison et al., 2007). Accordingly, the therapeutic values and pharmaceutical usage of numerous herbal medicines have already been validated. The herbal medicines which obtained from natural sources are considered as safe for human beings. However, they would have some antagonistic effects due to presence of other active ingredients (Izzo and Ernst, 2009).

Algae are found everywhere: in the sea, rivers, lakes, soil, walls, and as symbiont in animal and plants. Algae include four main divisions; namely, Red algae (Rhodophya), Brown Algae (Phycophyta), Green Algae (Chlorophyta) and Diatoms. Although, Seaweeds which are macroscopic, multicellular, and marine algae, are divided into three categories; red, green and brown organisms comprises about 30000 species. In most of Asian countries, seaweeds are traditionally traded as food items including sushi wrappings, seasonings, condiments, and vegetables (El Gamal, 2010; Mark et al., 2016).

Antioxidants have attracted the most interest among the many biologically-active compounds found in algae. Antioxidants are important compounds in the treatment and recovery from various diseases including cancer, chronic inflammation, atherosclerosis, cardiovascular disorders, and aging process (Kohen and Nyska, 2002). Although, the search for anticancer drugs has similar attention as marine compounds revealed promising results at different stages of cancer progress (Mayer and Gustafson, 2006). On the other hand, in developed and developing countries, the most people died following infectious bacterial and/or fungal diseases. The bacterial Gram-positive and Gram-negative organisms including

* Corresponding author at: P.O. Box 173, Riyadh 11942, Saudi Arabia.
E-mail address: amaniawaad@hotmail.com (A.S. Awaad).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.jsps.2017.11.003
1319-0164/

different species of *Bacillus*, *Proteus*, *Klebsiella*, *Staphylococcus*, *Salmonella* and *Pseudomonas* are the main source of severe infections in animals including humans (Nathan, 2004).

Among seaweeds, numerous macroalgae have potent cytotoxic activities (Mayer and Gustafson, 2006, Smit, 2004) and algal consumption has been suggested as a chemo-preventive agent against several cancers (Yuan and Walsh, 2006). Recently, due to their exceptional richness in bioactive compounds (e.g., antimicrobial, anti-inflammatory, and antitumoral activities), the seaweeds has significantly expanded into the pharmaceutical and para-pharmaceutical industry (Kornprobst, 2005; Smit, 2004). The current study aimed to assess the biological activity including antioxidant, antimicrobial, and anticancer of different extracts of the red algae *Galaxaura rugosa* and *Liagora hawaiiana*.

2. Material and methods

2.1. Algal samples collection, extraction and screening

2.1.1. Algal species collections

The algal species used in this study; namely, *Galaxaura rugose* and *Liagora hawaiiana* Butters were collected from Alharra, Umluj, Red Seashore, Kingdom of Saudi Arabia. Algal species were identified according to Aleem (1993) and Coppejans et al. (2009). Samples collected were air-dried in shade, reduced to fine powder, packed in tightly closed containers and stored for phytochemical and biological studies.

2.1.2. Algal extraction

Dry powder (830 and 795 g) of *Galaxaura rugose* and *Liagora hawaiiana*; respectively, were extracted by percolation in 95% ethanol (Awaad et al., 2017a) at room temperature for two days. The total ethanol extract was filtered and the residue was re-percolated by the same manor for five times. The ethanol extract was then concentrated, under reduced pressure at low temperature, and a yield of 81 and 77 g was obtained from *Galaxaura rugose* and *Liagora hawaiiana*, respectively.

The obtained extracts of each algae was separately suspended in water (300 ml) and filtered over a piece of cotton. The lipoidal matter, collected on top of the cotton piece (25 and 28 g. for *Galaxaura rugose* and *Liagora hawaiiana*, respectively) were obtained. The aqueous layer, which filtered off, was successively fractionated using chloroform and *n*-butanol. Each extract was dried over anhydrous sodium sulfate, concentrated and yielded 11 & 30 g and 14 and 26 g for chloroform and *n*-butanol of *Galaxaura rugos* and *Liagora* hawaiiana, respectively. However, after extraction with *n*-butanol some powder was precipitated from each algae and the filtration was carried out to separate it and. The leftover aqueous extract of each alga was dried using lyophilization (Awaad et al., 2017b) and kept for further investigation.

2.1.3. Phytochemical screening

Powdered sample of each investigated alga (*Galaxaura rugose* and *Liagora hawaiiana*) was subjected to phytochemical screening as published by Khan et al. (2011) to investigate their phytochemical constituents.

2.2. Antimicrobial activity

2.2.1. Test organisms

Different clinically isolated bacterial and fungal strains; namely, *Aspergillus fumigatus* (RCMB 02568), *Aspergillus niger* (RCMB 02724), *Bacillus substilis* (RCMB 010015), *Candida albicans* (RCMB 05003), *Candida. tropicalis* (RCMB 05004), *Cryptococcus neoformans* (RCMB 05642), *Escherichia coli* (RCMB 010052), *Geotricum candidum* (RCMB 05097), *Klebsiella pneumonia* (RCMB 0010093), *Microsporum canis* (RCMB 0834), *Penicillium expansum* (RCMB 01924), *Pseudomonas aeruginosa* (RCMB 0100243-5), *Proteous vlgaris* (RCMB 01004) *Staphylococcus aureus* (RCMB 010010), *Staphylococcus epidermidis* (RCMB 010009), *Streptococcus byogenes* (RCMB 0100174-2), *Stroptococcus mutans* (RCMB 0100017) *Salmonella typhimurium*, RCMB (RCMB 14028), *Syncephalastrum racemosum* (RCMB 05922) and *Trichophyton mentagrophytes* (RCMB 0925) were obtained from the Microbiology Laboratory, Regional Center for Mycology and Biotechnology, Al-Azhar University, Cairo, Egypt and used as test organisms.

2.2.2. Antimicrobial assay

The antibacterial and antifungal activities of total ethanol, lipoidal matters, chloroform *n*-butanol, aqueous extracts and powder of *Galaxaura rugosa* and *Liagora hawaiiana* were determined using the well-diffusion method (Almalki, 2017). Petri plates containing 20 ml of, nutrient (for bacteria) or malt extract (for fungi), agar medium were seeded with 1–3 day cultures of microbial inoculums. Wells (6 mm in diameter) were cut off from agar and 50 μl of algal extracts were tested in a concentration of 100 mg/ml and incubated at 37 °C for 24–48 h (bacterial strains) and for 3–5 days (fungal strains). The antibacterial and antifungal activities were determined by measurement of the diameter of the inhibition zone around the well.

2.2.3. Determination of minimum inhibitory concentration (MIC)

The minimum inhibitory concentration (MIC) of algal extract was determined by micro-dilution method using serially diluted (2 folds) algal extracts (Zain et al., 2012). The MIC of total ethanol, lipoidal matter, chloroform, *n*-butanol, aqueous extracts and powder of *Galaxaura rugosa* and *Liagora hawaiiana* were determined by dilution of concentrations from 0.0 to 100 mg/ml. Equal volumes of each extract and nutrient broth were mixed in a test tube. Specifically 0.1 ml of standardized inoculum ($1–2 \times 10^7$ cfu/ml) was added in each tube. The tubes were incubated at 37 °C for 24–48 h and/or 3–5 days. Two control tubes, containing the growth medium, saline and the inoculum were maintained for each test batch. The lowest concentration (highest dilution) of the algal extract that produced no visible microbial growth (no turbidity) when compared with the control tubes were regarded as MIC.

2.3. Antioxidant assay

The antioxidant activity of *Galaxaura rugosa* and *Liagora hawaiiana* different extracts were determined using DPPH free radical scavenging assay as describe by Aksoy et al. (2013) in triplicate and average values were considered. The tested extracts were also compared using the IC_{50} value; i.e., the concentration leading to 50% inhibition which was estimated from graphical plots of DPPH Radical Scavenging% Vs concentrations**.**

2.4. Antitumor activity

The antitumor activity of total ethanol, lipoidal matters, chloroform, *n*-butanol, aqueous extracts and powder of *Galaxaura rugosa* and *Liagora hawaiiana* were determined using A-549 (Lung carcinoma), CACO (colorectal carcinoma), HCT-116 (Colon carcinoma), Hela (Cervical carcinoma), HEp-2 (Larynx carcinoma), HepG-2 (Hepatocellular carcinoma), and MCF-7 (Breast carcinoma) cell lines as described by Kameyama et al. (2005).

2.5. Statistical analysis

All values were expressed as mean ± S.D. Comparisons between means were carried out using a one-way ANOVA test followed by the Tukey HSD test using SPSS, version 14 (SPSS, Chicago, IL). Differences at p50.05 were considered statistically significant.

3. Results and discussion

3.1. Preliminary phytochemical screening

The preliminary phytochemical analyses of *Galaxaura rugosa* and *Liagora hawaiiana* revealed the presence of different primary and secondary metabolites, they contains unsaturated sterols and/or triterpenoids, flavonoids, carbohydrates or glycosides, proteins and/or amino acids, tannins and coumarin, no saponins or alkaloids were detected. This variety of active metabolites give these algae high potentials to be used as source of medication specially the presence of flavonoids (Kosanić et al., 2015).

3.2. Antimicrobial activity

The antimicrobial activity of total ethanol, lipoidal matters, chloroform, n-butanol, aqueous extracts, and powder of *Galaxaura rugosa* and *Liagora hawaiiana* were determined against Gram-negative, Gram-positive bacteria and fungi (Tables 1 and 2). The results revealed that all the extracts of *Galaxaura rugosa* showed antibacterial and antifungal activities. On the other hand, only lipoidal matters, chloroform, *n*-butanol and aqueous extracts of *Liagora hawaiiana* showed antibacterial and antifungal activity, in addition to the powder which has only antifungal activity (Tables 1 and 2).

Among the extracts of *Galaxaura rugosa*, chloroform, n-butanol, and aqueous extracts inhibited the growth of nine, out of ten, bacterial test organism. While total ethanol extract and lipoidal matters showed antifungal activity against 8, out of ten, fungal test strains. Interestingly, the chloroform extract of *Galaxaura rugosa* exhibited antibacterial activity against *Klebsiella pneumoniae* (24 mm, 0.15 mg/ml) higher than the standard antibiotic Gentamycin (23 mm, 0.49 mg/ml). Moreover, the total ethanol, lipoidal matter and chloroform extracts showed antifungal activity (21, 22 and 25 mm, 1.25, 0.312 and 0.156 mg/ml) similar to the antibiotic Ketoconazole activity (23, 24 and 27 mm, 1.25, 0.312 and 0.156 mg/ml) against *Aspergillus fumigatus*, *A. niger* and *Candida trobicalis*, respectively (Tables 1 and 3). The chloroform extract of *Liagora hawaiiana* showed the best antibacterial and antifungal activities. With the exception of *Microcanis canis* and *Trichophyton mentagrophytes*, it inhibited the growth of all tested fungal strains in addition to all the bacterial strains. Furthermore, the potency of chloroform extract against *Candida tropicalis* (27 mm, 0.078 mg/ml) was similar to that of the standard antibiotic, Ketoconazole (27 mm, 0.98 mg/ml) (Tables 2 and 4).

From the previous studied it was concluded that researchers have isolated different compounds from algae including terpenoids, phlorotannins, polyphenols, phenolic acids, anthocyanins, hydroxycinnamic acid derivatives, and flavonoids (Bhat and Madyastha, 2000, 2001; Benedetti, 2004). Nevertheless, the antibacterial, antifungal and antiviral activities of algal extracts are extensively published (El-Fatemy and Said, 2011; Manilal et al., 2009; Rajasulochana et al., 2009; Ely et al., 2004). Although, the obtained results of the current study revealed the antimicrobial activity of extracts of *Galaxaura rugosa* and *Liagora hawaiiana* using different solvents which indicates the multiplicity and diversity of the compounds present in algae

3.3. Antioxidant activity

The antioxidant activity of *Galaxaura rugosa,* and *Liagora hawaiiana* were screened using DPPH assay. It is the most commonly used assay because it can run many samples in short time and detect the active components at low concentration (Piao et al., 2004). The current results exhibited that the total ethanol extract of *Galaxaura rugosa,* and *Liagora hawaiiana* have DPPH radical scavenging activity in a concentration–dependent manner (Table 5).

Table 1
Antimicrobial activity of different extracts of *Galaxaura rugosa*.

Extract Test organism	Mean diameter of inhibition zone (mm)						
	Total (Ethanol)	Lipoidal matter	Chloroform	*n*-Butanol	Aqueous	Powder	Standard antibiotic
Bacteria							*Gentamycin*
Gram-negative							
Escherichia coli	15	18	22	16	22	15	36
Klebsiella pneumoniae	14	19	24	15	16	14	23
Proteous vulgaris	18	22	20	19	15	16	31
Pseudomonas aeruginosa	00	00	15	00	00	00	25
Salmonella typhimrium	00	14	21	15	15	00	27
Gram-positive							
Bacillus substilis	14	18	17	16	16	15	32
Staphylococcus aureus	19	14	22	21	18	20	30
Staphylococcus epidermidis	20	00	19	21	17	14	34
Streptococcus mutans	00	00	14	15	20	00	26
Streptococcus pyogenes	00	00	00	14	18	00	28
Fungi	*Ketocona-zole*						
Aspergillus fumigatus	21	16	00	00	00	00	23
Aspergillus niger	15	22	00	00	00	00	24
Candida albicans	18	16	20	18	15	18	26
Candida trobicalis	17	19	25	19	16	23	27
Cryptococcus neoformans	20	15	27	22	18	15	31
Geotricum candidum	15	17	22	20	15	22	30
Penicillium expansum	14	23	00	00	00	00	28
Syncephalastrum racemosum	14	14	00	00	00	00	24
Dermatophytes	*Amphotericin B*						
Microsporum canis	00	00	00	00	00	00	30
Trichophyton mentagrophytes	00	00	00	00	00	00	29

Values are expressed as mean ± SEM of 3 determinants.

Table 2
Antimicrobial activity of different extracts of *Liagora hawaiiana*.

Extract Test organism	Mean diameter of inhibition zone (mm)						
	Total(Ethanol)	Lipoidal matter	Chloroform	*n*-Butanol	Aqueous	Powder	Standard Antibiotic
Bacteria	*Gentamycin*						
Gram-negative							
Escherichia coli	00	21	21	15	23	00	36
Klebsiella pneumoniae	00	22	20	16	16	00	23
Proteous vulgaris	00	15	18	21	15	00	31
Pseudomonas aeruginosa	00	14	15	00	00	00	25
Salmonella typhimrium	00	19	16	14	00	00	27
Gram-positive							
Bacillus substilis	00	15	17	00	00	00	32
Staphylococcus aureus	00	17	18	00	00	00	30
Staphylococcus epidermidis	00	14	14	00	00	00	34
Streptococcus mutans	00	20	24	00	00	00	26
Streptococcus pyogenes	00	19	19	00	00	00	28
Fungi	*Ketocona-zole*						
Aspergillus fumigatus	00	00	16	00	00	00	23
Aspergillus niger	00	00	16	00	00	00	24
Candida albicans	00	21	22	14	16	14	26
Candida trobicalis	00	22	27	15	18	15	27
Cryptococcus neoformans	00	24	25	19	21	17	31
Geotricum candidum	00	21	21	14	15	14	30
Penicillium expansum	00	00	20	00	00	00	28
Syncephalastrum racemosum	00	00	15	00	00	00	24
Dermatophytes	*Amphotericin B*						
Microsporum canis	00	00	00	00	00	00	30
Trichophyton mentagrophytes	00	00	00	00	00	00	29

Values are expressed as mean ± SEM of 3 determinants

Table 3
The minimum inhibitory concentration (MIC) of different extracts of *Galaxaura rugosa*.

Extract Test organism	Minimum Inhibitory Concentration (mg/ml)						
	Total (Ethanol)	Lipoidal matter	Chloroform	*n*-Butanol	Aqueous	Powder	Standard Antibiotic
Bacteria	*Gentamycin*						
Gram-negative							
Escherichia coli	5.000	2.500	0.312	5.000	0.625	5.000	03.90
Klebsiella pneumoniae	10.00	2.500	0.156	5.000	5.000	10.00	00.49
Proteous vulgaris	2.500	0.625	1.250	2.500	5.000	5.000	01.95
Pseudomonas aeruginosa	ND	ND	5.000	ND	ND	ND	01.95
Salmonella typhimrium	ND	10.00	0.625	5.000	5.000	ND	01.95
Gram-positive							
Bacillus substilis	10.00	1.250	2.500	5.000	5.000	5.000	01.95
Staphylococcus aureus	ND	10.00	0.625	0.625	2.500	1.250	01.95
Staphylococcus epidermidis	ND	ND	1.250	0.625	2.500	10.000	00.98
Streptococcus mutans	ND	ND	10.00	5.000	1.250	ND	01.95
Streptococcus pyogenes	ND	ND	ND	10.00	2.500	ND	00.98
Fungi	*Ketocona-zole*						
Aspergillus fumigatus	1.250	5.000	ND	ND	ND	ND	00.49
Aspergillus niger	5.000	0.312	ND	ND	ND	ND	03.90
Candida albicans	2.500	5.000	1.250	1.250	5.000	1.250	01.95
Candida trobicalis	2.500	1.250	0.156	2.500	5.000	0.312	00.98
Cryptococcus neoformans	1.250	5.000	0.078	0.625	2.500	5.000	01.95
Geotricum candidum	5.000	2.500	0.312	1.250	5.000	0.625	03.90
Penicillium expansum	10.00	0.312	ND	ND	ND	ND	01.95
Syncephalastrum racemosum	10.00	10.00	ND	ND	ND	ND	00.98

ND, not determined. Values are expressed as mean ± SEM of 3 determinants.

The maximum scavenging activity (80.96%, IC_{50} = 27.8 μg/ml) was provided by *Galaxaura rugosa*. However, the scavenging activity of *Liagora hawaiiana* was 66.87% (IC_{50} = 57.2 μg/ml) (Table 5).

The free radicals are involved in several diseases including cancer, AIDS and neurodegenerative diseases. The scavenging activity of antioxidants is very useful for the control of those diseases (Suresh et al., 2008; Koleva et al., 2002). Interestingly, the antioxidant activity of *Galaxaura rugosa* was very good (27.8 ± 1.22) and almost similar to the antioxidant activity of ascorbic acid (86.36%, IC_{50} = 11.2 μg/ml) (Table 5), this can be due to the presence of flavonoids in both algae (Farasat et al., 2014; Yen & Duh, 1994).

3.4. Antitumor activity

The cancer, cells growing out of control, causes are diverse, complex and not fully understood. The cancer diseases are classified according to the type of cell that the tumor cells resemble and are presumed to be the origin of the tumor. Herbal medicines are used worldwide for cancer prevention and treatment. The

Table 4
The minimum inhibitory concentration (MIC) of different extracts of *Liagora hawaiiana.*

Extract Testorganism	Minimum Inhibitory Concentration (mg/ml)						
	Total (Ethanol)	Lipoidal matter	Chloroform	*n*-Butanol	Aqueous	Powder	Standard antibiotic
Bacteria	*Gentamycin*						
Gram-negative							
Escherichia coli	ND	0.625	0.625	5.000	0.625	ND	03.90
Klebsiella pneumoniae	ND	0.312	1.250	5.000	5.000	ND	00.49
Proteus vulgaris	ND	10.00	2.500	0.625	10.00	ND	01.95
Pseudomonas aeruginosa	ND	10.00	5.000	ND	ND	ND	01.95
Salmonella typhimrium	ND	1.250	5.000	10.00	ND	ND	01.95
Gram-positive							
Bacillus substilis	ND	5.000	2.500	ND	ND	ND	01.95
Staphylococcus aureus	ND	2.500	1.250	ND	ND	ND	01.95
Staphylococcus epidermidis	ND	10.00	10.00	ND	ND	ND	00.98
Streptococcus mutans	ND	1.250	0.312	ND	ND	ND	01.95
Streptococcus pyogenes	ND	2.500	1.250	ND	ND	ND	00.98
Fungi	*Ketocona-zole*						
Aspergillus fumigatus	ND	ND	5.000	ND	ND	ND	00.49
Aspergillus niger	ND	ND	10.00	ND	ND	ND	03.90
Candida albicans	ND	0.625	0.625	10.00	5.000	10.00	01.95
Candida trobicalis	ND	0.312	0.078	5.000	2.500	5.000	00.98
Cryptococcus neoformans	ND	0.156	0.312	1.250	0.625	5.000	01.95
Geotricum candidum	ND	0.625	0.625	10.00	5.000	10.00	03.90
Penicillium expansum	ND	ND	1.250	ND	ND	ND	01.95
Syncephalastrum racemosum	ND	ND	5.000	ND	ND	ND	00.98

ND, not determined. Values are expressed as mean ± SEM of 3 determinants.

Table 5
The scavenging activity of DPPH radicals of *Galaxaura rugosa* and *Liagora hawaiiana*.

Concentration (μg/ml)	DPPH scavenging (%)		
	Galaxaura rugosa	*Liagora hawaiiana*	Ascorbic acid
000	00.00	00.00	00.00
001	10.87 ± 1.50	4.96 ± 1.32	12.98 ± 1.41
002	12.35 ± 1.11	9.83 ± 1.21	16.38 ± 1.44
004	21.39 ± 1.71	16.61 ± 1.54	62.98 ± 1.62
008	28.09 ± 1.32	22.35 ± 1.33	76.81 ± 1.57
016	34.35 ± 1.91	27.91 ± 1.38	78.72 ± 1.75
032	55.48 ± 1.22	35.65 ± 1.30	78.94 ± 1.51
064	66.00 ± 1.58	53.83 ± 1.27	80.21 ± 1.14
128	80.96 ± 1.30	66.87 ± 1.12	86.36 ± 1.09
IC_{50}	**27.8 ± 1.22**	**57.2 ± 1.35**	**11.2 ± 1.55**

Values are expressed as mean ± SEM of 3 replicates.

effect of natural products as anti-cancer was widely studied because their nature, low toxicity and side effects (Manglani et al., 2014, Mulla & Swamy, 2012, Jani & Jain, 2011).

In the present study, the *in vitro* antitumor activity of *Galaxaura rugosa* and *Liagora hawaiiana* extracts was determined against different cell lines including A-549 (Lung carcinoma), CACO (Intestinal carcinoma), HCT-116 (Colon carcinoma), Hela (Cervical carcinoma), HEp-2 (Larynx carcinoma), HepG-2 (Hepatocellular carcinoma), and MCF-7 (Breast carcinoma). Because it is reliable to assess the *in vitro* cytotoxicity of the anticancer compounds, MTT assay method (Allely et al., 1998) was used.

The obtained results revealed that the extracts of *Galaxaura rugosa* and *Liagora hawaiiana* have a remarkable antitumor activity against different types of tumor cells (Tables 6 and 7). Interestingly, the lipoidal matters of *Galaxaura rugosa* and *Liagora hawaiiana* possessed antitumor activity (IC_{50} = 15±1.7 and 21.2 ± 1.6,

Table 6
The antitumor activity of extracts of *Galaxaura rugosa* against different cell lines.

Cell line	Concentration (μg/ml)	Cell viability (%)						
		Total (Ethanol)	Lipoidal matters	Chloro-form	*n*-butanol	Aqueous	Powder	Vinblastine sulfate
A-549	000.00	100	100	100	100	100	100	100
Lung carcinoma	001.00	100	98.1	100	100	100	100	98.2
	002.00	98.1	92.3	100	100	100	100	94.7
	003.90	94.0	84.9	98.6	100	100	98.4	81.4
	007.80	87.3	67.2	93.7	100	98.1	91.7	73.8
	015.60	76.9	48.6	85.1	99.2	92.8	85.0	62.5
	031.25	63.1	40.9	70.4	95.0	84.0	72.3	40.7
	062.50	41.9	32.8	54.8	89.4	69.5	59.1	32.9
	125.00	30.6	21.9	38.7	68.1	42.7	38.6	25.2
	250.00	22.8	12.8	23.8	40.7	29.4	23.1	15.3
	500.00	10.7	06.3	12.9	27.8	14.5	10.9	06.8
CACO-2	**IC_{50} (μg/ml)**	**50.7 ± 3.5**	**15 ± 1.7**	**81.4 ± 4.5**	**208 ± 17.2**	**108 ± 9.2**	**90.4 ± 7.8**	**24.6 ± 0.7**
Intestinal carcinoma	000.00	100	100	100	100	100	100	100
	001.00	100	100	100	100	100	100	99.2
	002.00	100	98.7	100	100	100	100	93.8
	003.90	100	95.4	100	100	97.8	100	86.2
	007.80	99.4	89.2	99.4	97.4	92.4	99.4	79.4

(*continued on next page*)

Table 6 (*continued*)

Cell line	Concentration (μg/ml)	Cell viability (%)						
		Total (Ethanol)	Lipoidal matters	Chloro-form	*n*-butanol	Aqueous	Powder	Vinblastine sulfate
	015.60	96.1	72.3	95.2	90.6	85.2	96.2	67.5
	031.25	89.2	49.2	84.1	81.4	78.1	89.7	48.9
	062.50	72.5	38.4	70.6	68.0	65.7	70.8	31.4
	125.00	43.8	27.1	53.4	47.1	42.9	42.9	20.3
	250.00	31.7	14.2	34.9	36.2	28.7	28.8	08.9
	500.00	16.4	06.4	23.6	21.4	12.5	15.2	04.0
	IC_{50} (μg/ml)	**112 ± 10.4**	**30.7 ± 4.1**	**149 ± 12.2**	**117 ± 9.1**	**106 ± 8.4**	**109 ± 11.4**	**30.3 ± 1.4**
HCT-116	000.00	100	100	100	100	100	100	100
Colon carcinoma	001.00	100	79.4	100	100	100	100	66.4
	002.00	100	72.9	100	100	100	100	58.1
	003.90	98.7	60.7	100	100	100	98.7	47.3
	007.80	93.2	45.9	99.1	98.1	100	95.1	39.8
	015.60	86.9	38.2	93.7	91.8	99.7	89.5	28.7
	031.25	69.1	30.6	86.0	85.2	92.4	73.1	18.9
	062.50	43.5	22.8	68.1	68.0	69.5	49.5	15.5
	125.00	30.7	16.4	45.2	49.8	42.8	36.9	12.1
	250.00	18.6	08.7	31.7	35.4	24.9	23.8	06.7
	500.00	06.	03.9	18.6	23.8	08.7	09.2	04.0
	IC_{50} (μg/ml)	**54.7 ± 1.2**	**6.7 ± 0.2**	**112 ± 7.2**	**125 ± 5.3**	**108 ± 3.9**	**61.9 ± 3.1**	**3.5 ± 0.2**
HeLa	000.00	100	100	100	100	100	100	100
Cervical carcinoma	001.00	100	92.5	100	100	100	100	100
	002.00	99.5	81.4	100	100	100	100	98.1
	003.90	94.6	69.0	99.4	100	100	98.4	95.4
	007.80	89.7	52.7	96.0	100	97.8	92.3	90.6
	015.60	80.9	43.9	88.9	100	91.3	81.4	82.7
	031.25	65.2	35.1	80.7	100	80.6	69.8	71.9
	062.50	48.1	26.7	68.9	100	62.9	45.1	47.8
	125.00	31.4	18.4	47.5	100	43.0	30.6	34.5
	250.00	14.7	09.6	31.7	97.1	29.4	21.8	22.8
	500.00	08.9	05.7	17.2	89.2	15.8	09.2	09.1
	IC_{50} (μg/ml)	**59.1 ± 3.2**	**10.2 ± 0.6**	**118 ± 5.1**	**> 500**	**103 ± 4.8**	**56.3 ± 3.4**	**59.7 ± 2.1**
HepG-2	000.00	100	100	100	100	100	100	100
Hepatocellular carcinoma	001.00	100	90.6	100	100	100	100	60.9
	002.00	98.2	83.1	100	100	100	98.7	54.2
	003.90	91.7	70.4	99.3	100	98.6	94.0	45.0
	007.80	80.1	49.2	94.1	100	91.7	88.7	34.1
	015.60	69.4	37.0	86.2	100	82.0	72.1	26.8
	031.25	48.1	28.5	72.6	100	67.4	48.5	19.2
	062.50	34.5	20.6	51.3	100	53.9	36.4	14.3
	125.00	23.7	11.3	34.9	99.0	37.1	24.9	10.9
	250.00	11.9	06.9	26.4	93.7	21.3	15.3	05.8
	500.00	05.6	03.5	13.8	81.4	09.4	06.1	03.2
MCF-7	**IC_{50} (μg/ml)**	**29.9 ± 2.3**	**7.6 ± 0.5**	**67.6 ± 4.2**	**> 500**	**77.2 ± 5.9**	**30.3 ± 2.6**	**2.9 ± 0.3**
Breast carcinoma	000.00	100	100	100	100	100	100	100
	001.00	100	94.1	100	100	100	100	67.1
	002.00	100	89.2	100	100	100	100	58.7
	003.90	99.4	78.3	100	100	100	99.4	52.9
	007.80	96.2	63.1	100	100	100	96.2	47.2
	015.60	89.4	42.5	98.1	100	98.7	89.5	40.5
	031.25	72.3	31.7	89.7	100	92.4	70.8	31.9
	062.50	40.9	23.8	74.0	100	78.1	41.7	23.8
	125.00	26.4	14.7	48.7	98.7	45.2	28.5	15.1
	250.00	13.8	07.5	32.8	91.4	30.9	18.7	07.8
	500.00	06.7	03.8	19.4	76.8	13.7	08.9	05.4
	IC_{50} (μg/ml)	**53.5 ± 2.3**	**12.8 ± 1.4**	**122 ± 9.3**	**>500**	**116 ± 8.2**	**53.6 ± 4.6**	**5.9 ± 0.4**
PC-3	000.00	100	100	100	100	100	100	100
Prostate carcinoma	001.00	100	100	100	100	100	100	93.0
	002.00	100	100	100	100	100	100	88.2
	003.90	98.0	100	100	100	100	100	74.8
	007.80	91.7	97.8	100	100	98.7	100	68.9
	015.60	86.9	90.6	100	100	93.8	100	56.7
	031.25	71.4	79.5	97.6	100	84.1	100	37.8
	062.50	43.5	64.0	93.8	99.5	67.2	99.4	24.9
	125.00	29.4	38.1	85.1	92.4	43.9	96.2	13.7
	250.00	17.2	27.8	69.4	83.9	28.6	88.4	09.5
	500.00	08.2	15.8	46.2	70.2	15.8	74.5	05.3
	IC_{50} (μg/ml)	**55.3 ± 5.4**	**96.4 ± 8.3**	**459 ± 24.8**	**> 500**	**109 ± 7.8**	**> 500**	**21.2 ± 0.9**

Values are expressed as mean ± SEM of 3 determinants.

Table 7
The antitumor activity of extracts of *Liagora hawaiiana* against different cell lines.

Cell line	Concentration (μg/ml)	Cell viability (%)						
		Total (Ethanol)	Lipoidal matters	Chloro-form	*n*-butanol	Aqueous	Powder	Vinblastine sulfate
A-549	000.00	100	100	100	100	100	100	100
Lung carcinoma	001.00	100	99.6	98.7	100	100	100	98.2
	002.00	99.8	94.8	95.2	100	100	100	94.7
	003.90	96.7	89.5	86.7	100	100	100	81.4
	007.80	90.3	70.4	79.5	100	98.1	100	73.8
	015.60	80.6	56.2	63.8	98.0	91.4	98.7	62.5
	031.25	68.5	38.7	40.8	86.9	79.5	94.3	40.7
	062.50	53.2	28.1	31.9	72.1	63.8	87.1	32.9
	125.00	34.9	22.4	23.5	50.6	45.9	69.2	25.2
	250.00	21.8	14.0	14.8	39.8	37.6	51.8	15.3
	500.00	09.79	06.1	06.9	26.5	24.9	32.7	06.8
CACO-2	**IC$_{50}$ (μg/ml)**	**73.6 ± 5.8**	**21.2 ± 1.6**	**25 ± 3.1**	**132 ± 11.4**	**111 ± 8.9**	**274 ± 26.2**	**24.6 ± 0.7**
Intestinal carcinoma	000.00	100	100	100	100	100	100	100
	001.00	100	93.7	100	100	100	100	99.2
	002.00	100	89.4	99.4	98.1	100	100	93.8
	003.90	100	78.1	96.3	91.7	99.7	100	86.2
	007.80	98.0	65.3	87.2	86.4	93.8	100	79.4
	015.60	90.6	38.4	70.9	75.3	85.2	98.3	67.5
	031.25	78.1	28.9	37.4	60.8	69.1	92.5	48.9
	062.50	65.9	20.4	28.6	45.1	48.7	81.4	31.4
	125.00	47.8	13.2	19.4	36.2	39.4	65.1	20.3
	250.00	31.7	06.7	10.5	23.6	27.8	41.8	08.9
	500.00	18.6	03.2	05.9	11.7	15.9	30.6	04.0
	IC$_{50}$ (μg/ml)	**118 ± 10.5**	**12.2 ± 0.6**	**25.4 ± 1.2**	**52.9 ± 3.3**	**60.5 ± 4.7**	**206 ± 16.2**	**30.3 ± 1.4**
HCT-116	000.00	100	100	100	100	100	100	100
Colon carcinoma	001.00	100	96.7	91.4	100	100	100	66.4
	002.00	98.1	90.6	86.2	100	100	100	58.1
	003.90	94.2	83.9	78.1	100	99.4	100	47.3
	007.80	86.1	70.8	63.9	98.2	95.2	100	39.8
	015.60	71.8	52.3	50.6	92.4	88.7	99.4	28.7
	031.25	59.4	42.9	41.0	86.9	79.4	95.2	18.9
	062.50	36.7	33.9	31.7	72.8	65.9	86.1	15.5
	125.00	21.8	20.6	22.4	45.1	41.8	70.9	12.1
	250.00	12.9	13.2	12.9	36.2	28.7	42.1	06.7
	500.00	05.6	06.3	05.2	20.4	16.2	28.6	04.0
	IC$_{50}$ (μg/ml)	**44.2 ± 0.9**	**195 ± 0.7**	**16.6 ± 0.8**	**114 ± 9.2**	**104 ± 8.7**	**216 ± 12.3**	**3.5 ± 0.2**
HeLa	000.00	100	100	100	100	100	100	100
Cervical carcinoma	001.00	100	100	100	100	100	100	100
	002.00	100	99.7	98.6	100	100	100	98.1
	003.90	97.8	96.4	93.2	100	100	100	95.4
	007.80	90.3	90.6	85.4	100	100	100	90.6
	015.60	78.4	81.7	76.4	98.6	97.9	100	82.7
	031.25	63.1	69.4	62.1	91.7	90.6	100	71.9
	062.50	48.2	51.8	42.5	83.1	78.2	100	47.8
	125.00	31.5	36.7	30.4	70.8	65.1	99.7	34.5
	250.00	19.7	23.9	19.5	56.4	47.2	92.3	22.8
	500.00	08.3	14.5	08.7	38.6	31.5	81.6	09.1
	IC$_{50}$ (μg/ml)	**58.8 ± 1.4**	**70.2 ± 3.5**	**50.7 ± 2.9**	**340 ± 16.7**	**231 ± 20.1**	**> 500**	**59.7 ± 2.1**
HepG-2	000.00	100	100	100	100	100	100	100
Hepatocellular carcinoma	001.00	100	100	99.8	100	100	100	60.9
	002.00	100	99.2	93.1	100	100	100	54.2
	003.90	98.5	93.1	84.0	100	98.7	100	45.0
	007.80	90.1	85.7	69.5	100	93.1	100	34.1
	015.60	78.0	76.9	46.2	99.2	86.2	100	26.8
	031.25	65.4	60.8	32.8	94.0	75.3	100	19.2
	062.50	40.6	43.1	25.6	88.6	61.4	98.1	14.3
	125.00	28.3	30.4	14.3	73.1	43.0	91.8	10.9
	250.00	14.6	18.7	06.9	46.2	31.7	80.7	05.8
	500.00	06.8	10.2	03.4	28.9	19.4	68.9	03.2
MCF-7	**IC$_{50}$ (μg/ml)**	**50.8 ± 5.1**	**50.4 ± 4.3**	**14.4 ± 0.8**	**233 ± 19.6**	**101 ± 7.8**	**> 500**	**2.9 ± 0.3**
Breast carcinoma	000.00	100	100	100	100	100	100	100
	001.00	100	100	97.2	100	100	100	67.1
	002.00	100	100	91.7	100	100	100	58.7
	003.90	100	100	85.0	100	100	100	52.9
	007.80	99.5	97.0	76.9	100	99.3	100	47.2
	015.60	91.4	89.5	60.8	100	95.1	100	40.5
	031.25	79.8	71.3	39.6	99.4	89.5	100	31.9
	062.50	45.1	49.8	28.1	96.5	70.8	98.2	23.8
	125.00	32.7	36.2	19.4	81.4	47.2	94.5	15.1
	250.00	19.4	21.4	08.7	63.1	35.9	83.1	07.8

(*continued on next page*)

Table 7 (*continued*)

Cell line	Concentration (μg/ml)	Cell viability (%)						
		Total (Ethanol)	Lipoidal matters	Chloro-form	*n*-butanol	Aqueous	Powder	Vinblastine sulfate
	500.00	10.2	13.8	04.2	37.8	26.5	71.5	05.4
	IC_{50} (μg/ml)	**58.1 ± 3.7**	**62.2 ± 6.1**	**23.6 ± 3.4**	**380 ± 17.9**	**118 ± 82.3**	**> 500**	**5.9 ± 0.4**
PC-3	000.00	100	100	100	100	100	100	100
Prostate carcinoma	001.00	100	100	100	100	100	100	93.0
	002.00	100	98.6	98.0	100	100	100	88.2
	003.90	100	91.7	91.7	100	100	100	74.8
	007.80	100	84.3	84.1	100	98.7	100	68.9
	015.60	98.0	68.1	70.8	100	90.6	100	56.7
	031.25	90.6	47.2	41.5	99.5	82.1	98.4	37.8
	062.50	72.8	35.0	23.7	93.1	67.4	91.3	24.9
	125.00	47.8	23.6	19.5	86.4	46.2	80.1	13.7
	250.00	31.7	14.9	10.2	71.6	35.9	65.3	09.5
	500.00	18.9	06.3	06.3	46.8	21.3	41.9	05.3
	IC_{50} (μg/ml)	**120 ± 9.3**	**29.2 ± 1.3**	**26.7 ± 1.4**	**469 ± 38.6**	**114 ± 10.5**	**414 ± 43.1**	**21.2 ± 0.9**

Values are expressed as mean ± SEM of 3 determinants.

respectively) against lung carcinoma (A-549) better than vinblastine sulfate (IC_{50} = 24.6 ± 0.7). Although, the lipoidal matters of *Galaxaura rugosa* and *Liagora hawaiiana* antitumor activity against cervical carcinoma (HeLa) and intestinal carcinoma (CACO-2) (IC_{50} = 10.2 ± 0.6 and 12.2 ± 0.6, respectively) preferable than vinblastine sulfate (IC_{50} = 59.7 ± 2.1 and 30.3 ± 1.4, respectively) (Tables 6 and 7). These results give new promising resource of anticancer drug discovery from marine this was clear from the variation of the anticancer effect of the algae extracts which due to their huge biodiversity and safety, as they have long been used in traditional Asian foods and folk medicine (Namvar et al., 2014)

References

Aksoy, L., Erdi, K., YasinA, ZeynebA, Mustafa, K., 2013. Free radical scavenging activity, total phenolic content, total antioxidant status, and total oxidant status of endemic *Thermopsis turcica*. Saudi J. Biol. Sci. 20 (3), 235–239.

Aleem, A.A., 1993. The marine Algae of Alexandria, Egypt. Aleem (Ed.), Faculty of science, University of Alexandria, Egypt, Alexandria press, Alexandria, Cairo, 39pp.

Allely, M.C., Seudero, D.A., Monks, A., 1998. Feasibility of drug screening with panels of human tumor cell lines using micro culture tetrazolium assay. Cancer Res. 58, 589–601.

Almalki, M., 2017. Medicinal plants, antimicrobial activities, antifungal activities, mechanism of antimicrobial action, antioxidant properties. Pharm. Pharm. 8 (5), 27–32.

Amornlerdpison, D., Peerapornpisal, Y., Rujjanawate, C., Taesotikul, T., Nualchareon, M., Kanjanapothi, D., 2007. Antioxidant activity of *Padina minor* Yamada, KMITL. Sci. Tech. J. 7 (s1), 1–7.

Awaad, S.A., Hind, A.AL-Mudhayyif, Monerah, R.Al-Othman, Mohamed, E.Zain, Reham, M.El-Meligy, 2017a. Amhezole, a novel fungal secondary metabolite from *Aspergillus terreus* for treatment of microbial mouth infection. Phytother. Res. 31 (3), 395–402.

Awaad, S.A., Alothman, Monerah R., Zain, Yara M., Zain, Gh.ada.M., Alqasoumi, Saleh I., Hassan, Dena A., 2017b. Comparative nutritional value and antimicrobial activities between three *Euphorbia* species growing in Saudi Arabia. Saudi Pharmaceut. J. 25 (8), 1226–1230. https://doi.org/10.1016/j.jsps.2017.09.007.

Awaad, S.A., Al-Zaylaee, Haifa M., Alqasoumi, Saleh I., Zain, Mohamed E., Aloyan, Ebtesam M., Alafeefy, Ahmed M., Awad, Elham S.H., El-Meligy, Reham M., 2013. Anti-leishmanial activities of extracts and isolated compounds from *Drechslera rostrata* and *Eurotium tonpholium*. Phytother. Res. 28 (5), 774–780.

Benedetti, S., Benvenuti, F., Pagliarani, S., Francogli, S., Scoglio, S., Canestrari, F., 2004. Antioxidant properties of a novel phycocyanin extract from the blue-green alga *Aphanizomenon flosaquae*. J. Life Sci. 75, 2353–2362.

Bhat, V.B., Madyastha, K.M., 2001. Scavenging of peroxynitrite by phycocyanin and phycocyanobilin from *Spirulina platensis*: protection against oxidative damage to DNA. Biochem. Biophys. Res. Commun. 285, 262–266.

Bhat, V.B., Madyastha, K.M., 2000. C-phycocyanin: apotent peroxyl radical scavenger *in vivo* and in vitro. Biochem. Biophys. Res. Commun. 275, 20–25.

Coppejans, E., Leliaert, F., Dargent, O., Gunasekara, R., Clerck, O., 2009. University of Ruhuna, Dept. of Botany; Matora, Srilanka. Srilanka Seaweeds. Methodologies and Field Guide to the Dominant Species. pp. 1–265.

El-Fatemy, A.S., Said, A.A., 2011. Antifungal Activity of Methanolic Extract of Caulerpa prolifera of Ghemenis Coast, Libya. In: The 7th Annual International Conference of the Egyptian Society of Experimental Biology, Cairo University (2-6 April 2011).

El Gamal, A., 2010. Biological importance of marine algae. Saudi Pharm J. 18(1), 1–25.

Ely, R., Supriya, T., Naik, C.G., 2004. Antimicrobial activity of marine organisms collected off the coast of south East India. J. Exp. Biol. and Ecol. 309, 121–127.

Farasat, Massoumeh, Khavari-Nejad, Ramazan-Ali, Nabavi, Seyed Mohammad Bagher, Namjooyan, Foroogh, 2014. Antioxidant activity, total phenolics and flavonoid contents of some Edible Green Seaweeds from Northern Coasts of the Persian Gulf. Iran J. Pharm. Res. 13 (1), 163–170.

Izzo, A.A., Ernst, E., 2009. Interaction between herbal medicines and prescribed drugs. Drugs 69, 1777–1798.

Jain, R., Jain, S.K., 2011. Screening of in vitro cytotoxic activity of some medicinal plants used traditionally to treat cancer in Chhattisgarh states, India. Asian Pacific J. Trop. Biomed. 1, 147–150.

Kameyama, Y., Yamashita, K., Kobayashi, K., Hosokawa, M., Chiba, K., 2005. Functional characterization of SLCO1B1 (OATP-C) variants, SLCO1B1*5, SLCO1B1*15 and SLCO1B1*15+ C1007G, by using transient expression systems of HeLa and HEK293 cells. Pharmacogenet. Genom. 15, 513–522.

Khan, F.A., Hussain, I., Farooq, S., Ahmad, M., Arif, M., Rehman, U., 2011. Phytochemical screening of some Pakistanian Medicinal plants. Middle – EastJ. Scient. Res. 8 (3), 575–578.

Kohen, R., Nyska, A., 2002. Oxidation of biological systems: oxidative stress phenomena, antioxidants, redox reactions, and method for their quantification. Toxicol. Pathol. 30, 620–650.

Kosanić, M., Ranković, B., Stanojković, T., 2015. Biological activities of two macroalgae from Adriatic coast of Montenegro. Saudi J. Biolog. Sci. 22 (4), 390–397.

Kornprobst, J., 2005. Substances naturelles d'origine marine: chimiodiversite, pharmacodiversite, biotechnologies. Tec & Doc, Lavoisier, Paris, p. 599.

Manglani, M., Vaishnava, S., Damodaran, P., Sawarkar, H., 2014. In Vitro and In Vivo anticancer activity of leaf extract of Barleria grandiflora. Int J Pharm Pharm Res 6 (3), 7072.

Manilal, A., Sujith, S., Selvin, J., Kiran, G.S., Shakir, C., Gandhimathi, R., Panikkar, M.V. N., 2009. Biopotentials of seaweeds collected from southwest coast of India. J. Mar. Sci. Technol. 17, 67–73.

Mark, L., Philippe, P., James, S., John, A., Sabeeha, S., Katherine, E., Alison, G., Mary, E., Susan, H., 2016. Algae as nutritional and functional food sources: revisiting our understanding. J Appl Phycol. https://doi.org/10.1007/s10811-016-0974-5.

Mayer, A., Gustafson, K.R., 2006. Marine pharmacology in 2003–2004: anti-tumour and cytotoxic compounds. Eur. J. Cancer 42, 2241–2270.

Mulla, S.K., Swamy, P., 2012. Anticancer activity of ethanol and polyphenol extracts of *Portulasa quadrifida* Linn on human colon cancer cell lines. Intl Journal of Pharma and Bio Sci. 3 (3), 488–498.

Namvar, F., Baharara, J., Mahdi, A., 2014. Antioxidant and anticancer activities of selected persian gulf algae. Ind. J. Clin. Biochem. 29 (1), 13–20.

Nathan, C., 2004. Antibiotics at the crossroads. Nature 431, 899–902.

Piao, X.L., Park, I.H., Baek, S.H., Kim, H.Y., Park, M.K., Park, J.H., 2004. Antioxidative activity of furanocoumarins isolated from Angelicae dahuricae. J. Ethnopharmacol. 93, 243–246.

Rajasulochana, R., Dhamotharan, P., Krishnamoorthy, S., Murugesan, 2009. Antibacterial activity of the extracts of marine red and brown algae. J. Am. Sci. 5 (3), 20–25.

Smit, A.J., 2004. Medicinal and pharmaceutical uses of seaweed natural products: *a review*. J. Appl. Phycol. 16, 245–262.

Suresh, P.K., Sucheta, S., Sudarshana, V.D., Selvamani, P., Latha, S., 2008. Antioxidant activity in some selected Indian medicinal plants. Afr. J. Biotechnol. 7, 1826–1828.

Yen, G.C., Duh, P.D., 1994. Scavenging effect of methanolic extracts of peanut hulls on free radical and active oxygen species. J. Agric. Food Chem. 42, 629–632.

Yuan, Y.V., Walsh, N.A., 2006. Antioxidant and antiproliferative activities of extracts from a variety of edible seaweeds. Food Chem. Toxicol. 44, 1144–1150.

Zain, M.E., Awaad, A.S., Al-Outhman, M.R., El-Meligy, R.M., 2012. Antimicrobial activities of Saudi Arabian desert plants. Phytopharmacology 2 (1), 106–113.