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ORIGINAL ARTICLE

Antibacterial substances from marine algae isolated from Jeddah coast of Red sea, Saudi Arabia

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Abstract Marine algae are known to produce a wide variety of bioactive secondary metabolites and several compounds have been derived from them for prospective development of novel drugs by the pharmaceutical industries. However algae of the Red sea have not been adequately explored for their potential as a source of bioactive substances. In this context *Ulva reticulata, Caulerpa occidentalis, Cladophora socialis, Dictyota ciliolata,* and *Gracilaria dendroides* isolated from Red sea coastal waters of Jeddah, Saudi Arabia, were evaluated for their potential for bioactivity. Extracts of the algae selected for the study were prepared using ethanol, chloroform, petroleum ether and water, and assayed for antibacterial activity against *Escherichia coli* ATCC 25322, *Pseudomonas aeruginosa* ATCC 27853, *Stapylococcus aureus* ATCC 29213, and *Enterococcus faecalis* ATCC 29212. It was found that chloroform was most effective followed by ethanol, petroleum ether and water for the preparation of algal extract with significant antibacterial activities, respectively. Results also indicated that the extracts of red alga *G*. dendroides were more efficient against the tested bacterial strains followed by green alga *U*. *reticulata*, and brown algae *D*. *ciliolata*. Chemical analyses showed that *G*. dendroides recorded the highest percentages of the total fats and total proteins, followed by *U*. *reticulata*, and *D*. *ciliolate*. Among the bioflavonoids determined Rutin, Quercetin and Kaempherol were present in high percentages in *G*. *dendroides*, *U*. *reticulata*, and *D*. *ciliolate*. Estimation of saturated and unsaturated fatty acids revealed that palmitic acid was

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present in highest percentage in all the algal species analyzed. Amino acid analyses indicated the presence of free amino acids in moderate contents in all the species of algae. The results indicated scope for utilizing these algae as a source of antibacterial substances.

1. Introduction

Marine organisms are potential sources of bioactive secondary metabolites with potential for use in the development of new pharmaceutical agents (Abedin and Taha, 2008; EL-Gamal, 2010) and many of these substances have been demonstrated to possess interesting biological activities (Faulkner, 2002; Abdel-Raouf et al., 2008). Marine algae were reported to produce a wide variety of bioactive secondary metabolites as antimicrobial, antifeedant, antihelmintic and cytotoxic agents and the bioactive substances included alkaloids, polyketides, cyclic peptide, polysaccharide, phlorotannins, diterpenoids, sterols, quinones, lipids and glycerols (Cabrita et al., 2010) and marine macro-algae are considered as the actual producers of some bioactive compounds with high activity (Shimizu, 1996). Hence they have drawn great attention recently (Abdel-Raouf et al., 2008; Ibraheem et al., 2008; Al-Haj et al., 2009; Bazes et al., 2009; Vallinayagam et al., 2009; Cabrita et al., 2010).

Bromophenol compounds have been frequently encountered in various marine algae including red and brown algae. Especially, the red algae of family Rhodomaceae are known as a rich source of bromophenols (Oh et al., 2008). Some of these compounds previously isolated from the family exhibited a wide spectrum of pharmacological activities such as enzyme inhibition, cytotoxic, antioxidant, feeding deterrent, antiflammatory and antimicrobial activities (Tapiero et al., 2002; Matanjun et al., 2008; Jaganathan and Mandal, 2009; Williamson and Carughi, 2010).

The green algae *Ulva lactuca* commonly known as sea lettuce has long been used as food and as a traditional medical agent to treat helminthic infections, fever, urinary diseases and dropsy (Kim et al., 2007). The antimicrobial activity of *Ulva lactuca* was reported to be caused by the acrylic acid commonly found in the algae (El-Yamany, 2008). Extract of green algae *Caulepra prolifera* was reported to exhibit significant activity against strains of marine bacteria (Rajasulochana et al., 2009). Adiphenyl ether isolated from the extract of the green algae *Cladophora fascicularis* was found to inhibit the growth of *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus* (Kuniyoshi et al., 1985). Diterpene isolated from unidentified species of *Dictyota* exhibited significant cyotoxicity (Awad, 2004). Extracts from algae from Indian waters *Dictyota dichotoma*, and *Padina gymnosora* were reported to be effective against *Bacillus megatherium* and *S. aureus* (Rao et al., 1977). Ethanolic extracts of *Zandariania prototypus*, *Cystoseria sricata* and *Cymbula compressa* were reported to inhibit the growth of different bacteria and fungi (Pesando and Caram, 1984). Extracts of Egyptian marine algae *Dictyota dichotoma*, *Dilophus fasciola* and *Cystoseria barbata* were found to show antibacterial activities (El-Naggar, 1987). Antibacterial effects of hexane and methanol extracts of the macro-algae *Mastocarpus stellatus*, *Laminaria digitata* and *Ceramium rubrum* on 12 marine and 7 prominent fish pathogenic bacteria were also reported (Dubber and Harder, 2007). Methanolic extracts from 32 macro-algae from the Atlantic and Mediterranean coasts of Morocco were evaluated for the production of antibacterial compounds against *E. coli, S. aureus*, *Enterococcus faecalis* and *Klebsiella pneumonia* (Ibtissam et al., 2009). The antibacterial activities of four important seaweeds namely *Ulva lactuca*, *Padina gymnospora*, *Sargassum wightii* and *Gracilaria edulis* were screened against human bacterial pathogen (Vallinayagam et al., 2009).

In fact the potential biological resources of marine environments of the Kingdom of Saudi Arabia represented by the Red sea and the Arabian Gulf have not been adequately explored and harnessed for biotechnological applications and deriving biopharmaceuticals. In this context a study was undertaken to isolate and evaluate prospective bioactive substances from marine algae of the Red sea coast. Herein we report the isolation of antibacterial substances from selected species of algae and the phytochemical composition of the extracts of algae that showed antibacterial activities.

2. Materials and methods

2.1. Algae

Algal materials were collected from the littoral zone of the Obhor region between (0.2–2.5 m depth) along the Red sea coast of Jeddah, Saudi Arabia. The collected algal samples were stored in plastic bags and transported to the laboratory under iced conditions. The samples were initially washed thoroughly with sea water to remove sand and any adhering substance and then washed thoroughly with fresh water to remove salts, and stored at −20 °C until compound extraction. The algal species were identified based on the schemes reported in the literature (Nasr and Aleem, 1949; Smith, 1944; Levring, 1946; Bouck, 1965; Scagel, 1966; Bold, 1978; Aleem, 1993; Coppejans et al., 2009) and saved in the Lab of Phycology, Botany and Microbiology Department, Faculty of Science, King Saud University (El-Malaz Center), Riyadh, Saudi Arabia.

2.2. Extraction of selected algal species

After washing with distilled water for several times, the algal samples were again washed with 5% ethanol to remove any epiphytes or any salts. One portion of the samples was kept under frozen condition and another small portion was kept in media containing Sea water-Formalin-Glycerol-Cupper sulfate. The remaining parts of the samples were subjected to air drying under the shade. After drying they were ground either mechanically or by an electrical mixer untill they became a powder. Then the powdered samples were stored in a dark place, and subjected to different extraction methods.

Extraction of powdered algal samples was done using ethanol, chloroform, petroleum ether and water. Aliquots of

25 g of the powdered algal samples were soaked in 250 ml of the solvents for 24 h. Later the soaked samples were homogenized in an electric blender along with the solvents at room temperature, filtered, and concentrated under reduced pressure using a rotary evaporator.

2.3. Determination of antibacterial activity

Antibacterial activities of the selected algal extracts were tested using pathogenic bacteria kindly supplied by the Security Forces Hospital Program (SFHP), Riyadh, Saudi Arabia. The pathogens included *S. aureus* ATCC 29213 and *Enterococcus faecalis* ATCC 29212, *Escherichia coli* ATCC 25922 and *Pseudomonas aeruginosa* ATCC 27853. The bacterial strains were grown in Nutrient agar medium (Wedberg, 1966) at 37 °C. Stock cultures were maintained in nutrient medium at 4 °C and sub cultured at regular intervals. The nutrient agar medium contained g/L: 5 g peptone, 3 g beef extract, 5 g NaCl, and 20 g agar agar in distilled water.

Antimicrobial activity was evaluated using the agar diffusion technique in Petri dishes. Briefly, sterile filter paper discs, 6 mm in diameter (E-760), were loaded with 20 ml of the different antibacterial compound extracts and air dried. Discs containing standard concentrations of ampicillin, oxacillin and ceftazidime were used as controls. The discs were placed on Muller Hinton agar plates inoculated with each of the previously mentioned microorganisms. Plates were incubated for 24 h at 37 °C and the inhibition zones that formed around the discs were measured (mm diameter). Each set was prepared in triplicate. The control discs were prepared with the solvents alone.

2.4. Total soluble protein

Total soluble proteins were determined quantitatively according to the Bradford method (Bradford, 1976) and expressed as mg protein/g fresh weight. Bovine serum albumin was used as the standard.

2.5. Fatty acid content

Fatty acids in algal extracts were analyzed using Gas Chromatography–Mass Spectrometry (GC–MS) using gas chromatograph (GC–MS QP5050A SYSTEM: Model 2003 from SHIMADZU, JAPAN) equipped with a DB-5 ms column (mm inner diameter 0.25 mm, length 30.0 m, film thickness 0.25 μm) mass spectrometer (ion source 200 °C, RI 70 eV) programed at 40–65 °C with a rate of 4 °C/min. Injector temperature was 280 °C; carrier gas was He (20 psi), column flow rate was 1.4 ml/min injection mode-split.

2.6. Amino acid content

Amino acid in algal extracts was estimated using HPLC (Model 2003 from SHIMADZU, JAPAN (Florescent Detection by Gradient Pump).

2.7. Flavonoids content

Flavonoids Rutin, Quercitin, and Kaempferol in algal extracts were estimated using the HPLC method. MP = 50% MEOH, 50% water, 1% acetic acid; FR = 1 ml/min lamda = 365 nm; COLUMN = CLC ODS column 15 cm; 2 gm (SEED) & 20 ml (JUICE) sample taken for hydrolysis (100 ml of 6% HCl:MEOH, sonicated at 60° time for 15 min, extracted into diethyl ether 25 ml × 3 times. Washed with water to remove acid, evaporated to dryness and made up to 2 ml by MEOH, ready for HPLC injection.

2.8. Statistical analysis

The data for various biochemical parameters were analyzed statistically by one-way ANOVA (Duncan, 1957).

3. Results

3.1. Antibacterial activity

Among the different species of algae collected from the sea water of neritic zone of the Red sea along the coastal region of Jeddah, Saudi Arabia five species namely *Ulva reticulate, Caulerpa occidentalis, Cladophora socialis, Dictyota ciliolate,* and *Gracilaria dendroides* were evaluated for their potential for bioactivity. Table 1 revealed that the four algal extracts prepared with ethanol and chloroform had active principles that could inhibit growth of the pathogenic bacteria tested except ethanol extract of *C. occidentalis* only inhibited *Enterococcus faecalis* (11 mm). However, the water extract of *C. occidentalis* did not record antibacterial activity against all the tested pathogenic bacteria. On the other hand, petroleum ether extracts of *C. occidentalis* and *Cladophora socialis* recorded inhibitory activities against *Enterococcus faecalis*.

Further from the results obtained it was observed that all the algal extracts prepared with ethanol and chloroform could record higher inhibitory activities against *E. coli* compared to ampicilin (11.6 mm), whereas the same extracts did not show higher inhibitory activities against *Enterococcus faecalis* compared to ampicillin. *P. aeruginosa* was found to be inhibited by Ceftazidime (14.6 mm) alone among the three antibiotics tested. Among the algal extracts tested for inhibitory activities, extract prepared with chloroform showed relatively higher inhibitory activities against *P. aeruginosa* except in the case of *C. occidentalis*. Ethanolic extracts of *Cladophora socialis* (23 mm) and *D. ciliolate* (16 mm) showed higher inhibitory activities compared to other algal extracts, whereas, ethanolic extract of *C. occidentalis* did not show any inhibitory activity against *P. aeruginosa*. *S. aureus* was inhibited only by Oxacillin (18.1) among the three antibiotics studied. Whereas extracts prepared using ethanol and chloroform from all the 5 algae, except *C. occidentalis,* showed inhibition of growth of *S. aureus* although the activities were lesser than that compared with oxacillin. *Enterococcus faecalis* was inhibited by ampicillin (19.5 mm) among the three antibiotics tested. Although the algal extracts prepared with ethanol and chloroform showed inhibition against *Enterococcus faecalis* the activities were not higher than ampicillin.

With respect to the solvents used for the preparation of extracts chloroform was observed to be efficient to yield higher inhibitory activities against pathogens tested compared to ethanol in the case of all the five algae tested. Further the chloroform extract of all the five algae were found to be effective against *E. coli* and *P. aeruginosa* compared to that against *S. aureus* and *Enterococcus faecalis*.

Table 1 Antibacterial activity of extracts of algae against pathogenic bacteria (inhibition of growth expressed as mm diameter of inhibition zone).

	Escherichia coli ATCC 25322	*Pseudomonas aeruginosa ATCC 27853*	*Stapylococcus aureus ATCC 29213*	*Enterococcus faecalis ATCC 29212*
Ampicillin	11.6	0	0	19.5
Oxacillin	0	0	18.1	0
Ceftazidime	0	14.6	–	0
Ulva reticulata				
Ethanol	25	14	12.6	15
Chloroform	29.3	24	16.6	11
Petroleum Ether	0	0	0	0
Water	0	0	0	0
Caulerpa occidentalis				
Ethanol				11
Chloroform	30	9.6	18	10
Petroleum Ether	0	0	0	9.5
Water	0	0	0	0
Cladophora socialis				
Ethanol	20	23	15	11
Chloroform	28	27	10	10
Petroleum Ether	0	0	0	10
Water	0	0	0	0
Dictyota ciliolata				
Ethanol	13	16	12	14
Chloroform	30	25	15	11
Petroleum Ether	0	0	0	0
Water	0	0	0	0
Gracilaria dendroides				
Ethanol	26.3	12.3	8	12
Chloroform	32.6	24.6	10	12.6
Petroleum Ether	0	0	0	0
Water	0	0	0	0

Table 2 Flavanoids, total protein and total fat content in the marine algae.

Algae	Flavonoids (mg/kg)			Total protein (%)	Total fat (%)
	Rutin	Quercetin	Kaempherol		
Ulva reticulata	0.04 ± 0.01	0.12 ± 0.014	0.35 ± 0.02	5.86	1.05
Caulerpa occidentalis	0.55 ± 0.01	0.15 ± 0.014	0.07 ± 0.02	1.77	0.12
Cladophora socialis	0.27 ± 0.01	0.23 ± 0.01	0.02 ± 0.01	2.35	0.24
Dictyota ciliolata	**2.28 ± 0.01	*1.86 ± 0.50	***7.33 ± 1.00	3.12	0.21
Gracilaria dendroides	***10.5 ± 1.00	***7.5 ± 0.990	***15.2 ± 1.04	13.4	5.5

* High significant at $P < 0.05$.
** High significant at $P < 0.01$.
*** High significant at $P < 0.001$.

From the data illustrated in Table 2 it was observed that three flavanoids namely rutein quercetin and kaempherol were present in the extracts in all the algal samples studied. Rutein content was found to show a remarkable variation among the algae and a very high level (10.5 mg/kg) was recorded in *G. dendroides* followed by *Dictyota ciliolata* (2.28 mg/kg) and *C. occidentalis* (0.55 mg/kg) compared to other algal species. The quercetin content was observed to be high in *G. dendroides* (7.5 mg/kg) followed by *D. ciliolata* (1.86 mg/kg). High contents of kaempherol were recorded in *G. dendroides* (15.2 mg/kg) and *D. ciliolata* (7.33 mg/kg). Maximum percentage of total protein was obtained with *G. dendroides* (13.4%) then *U. reticulata* (5.86%) followed by *D. ciliolata* (3.12%) respectively (Table 2), while, a minimum percentage of total protein was recorded with *C. occidentalis* (1.77%). Data presented in Table 2 indicated that the *G. dendroides* contains high percentage of total fat (5.5%) than *U. reticulata* (1.05%). It was also noted that protein contents were twice the level of total fat in all the five algal species.

Results documented in Table 3 show that 25 fatty acids were present in all the five algae studied. Further among the different fatty acids maximal levels were observed with Palmitic acid in all the investigated algal species compared to other fatty acids. The dominant fractions of fatty acids

Table 3 Percent composition of fatty acids in marine algae (expressed as %).

Fatty acid	*Ulva reticulate*	*Caulerpa occidentalis*	*Cladophora socialis*	*Dictyota ciliolata*	*Gracilaria dendroides*
Caproic acid C6H1202	0.01	0.015	0.045	0.08	0.1
Caproic acid C8H1602	0.005	0.01	0.035	0.01	0.02
Capric acid C10H2002	0.01	0.015	0.095	0.01	0.01
Lauric acid C12H2402	0.175	0.16	0.29	0.165	0.09
Myristic acid C14H2802	11.2	6.37	3.95	3.235	2.13
Pentadecanoic acid C15H3002	0.765	0.73	0.93	0.695	0.52
Palmitic acid C16H3202	43.7	50.6	53.445	65.225	75.5
Palmitoleic acid C16H3002	3.025	5.145	2.92	3.685	2.40
Margaric acid C17H3402	0.13	0.225	0.16	0.285	0.09
Stearic acid C18H3602	1.345	1.9	3.96	3.025	1.61
Oleic acid C18H340	16.535	11.285	17.24	5.935	3.53
Linoleic acid C18H3202	16.56	2.77	6.53	1.99	0.605
Eicosanois acid C20H4002	0.105	0.09	0.345	0.115	0.09
Linolenic acid C18H3002	0.315	0.25	4.26	0.31	0.135
11-Elcosenoic acid C20H3802	0.205	0.15	0.35	0.09	0.09
11,14-Elcosadienioc acid c20h3602	0.305	0.1755	0.075	0.46	0.02
Docosanoic(bhenic) acid c22h4402	0.185	0.115	2.985	0.17	0.135
7,10,13-Elcosatrienoic acid c20h3402	0.225	0.33	0.135	3.355	1.17
13-Docosenoic acid (erucic)c22h4202	0.315	0.485	0.605	0.36	0.13
5,8,11,14-Elcosatetraenoic(archidonic) acid c20h3202	1.61	8.385	0.55	9.695	9.1
Tricosanoic acid c23h4602	0.02	0.035	0.025	0.105	0.09
5,8.11,14,17-Elcosapentanoic acid c20h3002	0.705	10.	0.43	0.32	0.135
Tetracosanoic acid c24h4802	1.575	0.365	0.415	0.45	0.52
15-Tetracosanoic acid C24H4602	0.03	0.045	0.025	0.145	0.155
Hexacosanoic acid C26H5202	0.945	0.12	0.2	0.145	0.1

Table 4 Percent composition of amino acid in selected marine algae (expressed as %).

Amino acid	*Ulva reticulate*	*Caulerpa occidentalis*	*Cladophora socialis*	*Dictyota ciliolata*	*Gracilaria dendroides*
Aspartic acid	0.43	0.16	0.28	0.27	1.5
Threonine	0.18	0.08	0.10	0.13	0.9
Serine	0.16	0.07	0.11	0.13	2.2
Glutamic acid	0.45	0.15	0.27	0.28	0.95
Glycine	0.23	0.08	0.12	0.15	0.98
Alanine	0.24	0.09	0.15	0.17	0.8
Valine	0.23	0.09	0.12	0.16	3.0
Methionine	0.12	0.05	0.04	0.08	0.5
Isoleucine	0.17	0.08	0.08	0.15	0.95
Leucine	0.28	0.10	0.13	0.12	2.1
Tyrosine	0.17	0.08	0.07	0.12	0.52
Phenylalanine	0.26	0.10	0.13	0.18	0.63
Histidine	0.09	0.04	0.04	0.07	0.1
Lysine	0.25	0.09	0.13	0.20	0.5
Arginine	0.16	0.7	0.15	0.14	0.56

observed with the algal extracts were in the following order: Palmitic acid > Oleic acid > Linoleic acid > Myristic acid. 43.7–75.5 > 3.53–17.24 > 0.6–16.56 > 2.13–11.2%, respectively. Further highest percentage of Palmitic acid (75.5%) was estimated in *G. dendroides* followed by *D. ciliolata* (65.2%), *Cladophora socialis* (53.4%), *C. occidentalis* (50.6%) and *U. reticulata* (43.7%). With respect to oleic acid the percentage was higher in *Cladophora socialis* (17.2) than in *U. reticulate (16.4)* and *C. occidentalis* (11.2). Linoleic acid percentages were higher in *U. reticulate* (16.56). Highest percentage of myristic acid (11.2%) was recorded in *U. reticulate*.

From the results presented in Table 4 it was inferred that 15 amino acids were present in the extracts of algae and among the algae *G. dendroides* recorded all the amino acids in relatively higher amounts followed by *U. reticulate*. Among the amino acids Valine (3%) > Serine (2.2%) > Leucine (2.1%) > Aspartic (1.5%) were found to be present in higher levels in red algae *G. dendroides*.

4. Discussion

The ability of marine algae to produce secondary metabolites of potential interest has been extensively documented (Cabrita et al., 2010). According to earlier reports anti-bacterial activity depends on algal species, the efficiency of the extraction

method, and the resistance of the tested bacteria (Seenivasan et al., 2010). Data obtained in the present study indicated that, chloroform was the most effective solvent for the extraction of the bioactive compounds followed by ethanol. Furthermore, *G. dendroides* were the most effective marine algae against tested bacterial species followed by *D. ciliolata*, *U. reticulata, C. occidentalis* and *Cladophora socialis*. These results are in agreement with those earlier reports (Khalil and El-Tawil, 1982; Meyer and Paul, 1992; Isnansetyo et al., 2003; Burkholder et al., 2009; Saeidnia et al., 2009; Williamson and Carughi, 2010). In the Chlorophyta, the ethanolic and lipid soluble extracts of *Caulerpa ashmeadii* and *Caulerpa prolifera* had the broadest spectrum of antimicrobial activity and the high bioactivity found in the *Caulerpa* extracts has been documented (Kim et al., 2007). Present results obtained with *C. occidentialis* are in agreement with those earlier studies (Williamson and Carughi, 2010). Ethanol extraction has been reported to result in extracts with higher antibacterial activity than petroleum ether, while few other reports indicated chloroform as better extractant than ethanol and petroleum ether (Rajasulochana et al., 2009). From the results of the present study it is clear that, organic solvents always have higher efficiency in extracting anti-bacterial compounds compared to water as extractant and chloroform as a solvent proved to be best suited for the extraction of the antibacterial constituent(s) from the algae. These results are in agreement with those reported earlier for extracting antibacterial substances such as hydroquinones, sesterpenoids, phenols, brominated phenols and polyphenols from species of Chlorophyceae, Phaeophyceae and Rhodophyceae (Faulkner, 2002).

Active antibacterial extracts from different brown algae have been found to be made up of saturated and unsaturated fatty acids with a predominance of myristic, palmitic, oleic and eicosapentaenoic acids (Bazes et al., 2009). So, the antibacterial activities of the algae tested could be attributed to the type and amount of free fatty acids which have a role in the overall defense against the studied pathogenic Gram-positive and Gram-negative bacteria (Benkendorff et al., 2005). Terpenoid content is considered to contribute to antibacterial activity (Fenical and Paul, 1984). In the present investigation palmitic acid was observed as a major component of the total fatty acids in *U. reticulata, C. occidentalis*, *Cladophora socialis*, *D. ciliolata* and *G. dendroides* and higher values of estimated total fats were recorded in *G. dendroides* and *U. reticulata*. The fats and fatty acids from marine algae may play an important role in the formation of many other bioactive secondary metabolites since some fatty acids have been shown to possess antibacterial activities (Barbosa et al., 2007; Oh et al., 2008). Further palmitic acid has been assumed to be responsible for the antibacterial activity (Bazes et al., 2009). Furthermore species of the order Dictyotales is known to produce biologically active compounds such as dictyterpenoids that control seaweeds herbivore interactions (Suzuki et al., 2002).

Flavonoids comprise a large group of naturally occurring compounds widely distributed in the plant kingdom and some of these compounds have been reported to contain various and potent biological activities including antioxidative tissue protective and tumoristatic effects as well as the inhibition of hepatic cholesterol biosynthesis (Kim et al., 2007; Krant et al., 2005; Volk, 2009; Matanjun et al., 2008). Present results, showed that rutin, quercetin and kaempherol were present in all algal samples but in different ratios. *G. dendroides* recorded the highest values of rutin, quercetin and kaempherol while moderate values of three flavonoids were evaluated in *D. ciliolate*. In the same manner, the highest percentage of total protein was determined in *G. dendroides*, followed by *U. reticulata* than *D. ciliolata, Cladophora socialis* and the lower value was recorded in *C. occidentalis*. Also, the highest percentage of total fat was noted in *G. dendroides* than in *U. reticulata*. Additionally, moderate percentages of amino acids were detected in *G. dendroides* then *U. reticulata* followed by *D. ciliolata*. These results are in agreement with several reports (Ruperez et al., 2002; Nagai and Yukimoto, 2003; Matanjun et al., 2008; Jaganathan and Mandal, 2009).

According to the previous reports in literature marine algae are rich sources of dietary fiber, minerals, proteins and vitamins, and anti-oxidant activity of these seaweeds would elevate their value in the human diet as food and pharmaceutical supplements. Moreover, the results of this study suggested that flavonoids can be used clinically to treat patients with hypercholesterolemia and hypertension (Abdel-Raouf et al., 2011). Present results were in accordance with an earlier report (Jaganathan and Mandal 2009) which stated that Quercetin and Kaempherol have evolved as promising pharmacological agents in the treatment of cancer. Further results of the present study also indicated remarkable differences in antibacterial activities among the tested bacterial pathogens which may be attributed to the exposure of marine algae to the combined effect of light and oxygen that leads to the formation of free radicals and other strong agents. But the absence of oxidative damage in structural components of seaweeds and their stability to oxidation during storage suggest that their cells have protective antioxidative defense systems (Matanjun et al., 2008). Indeed, marine algae contain polyphenols, carotenoids and flavonoids referred to as antioxidants, protect the body's tissues against oxidative stress and associated pathologies such as cancer and inflammation (Tapiero et al., 2002).

In conclusion the results of the present investigation on selected species of marine algae indicated scope for deriving biologically active compounds which are effective in inhibiting the growth of the pathogenic bacteria both Gram-positive and Gram-negative. Further the Red sea marine environment of the Jeddah Seashore has potential to return pharmaceutically useful seaweeds which can be harnessed for the development of drugs for use in management of human pathogens, cancer, tumor, AIDS and many human degenerative diseases. There is great scope for further investigations toward drug development.

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