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Antimicrobial and antioxidant activity of brown algae from the Aegean Sea

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Abstract: The present study was conducted to evaluate the antioxidant and antimicrobial activity of methanol, dichloromethane and hexane extracts, as well as the essential oils of brown algae (Phaeophyta) *Colpomenia sinuosa*, *Dictyota dichotoma*, *Dictyota dichotoma* var. *implexa*, *Petalonia fascia* and *Scytosiphon lomentaria*. The essential oil of the macroalgae was obtained by steam distillation and analyzed by GC and GC/MS. The antioxidant activity of the algal extracts was determined using the procedures of inhibition of β-carotene bleaching and $ABTS^+$ methods. The antioxidant effects of the extracts were compared with those of commercial antioxidants, such as butylated hydroxytoluene (BHT), butylated hydroxyanisol (BHA) and α-tocopherol. The hexane extracts of *D. dichofoma* var. *implexa* had a higher phenolic content than the other extracts. The dichloromethane extract of *S. lomentaria* was found to be more active in the decolorization of $ABTS^+$ than the other extracts and generally the dichloromethane extracts were more active than the methanol and hexane extracts. Antimicrobial activities of the extracts were assessed against Gram (+) and Gram (–) bacteria and one yeast strain by the disk diffusion method. According to the results, the dichloromethane extracts generally showed more potent antimicrobial activity than the methanol and hexane extracts at concentrations 1.5 and 1.0 mg/disk.

Keywords: brown algae; antioxidant activity; antimicrobial activity; essential oil.

INTRODUCTION

Marine organisms are rich sources of structurally new and biologically active metabolites.[1] In recent years, there have been many reports of macroalgae derived compounds that have a broad range of biological activities, such as antibiotic, antiviral, antioxidant, antifouling, anti-inflammatory, cytotoxic and antimitotic activities.[2] Seaweeds are known to contain reactive antioxidant mole-

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cules, such as ascorbate and glutathione (GSH) when fresh, as well as secondary metabolites, including carotenoids (α- and β-carotene, fucoxanthin, astaxanthin), mycosporine-like amino acids (mycosporine-glycine) and catechins (*e.g.*, catechin, epigallocatechin, epigallocatechin), gallate, phlorotannins (*e.g.*, phloroglucinol), eckol and tocopherols (α-, χ-, δ-tocopherols).[3] Brown-algal polyphenols phlorotannins worked as antioxidants, antibacterial and anti-algal compounds.[4,5]

Antibacterial halogenated compounds, such as bromophenols, have been isolated from many types of seaweed.[6] *Colpomenia sinuosa* synthesize fatty acids and sterols, and the main sterol of this alga is found as fucosterol.[7,8] The *Dictyota dichotoma*-isolated dolabellane (dolabellane, and perhydroazulene diterpenes, diterpenoids) derivatives possess antimicrobial activity against bacteria.[9] *C. sinuosa* exhibited significant antitumoral, antileukemic, antiprotozoan[10] and hypolipidemic activity.[11]

Thus, the objectives of this study were: 1) to analyze the chemical composition of the essential oil of *C. sinuosa*, *D. dichotoma*, *D. dichotoma* var. *implexa*, *Petalonia fascia* and *Scytosiphon lomentaria*, which were collected from the Aegean Sea in the Izmir Bay, by GC/MS in order to determine the essential oil chemotype; 2) to investigate the antimicrobial and antioxidant activities of the methanol, dichloromethane and hexane extracts, and the essential oil from these algae.

EXPERIMENTAL

Algal material

Field collections of seaweeds, *Colpomenia sinuosa* (No. EGE 40777), *Dictyota dichotoma* (no EGE 40775), *Dictyota dichotoma* var. *implexa* (No. EGE 40774), *Petalonia fascia* (No. EGE 40773) and *Scytosiphon lomentaria* (No. EGE 40776) were deposited in the EGE herbarium (Ege University, Department Herbarium, Izmir, Turkey). Macroalgae were obtained from several reefs (depths of 1–2 m) along the Izmir coast (Turkey) and identified by Dr. Atakan Sukatar. The harvested fresh macroalgae samples were cleaned from their epiphytes, frozen immediately after harvesting and stored at –20 °C until they were freeze-dried.

Preparation of algal extracts

Freeze-dried samples were pulverized and 15 g of each were sequentially extracted as reported by Vlachos *et al.*[12] in 150 mL methanol, dichloromethane and hexane for 24 h using a Soxhlet extraction apparatus. The solvents were evaporated and the resulting extracts were kept at +4 °C. All employed solvents were of analytical reagent grade and obtained from Sigma Chemical Co. (St. Louis, CA).

Isolation of the essential oil

To obtain the essential oil, dried samples of each alga (10 g) were exposed to steam distillation for 4 h using a Clevenger-type apparatus according to the European Pharmacopoeia (1975)[13] and the obtained distillate was diluted with hexane.

GC/MS analysis

The steam-distilled components were analyzed by GC and GC/MS. An HP 6890 gas chromatograph equipped with an FID and a 5 m×0.2 mm HP-1 capillary column (0.33 μm coating) was employed for the GC analysis. GC/MS analysis was performed using a HP 5973

mass selective detector coupled with an HP 6890 gas chromatograph, equipped with a HP-1 capillary column. Identification of the individual components was performed by comparison of mass spectra with literature data and by comparison of their retention indices (*RI*) relative to a C8–C32 *n*-alkene mixture.[14] A computerized search was performed using the Wiley 275 L GC/MS library and the ARGEFAR GC/MS library created with authentic samples.

Antimicrobial activity

Eight bacteria strains (*Bacillus subtilis* ATCC 6633, *Staphylococcus aureus* ATCC 6538P, *Enterobacter aerogenes* ATCC 13048, *Escherichia coli* ATCC 29998, *Proteus vulgaris* ATCC 6897, *Salmonella typhimurium* CCM 583), two specific pathogenic strains (methicillin-oxacillin-resistant *Staphylococcus aureus* ATCC 43300, hemorrhagic *Escherichia coli* (O157: H7) RSSK 232 and one yeast strain *Candida albicans* ATCC 10239 were obtained from the Microbiology Department Culture Collection of Ege University, Faculty of Science, Turkey.

Disk diffusion method

20 and 30 μL each algal solvent extracts (1.0 and 1.5 mg disk^{-1}) were applied per sterile 6 mm diameter filter paper disks (Schleicher and Schüll, No. 2668, Dassel, Germany).[15]

The suspensions of organisms were initially adjusted with sterile distilled water to a density equivalent to the 0.5 McFarland standards. 0.20 ml of a 24 h-broth culture (10^6 cfu/ml) of the bacteria species were spread on the surface of gelled sterile Mueller-Hinton Agar plates. The algal extracts were prepared with methanol, dichloromethane and hexane and then adsorbed onto the sterile disks (20 and 30 μL) and the same volume of solvent was used as the negative control. The paper disks containing the extracts were air-dried and placed on the surface of each plate. The antimicrobial activity of the extracts against the test bacteria was indicated by the growth-free "zone of inhibition" near the respective disk. Methanol, dichloromethane and hexane did not show any antimicrobial activity. All tests were performed under sterile conditions in duplicate and repeated three times. Tobramycin disks (Bioanalyse, 10 μg/disk) and nystatin disks (Oxoid, 30 μg/disk) were used as the positive controls.

Antioxidant activity

ABTS radical cation decolorization assay. The experiments were performed using an improved ABTS (2,2'-azinobis(3-ethylbenzothiazoline-6-sulfonic acid)) decolorization assay.[16] BHA (butylated hydroxyanisol), BHT (butylated hydroxytoluene) and *α*-tocopherol (Vitamin E) were used as the positive controls. All determinations were performed in triplicate. The inhibition percentage, *I*, of the absorbance was calculated as follows (1):

$$I = 100\left(\frac{A_0 - A_1}{A_0}\right) \quad (1)$$

where A_0 is the $ABTS^+$ absorbance value at the initial time and A_1 is the $ABTS^+$ absorbance value after 6 min incubation.

β-*Carotene bleaching assay*. This experiment was performed by measuring the coupled auto-oxidation of *β*-carotene and linoleic acid.[17] The antioxidant activity, *AA*, is expressed as percent inhibition relative to the control after 120 min incubation using the following equation:

$$AA = 100\left[1 - \left(\frac{A_0 - A_t}{A_0^o - A_t^o}\right)\right] \quad (2)$$

where A_0 and A_0^o are the absorbance values measured at the initial incubation time for the sample and control, respectively, while A_t and A_t^o are the absorbance values measured in the samples or standards and control at t = 120 min, respectively.

Total phenolic content. The total phenolic compound concentrations were determined as described previously.[18] The phenolic content is expressed as gallic acid equivalent (GAE) in milligram per 1 g algal extract.

Statistics

The antioxidant activities of the data are expressed as means ±*SE*. Statistical analysis was performed by ANOVA with LSD test and Student's *t*-test. A *P* value of 0.05 or less was taken to indicate statistical significance.

RESULTS AND DISCUSSION

Antimicrobial activity

The methanol, dichloromethane and hexane extracts of five lyophilized brown algae were investigated for *in vitro* antimicrobial activity (Table I). The concentrations of 1.0, 1.5 mg/disk of the algae extracts inhibited the growth of all microorganisms. Some studies concerning the effectiveness of extraction methods highlight that methanol extraction yields higher antimicrobial activity than hexane and ethyl acetate, whereas others report that chloroform extraction is better than methanol and benzene.[19] According to the present experimental results, the dichloromethane extracts caused better halo-zones than methanol for all strains. The seaweed extracts are responsible for its activity against Gram (+) bacteria, especially *Bacillus subtilis* and *Staphylococcus aureus*. The dichloromethane extracts exhibited a higher degree of activity as compared to the methanol and hexane extracts. There are some reports regarding the antimicrobial activity of seaweeds from the Aegean Sea, Turkey.[19–21] The previous reports showed that the algal extracts were generally more effective against Gram (+) than Gram (–) bacteria, probably due to the more complex structure of the cell wall of Gram (–) bacteria.[22] Salvador *et al*.[2] described the antimicrobial activities of 82 seaweeds extracts (18 Chlorophyceae, 25 Phaeophyceae and 39 Rhodophyceae) as fresh and freeze-dried forms in each season. The effect of freeze-drying on the bioactivity of algal sample was generally such that it enabled greater extraction rates of the compounds. Taskin *et al*.[21] showed that the methanolic extracts of *Dictyota dichotoma* inhibited *S. aureus*. The dichloromethane extract of *Dictyota dichotoma* var. *implex*, *D. dichotoma*, exhibited antibacterial activity against *Salmonella typhimurium*. Only one species, *Scytosiphon lomentaria,* showed antimicrobial activity against nine test microorganisms.

Composition of the essential oil

The composition of the volatile compounds of the five brown macroalgae was determined by GC/MS. Different groups of compounds were identified, such as hydrocarbons, terpenes, acids, phenols, sulfur-containing compound, aldehy-

des, naphthalene skeleton and alcohols (Table II). Eight for *D. dichotoma* var. *implexa*, twelve for *D. dichotoma*, four for *Petalonia fascia*, six for *S. lomentaria* and fourteen compounds for *Colpomenia sinuosa* were identified from the distillate, accounting for 58.41, 83.53, 91.71, 87.89 and 74.17 % of the total composition of the essential oil, respectively. In recent years, many studies on volatile compounds from marine algae have been published.[22] The most common volatile compounds determined from marine algae were terpenoids, thymol, carvacrol, β-cubebene, β-eudesmol, β-ionone, dactylol and pachydictol A. It is known that β-ionone has a deterring action against some arthropods, and that it possesses antibacterial and antifungal activity.[23] Alcoholic and phenolic compounds have not been found in *D. dichotoma*, *P. fascia* and *S. lomentaria*. Heptadecane and hexadecane have been reported as common major volatile components in seaweeds.[20] The highest concentration of crown ether (18-crown-6-ether) was found in *S. lomentaria.* One sulfur-containing compound, dihexylsulfide, which are rarely found in algae,[23] was also identified in *C. sinuosa*.

TABLE I. Antimicrobial activity (diameter of zone of inhibition, including the diameter of the filter paper disk (6 mm), in mm, mean value of three independent experiments) of brown macroalgae extracts; I – *D. dichotoma* var. *implexa*, II – *D. dichotoma*, III – *P. fascia*, IV – *S. lomentaria* V – *C. sinuosa*, VI – Standards; 1. *B. subtilis* (ATCC 6633), 2. *S. aureus* (ATCC 6538-p), 3. *S. aureus*, methicillin-oxacillin resistant (ATCC 43300), 4. *E. aerogenes* (ATCC 13048), 5. *E. coli* (ATCC 29908), 6. *E. coli* hemorrhagic, O157:H7 (RSSK 232), 7. *P. vulgaris* (ATCC 6897), 8. *S. typhimurium* (CCM 5445), 9. *C. albicans* (ATCC 10239)

Algae	Extractant	Extract concentration mg/disk	Microorganisms								
			1	2	3	4	5	6	7	8	9
			Gram								
			+	+	+	–	–	–	–	–	
I	Methanol	1	na[a]	na	na	na	na	na	na	na	na
		1.5	6.5	6.5	na	na	na	na	6.5	na	na
	Dichloromethane	1	6.5	7	7	9	8	8	10	10	na
		1.5	7	8	8	11	12	11	12	13	na
	Hexane	1	8	7	na	na	na	na	na	na	na
		1.5	9	10	10	na	na	na	na	na	6.5
II	Methanol	1	na	7	7	na	na	na	na	na	na
		1.5	6.5	7.5	7.5	na	na	na	na	na	na
	Dichloromethane	1	6.5	na	6.5	na	na	na	9	na	na
		1.5	7	na	7	6.5	6.5	6.5	11	7	na
	Hexane	1	8	7	na	na	na	na	na	na	na
		1.5	9	7.5	na	na	na	na	na	na	na
III	Methanol	1	na	na	na	na	na	na	na	na	na
		1.5	na	na	na	na	na	na	na	na	na
	Dichloromethane	1	6.5	6.5	na	na	na	na	na	na	na
		1.5	7	7	6.5	6.5	na	na	na	na	na
	Hexane	1	na	na	na	na	na	na	na	na	na
		1.5	na	6.5	na	na	na	na	na	na	na

TABLE I. Continued

Algae	Extractant	Extract concentration mg/disk	Microorganisms								
			1	2	3	4	5	6	7	8	9
			Gram								
			+	+	+	–	–	–	–	–	
IV	Methanol	1	7	7	6.5	na	na	na	na	na	na
		1.5	7.5	7.5	7	na	na	na	na	na	na
	Dichloromethane	1	7.5	7.5	7	na	na	7	7	na	na
		1.5	8.5	8.5	7.5	6.5	9	9.5	7.5	6.5	6.5
	Hexane	1	6.5	7	9	6.5	6.5	6.5	7	7	6.5
		1.5	7.5	8	11	7	7	7	8	8	7.5
V	Methanol	1	na	8	6.5	na	na	na	na	na	na
		1.5	na	9	8	na	na	na	6.5	na	na
	Dichloromethane	1	7	7	7.5	na	na	na	na	na	na
		1.5	7.5	7.5	8.5	na	na	na	6.5	na	na
	Hexane	1	na	6.5	na	na	na	na	na	na	na
		1.5	na	7	na	na	na	na	6.5	na	na
VI	Tobramycin	10	24	16	7	19	10	25	13	10	NT[b]
	Nystatin	30	NT	NT	NT	NT	NT	NT	NT	NT	18

[a]No activity; [b]not tested

TABLE II. Content (GC/MS analysis) of essential oil components (%) as parts of the total volatile compounds; I – *D. dichotoma* var. *implexa*, II – *D. dichotoma*, III – *P. fascia*, IV – *S. lomentaria*, V – *C. sinuosa*, VI – t_R / min

Component	Algae					
	I	II	III	IV	V	VI
Hydrocarbons						
n-Tridecane	–	–	4.11	–	–	10.87
n-Eicosane	–	–	12.65	–	–	18.91
Methylcyclohexane	–	–	–	–	8.37	6.36
n-Heptane	–	–	–	–	3.92	6.51
3-Methylheptane	–	–	–	–	0.85	6.70
2,3,4-Trimethylhexane	–	–	–	–	1.62	7.33
2,4-Dimethyl-1-heptene	–	–	–	–	2.69	7.55
2,4,6-Trimethyldecane	–	–	–	–	1.16	11.46
5-Methylundecane,	–	–	–	–	0.80	12.37
n-Nonadecane	–	–	–	–	2.54	26.31
n-Pentadecane	9.13	1.24	–	5.69	–	12.18
Crown ether						
18-crown-6-ether	9.45	0.44	–	41.27	–	23.75
Terpenes						
Thymol	–	–	12.48	–	–	25.12
Carvacrol	–	–	62.47	–	–	25.39
β-Cubebene	4.23	2.95	–	–	–	16.24
β-Eudesmol	–	2.42	–	–	–	19.62
β-Ionone	5.80	1.95	–	15.11	–	20.02

TABLE II. Continued

Component	Algae					
	I	II	III	IV	V	VI
Terpenes						
Dactylol	–	7.90	–	–	–	20.84
Pachydictol A	–	39.54	–	–	–	28.29
Acids						
Palmitic acid	–	–	–	–	1.60	16.07
Phenols						
2,4-Bis(1,1-Dimethylethyl)phenol	–	–	–	–	2.96	20.41
S-Containing compounds						
Dihexylsulfide	–	–	–	–	6.72	19.65
Aldehydes						
Stearaldehyde	–	–	–	–	6.33	24.70
Olealdehyde	–	–	–	–	9.18	29.64
Myristaldehyde	12.28	9.81	–	10.29	–	17.89
Hexadecanal		6.64	–	6.69	–	21.32
(*Z*)-13-Octadecenal	14.56	7.68	–	–	–	22.02
Alcohols						
1-Octen-3-ol	1.99	–	–	–	–	11.19
Others						
2,2,4-Trimethyl-1,3-dioxolane	–	–	–	–	25.43	6.18
Hexaethylene glycol	0.97	0.92	–	8.57	–	20.13
Naphthalene skeleton						
Mixture of 1-isopropyl-4,6-dimethyl-1,2,3,4--tetrahydronaphthalene and 4-isopropyl-1,6--dimethyl-1,2,3,4-tetrahydronaphthalene	–	2.04	–	–	–	25.85
Total	58.41	83.53	91.71	87.89	74.17	–

Antioxidant activity

Antioxidant activities of different extracts from the five brown macroalgae were analyzed by means of different *in vitro* tests, such as the presented antioxidant activity in terms of scavenging of hydrosoluble radicals ($ABTS^+$ decolorization), inhibition of β-carotene bleaching (β-carotene-linoleate model system) and the total phenolic compounds (Table III). The phenolic content of the brown algae extracts varied form 0.4±0.2 mg GAE/g to 189.6 ± 8.6 mg GAE/g. Hexane extracts of *D. dichotoma* var. *implexa* were found to have the highest phenolic contents. In this way, within the brown seaweeds, *Dictyota* sp. has been described as a significant source of terpenoids.[24] Several studies have shown a highly significant correlation between the phenolic content and the antioxidant activity in seaweed extracts. In addition, some studies described the antioxidant activity of some phenolic compounds purified from *Eisenia bicyclis* and *Sargassum kjellmanianum*.[25] Kulevanova *et al*.[26] reported that phenolic compounds have more effective antioxidant properties than α-tocopherol and an activity com-

TABLE III. Antioxidant activity of brown macroalgae extracts; I – *D. dichotoma* var. *implexa*, II – *D. dichotoma*, III – *P. fascia*, IV – *S. lomentaria*, V – *C. sinuosa*, VI – BHT, VII- α-tocopherol, VIII – BHA; 1 – ABTS inhibition, %; 2 – β-carotene inhibition, %; 3 – mg GAE/g

Algae	Concentration mg/ml	Extractant								
		Methanol			Dichloromethane			Hexane		
		1	2	3	1	2	3	1	2	3
I	0.5	19.3±0.7	32.8±1.2	24.5±1.3	21.2±1.3	15.5±4.4	66.3±3.2	8.2±1.7	4.4±1.7	79.3±0.5
	1	33.4±0.3	37.4±1.5	47.9±0.9	37.8±0.5	48.5±2.9	81.7±1.7	16.9±1.3	16.8±7.3	123.9±1.1
	2	49.8±1.9	57.9±1.5	78.5±1.2	59.6±0.5	70.2±1.5	119.8±1.8	38.7±0.1	28.6±1.6	189.6±8.6
II	0.5	19.4±1.7	–	0.4±0.2	25.3±0.9	21.8±4.5	35.4±2.8	25.3±0.6	10.1±1.7	23.9±0.8
	1	29.9±0.2	7.6±1.5	21.3±3.4	42.2±1.5	29.0±1.8	62.1±1.4	39.5±0.7	25.0±0.9	43.4±1.3
	2	44.8±0.8	41.2±6.4	41.6±0.5	67.6±0.7	84.8±2.9	78.4±5.2	63.8±0.3	46.2±1.8	65.1±2.0
III	0.5	26.3±1.2	6.0±2.0	3.5±1.2	38.1±2.0	26.4±3.2	31.1±2.6	10.2±3.3	9.1±5.4	10.8±1.5
	1	45.5±0.4	8.7±2.7	10.5±0.8	58.5±1.0	56.6±2.6	51.8±0.5	19.4±0.6	25.4±3.1	24.0±0.4
	2	66.5±3.2	23.5±1.2	26.6±0.8	71.9±0.9	56.7±7.5	83.4±0.5	31.3±0.9	43.5±4.2	40.0±1.5
IV	0.5	5.6±1.4	–	–	51.9±3.1	22.9±2.1	47.7±2.0	32.2±2.5	20.0±7.5	29.8±5.1
	1	7.5±0.5	–	–	73.4±1.8	34.3±2.1	69.8±0.9	53.6±1.7	38.3±6.2	33.4±5.2
	2	11.4±0.7	–	3.4±0.5	79.4±0.8	38.5±7.1	107.5±3.9	69.8±3.1	59.8±6.9	61.0±1.0
V	0.5	6.2±0.9	–	–	36.8±2.3	8.8±1.5	28.1±1.4	19.5±4.3	–	13.6±1.8
	1	9.2±0.1	–	–	55.4±1.5	20.6±6.0	42.4±0.9	35.7±1.5	0.6±4.2	23.4±2.2
	2	14.0±0.3	2.6±4.3	1.1±0.4	62.1±1.1	40.3±6.5	76.4±0.8	49.9±4.2	7.3±3.8	39.0±1.0
VI	0.1	94.3±3.1	97.1±1.6	–	94.4±3.0	97.1±1.6	–	94.4±3.0	97.1±1.6	–
VII	0.1	84.7±4.1	94.4±3.6	–	85.2±3.9	94.4±3.6	–	85.0±4.0	94.4±3.6	–
VIII	0.1	97.9±0.4	93.9±1.3	–	98.0±0.4	93.9±1.3	–	98.0±0.4	93.9±1.3	–

parable to that of synthetic antioxidants, BHA and BHT. There is a decrease in the absorbance of β-carotene and linoleic acid undergoes oxidation in the absence of an antioxidant.[27] Another colorimetric antioxidant activity screening method, the ABTS radical cation decolorization assay, showed quite similar results compared to those obtained in the β-carotene bleaching assay (Table III).

CONCLUSIONS

Marine organisms have several active chemicals such as antioxidant and antimicrobial compounds. In this research, the antioxidant and antimicrobial activity of brown algae from the Aegean Sea were investigated. Marine organisms are currently undergoing detailed investigations with the objective of isolating biologically active molecules along with the search for new compounds. Moreover, it was indicated that the Aegean Sea is a potential source of a variety of biologically active marine organisms and it is hope that the present results will provide a starting point for investigations aimed at exploiting new natural antioxidant substances present in the extracts of algae collected from the Izmir Bay.

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И З В О Д

АНТИМИКРОБНА И АНТИОКСИДАТИВНА АКТИВНОСТ МРКИХ АЛГИ ИЗ ЕГЕЈСКОГ МОРА

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Циљ описане студије је био да процени антиоксидативну и антимикробну активност метанолног, дихлорметанског и хексанског екстракта, као и есенцијалног уља мрких алги (Phaeophyta) *Colpomenia sinuosa*, *Dictyota dichotoma*, *Dictyota dichotoma* var. *implexa*, *Petalonia fascia* и *Scytosiphon lomentaria*. Етарско уље макроалги је добијено дестилацијом воденом паром и анализирано је методама GC и GC/MS. Антиоксидативна активност екстраката алги је одређена применом методе инхибиције губитка боје β-каротена и $ABTS^+$ методом. Антиоксидативни ефекти екстраката су упоређивани са ефектима комерцијалних антиоксиданаса, као што су бутил-хидрокситолуен, бутил-хидроксианизол и α-токоферол. Хексански екстракт *D. dichotoma* var. *implexa* је садржао више фенола него други екстракти. Дихлорметански екстракт *S. lomentaria* је био потентнији у обезбојавању $ABTS^+$ од осталих екстраката. Уопштено, дихлорметански екстракти су имали већу активност од метанолних и хексанских. Антимикробна активност екстраката је одређивана спрам Грам (+) и Грам (-) бактерија, укључујући два специфична соја: метицилин-оксацилин резистентни *Staphylococcus aureus* ATCC 43300 и *Escherichia coli* O157:H7 RSSK 232, као и спрам квасца, методом дифузије на диску. Према нашим резултатима, дихлорметански екстракти су испољили већу антимикробну активност од метанолних и хексанских екстраката, при концентрацији од 1,5 и 1,0 mg по диску.

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