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Volatile bioactive compounds from marine macro-algae and their pharmacological properties

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The present study is aimed at identification of bioactive compounds and their pharmacological properties of four macro-algae (*Hydropuntia edulis*, *Halymenia venusta*, *Ulva lactuca* and *Padina gymnospora*) from the Hare Island, Tuticorin district of Tamil Nadu, India. The characterization of ethanol extracted compounds was done using GC-MS techniques. The major secondary metabolites such as alkaloids, phenol, saponins, flavonoids, steroids, terpenoids and tannins were recorded from all the algal samples. The numbers of major volatile compounds recorded in the GC-MS analysis are 32, 19, 8 and 14 in *H. edulis*, *H. venusta*, *U. lactuca* and *P. gymnospora*, respectively. All these identified compounds could be of therapeutic values for many acute and chronic diseases and disorders. These secondary metabolites belong to alkanes, aliphatic amines, aromatics, aldehydes, 1°, 2° amines and ketone groups. Many of these characterized compounds could be used for therapeutic purposes.

[**Keywords**: Bioactive compounds, Marine macro-algae, Pharmacological properties, Secondary metabolites, Therapeutic values]

Introduction

The marine organisms especially the marine macro algae are rich in structurally new bioactive compounds with great biomedical and pharmacological applications. Recently, the bioactive compounds from marine macro algae are found to be responsible for the treatment of several acute and chronic diseases and disorders such as antimicrobial, anti-inflammatory, anticancer, anifungal, anti-diabetic, etc.[1]. Since several decades, people from Asian and European countries utilize bioactive compounds and biopolymers from macro-algae as a source of food and pharmaceuticals. The primary and secondary metabolites produced by marine macro-algae are potential bioactive compounds which generated interest in the pharmaceutical industry to develop novel drug against diseases requiring short term and long term treatment. Marine macro algae are pools of bioactive compounds such as polysaccharids, carotenoids, pigments, enzymes and polyphenols as well as vital water soluble and fat soluble vitamins[2].

Currently, marine macro-algae are used worldwide for many different purposes such as human consumption, improving nutrients in animal feeds, cosmetics, medicine, fertilizer, etc. and they have shown non-toxic nature which apart from regulation of metabolism in human beings and animals also protect from various diseases[3]. The macro-algae develop many innovatory physiological and biochemical system in marine environment resulting in the production of several biologically active metabolites which are characterized by several biological activities such as anti-diabetic[4], antiviral[5], antifungal[6], anticoagulant[7], antitumor[8] and anti-inflammatory activities[9]. The biopolymers (alginate, carrageenan and agar) from marine macro-algae have been used in medicine and food[1]. Based on above rationale, the bioactive compounds from marine macro-algae are considered as a potent therapeutic agent. Hence, the present study is focused at extraction and characterization of bioactive compounds from marine macro algae (*H. edulis*, *H. venusta*, *U. lactuca* and *P. gymnospora*).

Materials and Methods

Macro-algae sampling and identification

Bulk samples (7±1 kg) of marine macroalgae were sampled from intertidal waters of coastal region of Tuticorin, Tamil Nadu coast (Lat. 8°48′36″ N; Long. 78°8′24″ E), by hand picking in shallow water and also from a depth ranging between 1 and 3 m. Altogether, four different seaweed samples (*Hydropuntia edulis* (S. G. Gmelin) Gurgel & Fredericq, 2004; *Halymenia venusta* Børgesen, 1932;

Ulva lactuca Linnaeus, 1753 and *Padina gymnospora* (Kützing) Sonder, 1871) were collected from different locations and morphological characterization and identification was carried out by following the descriptions from standard literature[10].

Extraction of crude bioactive compound

The different powder samples were soaked in ethanol solvent and resulted extract was concentrated at room temperature and stored for further studies.

Investigation of primary phytoconstituents

The crude extract of marine macroalgae were subjected to qualitative phytochemical analysis using stranded procedure to detect major phytoconstituents such as alkaloids, phenol, saponins, flavonoids, steroids, phytosterol, glycosidase, carbohydrates, protein and lipid[11].

Identification of bioactive compounds

Separation and characterization of bioactive compounds

The identification of bioactive compounds from different crude extract of marine macroalgae was performed using GC (GC-7890A/MS-5975C) from Agilent Technologies, USA with column size 30 m in length × 250 µm in diameter × 0.25 µm in thickness of film. For mass spectroscopic detection, high energy of 70 eV was used for electron ionization. The 99.95 % of pure helium gas with initial temperature (50 to 150 °C) and final temperature (300 °C) with increasing rate 3 °C per min to 10 °C per min are used, respectively. 1 µL of crude extract dilute with respective solvent (ethanol) was injected in splitless mode. The relative quantities of the bioactive compounds present in each crude extracts were expressed as percentage peak in GC chromatogram. The identification of bioactive components was based on National Institute of Standards and Technology (NIST) libraries using Retention Time (RT). The constituents were identified after comparison with those available in the computer library (NIST and Willey) attached to the GC-MS instrument and the results obtained have been tabulated.

Results

Phytochemical compounds

The results of the phytochemical analysis show the occurrence of compounds like alkaloids, phenol, saponins, flavonoids, steroids, terpenoids and tannins in the crude extracts of the algal species (Table 1). Number of compounds recorded in the four macro-algal species ranged between five and nine. Maximum of nine compounds were extracted from *H. edulis* and *H. venusta* while eight and six compounds were resulted from *U. lactuca* and *P. gymnospora*, respectively. Phenol, flavonoids and steroids occurred in the extracts of all the four species of macroalgae. Number of other phytochemicals showed variations pertaining to their occurrence in the four species of macro-algae.

Table 1 — Phytochemical compounds from crude extract of marine macro-algae

Phytochemicals	*H. edulis*	*H. venusta*	*U. lactuca*	*P. gymnospora*
Alkaloids	+	+	-	-
Phenol	+	+	+	+
Saponins	+	-	-	+
Flavonoids	+	+	+	+
Steroids	+	+	+	+
Phytosterol	-	+	+	+
Glycosidase	+	+	+	-
Carbohydrates	+	+	+	-
Protein	+	+	+	+
Lipid	+	+	+	-

(+ Presence; - Absence)

GC-MS analysis

GC-MS analysis results of four marine macro-algal species recorded totally 72 volatile compounds. The number of compounds recorded in *G.edulis*, *H. venusta*, *U. lactuca* and *P. gymnospora* are 32, 19, 8 and 14, respectively (Figs. 1 – 4 & Tables 2 – 5). Of these compounds, L-alanine is the only compound occurred from the extracts of *H. edulis* and *H. venusta*. The molecular weight of compounds from *H. edulis* ranged between 32.046 g/mol (Hydrazine-H_2N-NH_2) and 604.466 (3-d-ribofuranosyl-$C_{21}H_{29}N_6O_{13}P$) g/Mol. Most of the bioactive compounds of *H. edulis* are antioxidant, antiviral, anti-inflammatory, antibacterial, antifungal, antiprotozoal, antidepressants, antineoplastic, antiherpes, antidiabetic, anticoagulant and anticancer. Some of the compounds of this species also exhibit cytotoxic activity, cardioprotective, hepatoprotective and neuroprotective properties. The molecular weight of compounds from *H. venusta* ranged between 59.068 g/mol (Acetamide-C_2H_5NO) and 346.47 (Diisopropylidene- $C_{24}H_{26}O_2$) g/mol. The bioactive compounds of this species mostly act as antiarrhythmic, inhibitor of Bloom's syndrome, hypocholesterolemic, anticancer, HCV antidiabetic and immunomodulatory agents. The molecular weight of compounds from *U. lactuca* ranged between

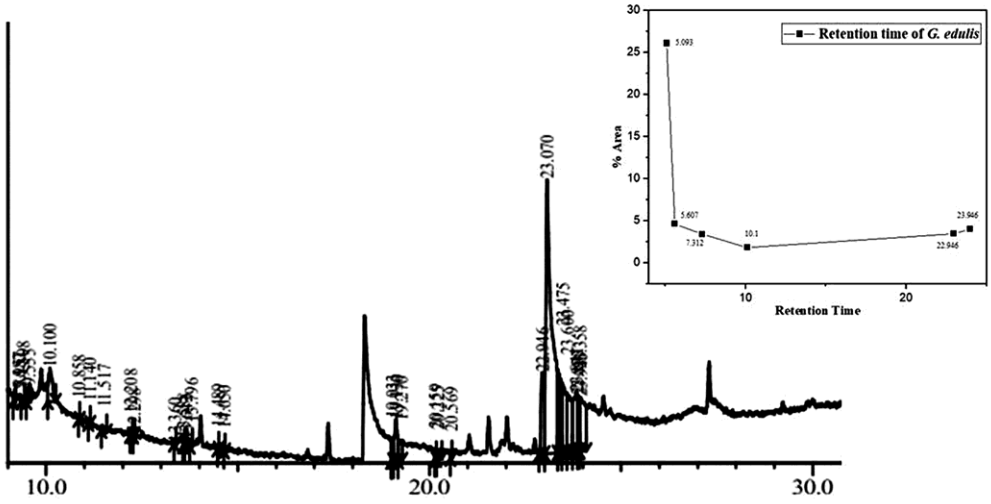

Fig. 1 — GC Chromatogram of bioactive compounds of *H. edulis*

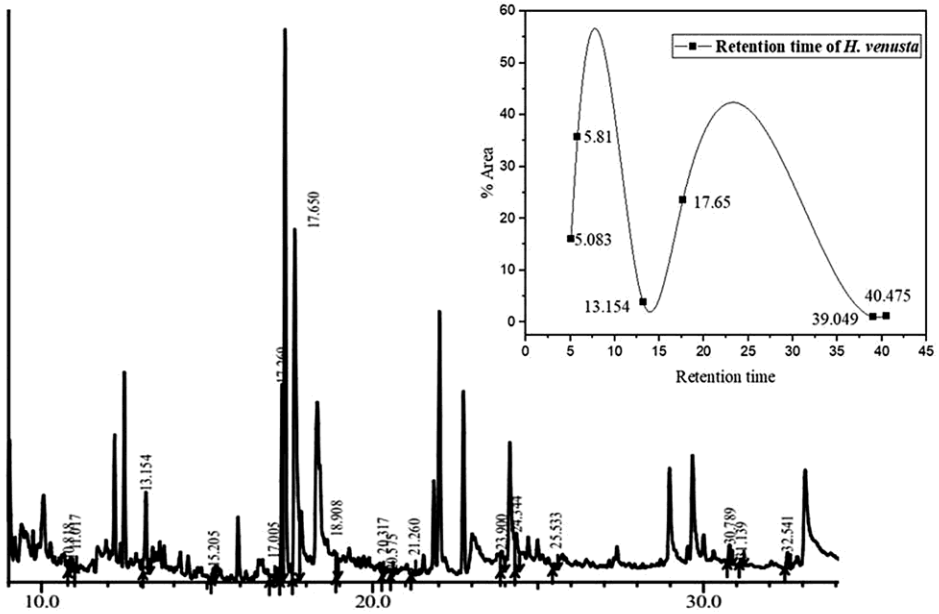

Fig. 2 — GC chromatogram of bioactive compounds of *H. venusta*

74.079 g/mol (Propanoicacid - $C_3H_6O_2$) and 390.564 g/mol (Isooctyl Phthalate- $C_{24}H_{38}O_4$). The bioactive compounds of this species apart from common activities like anti-inflammatory, antimicrobial and cytotoxic cctivity, they are antirheumatic, anti-androgenic and antitubercular agents. Similarly, the molecular weight of compounds from *P. gymnospora* ranged between 110.2 g/mol (3-Octyne - C_8H_{14}) and 607.3 g/mol (Octasiloxane- $C_{18}H_{54}O_7Si_8$). In addition to anti-inflammatory and antimicrobial activity, the bioactive compounds of this species perform antiobesity, antihyperlipidemic and hepatoprotective activities.

Discussion

The phytochemicals occur naturally in the seaweeds. These phytochemicals are biologically significant and plays an essential role in defending seaweeds against various pathogenic microbial invasion and acute and chronic disorders. There is evidence of phytochemicals from marine macroalgae possessing anticancer activity due to producing high amount of dietary fiber and polyphenol compound, which act against free radical scavenging activity and anti-inflammatory effects[1-2]. The research approach on phytochemicals is considered effective in discovering bioactive profile of the marine algae of

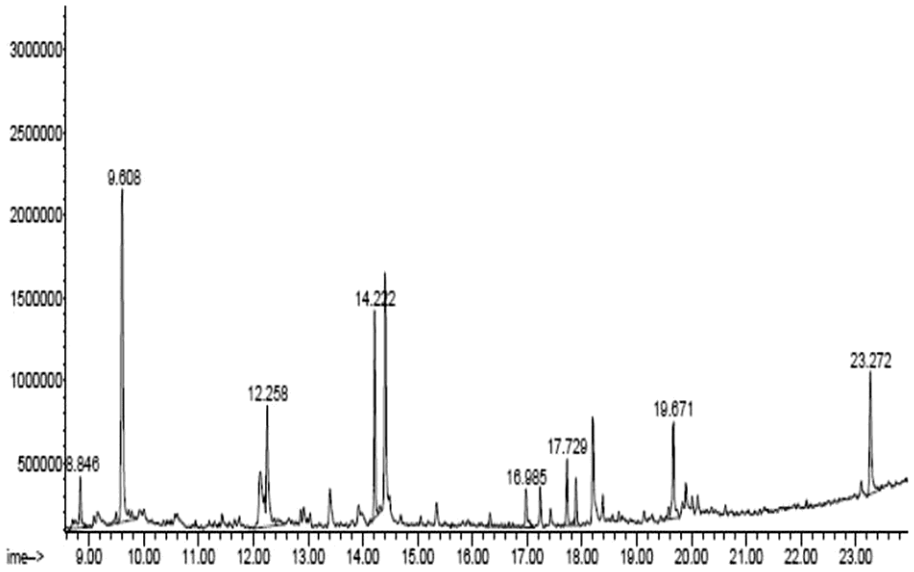

Fig. 3 — GC Chromatogram of bioactive compounds of *U. lactuca*

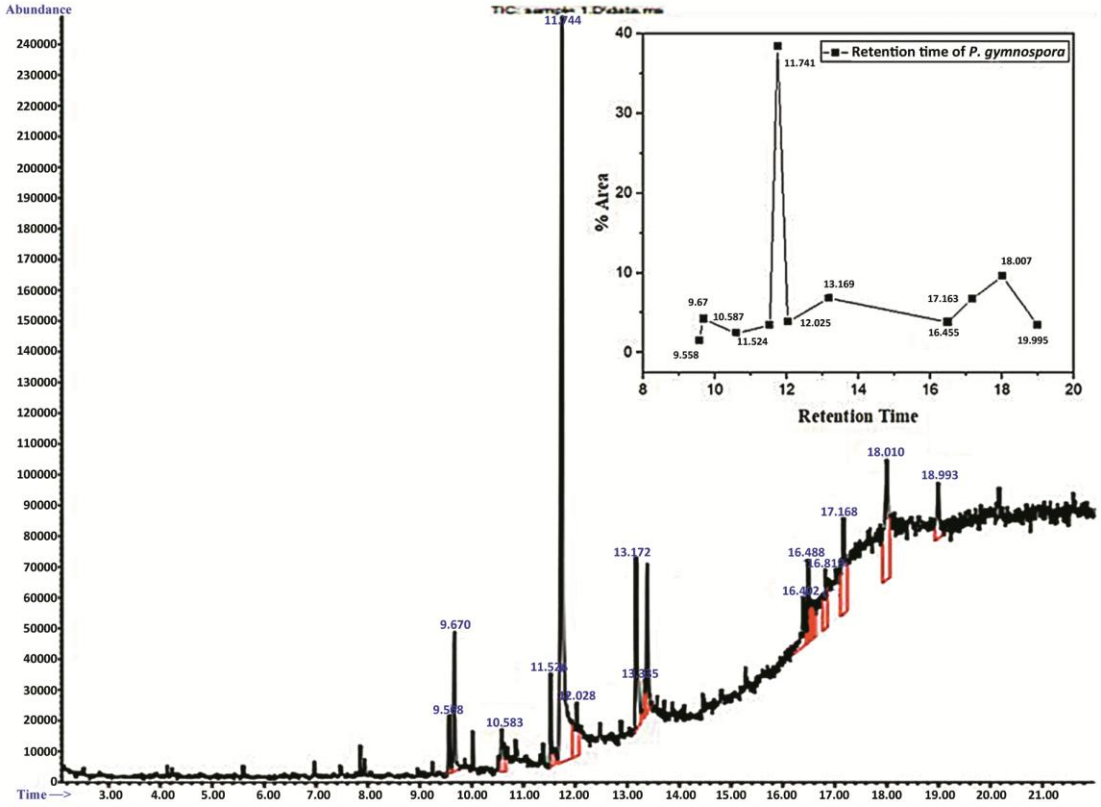

Fig. 4 — GC Chromatogram of bioactive compounds of *P. gymnospora*

therapeutic importance. Screening and evaluation of bioactive compounds revealed occurrence of a wide range of secondary metabolites (alkaloids, phenol, saponins, flavonoids, steroids, terpenoids, tannins, carbohydrates, protein and lipid) which could be nutraceutical as well as of pharmaceutical importance. Preliminary phytochemical screening is a part of chemical evaluation. In the present study, presence

Table 2 — GC MS analysis of bioactive compounds from *H. edulis*

Peak No.	Retention time	Name	Molecular formula	Molecular weight (g/mol)
1.	5.093	N-(cyclohexylcarbonyl)-	$C_{14}H_{17}NO_2$	231.295
2.	5.607	Glycine	$C_{10}H_{15}NO_4$	213.2304
3.	5.658	Nitro-L-arginine	$C_6H_{13}N_5O_4$	219.2
4.	6.493	dl-Phenylephrine	$C_9H_{13}NO_2$	167.208
5.	7.312	Actinobolin	$C_{13}H_{20}N_2O_6$	300.311
6.	7.515	Hydrazine	$H_2N\text{-}NH_2$	32.046
7.	7.599	3-d-ribofuranosyl	$C_{21}H_{29}N_6O_{13}P$	604.466
8.	8.339	Pyrido[3,4-d]imidazole	$C_8H_9N_3O_4$	211.177
9.	8.633	Cyanoacetylurea	$C_4H_5N_3O_2$	127.103
10.	8.957	17-Octadecen-14-ynoic acid	$C_{19}H_{32}O_2$	292.463
11.	9.398	2-Hydrazinopyridine	$C_5H_7N_3$	109.132
12.	9.555	Norephedrine	$C_9H_{13}NO$	151.209
13.	10.1	2(1H)-Pyridone	C_5H_5NO	95.101
14.	10.858	3-Hydroxypiperidine	$C_5H_{11}NO$	101.149
15.	11.14	2-Pyrroline, 1,2-dimethyl-	$C_6H_{11}N$	97.161
16.	11.517	1-Methyldecylamine	$C_{13}H_{28}N_2O$	228.38
17.	12.208	Akuammilan-17-ol	$C_{20}H_{24}N_2O_2$	324.424
18.	12.298	l-Guanidinosuccinimide	$C_5H_7N_3O_2$	141.13
19.	13.36	(2-Aziridinylethyl)amine	$C_4H_{10}N_2$	86.138
20.	13.588	Actinobolin	$C_{13}H_{20}NO_6$	300.311
21.	13.642	Piperidine, 3-methyl-	$C_{13}H_{19}N$	189.302
22.	13.796	dl-Alanyl-dl-leucine	$C_9H_{18}N_2O_3$	202.254
23.	14.65	N-dl-Alanylglycine	$C_5H_{10}N_2O_3$	146.146
24.	19.13	Thiophene-3-ol	C_4H_4OS	100.135
25.	19.27	Glutaraldehyde	$C_5H_8O_2$	100.117
26.	20.159	dl-Alanyl-l-alanine	$C_6H_{12}N_2O_3$	160.173
27.	20.225	L-alanine	$C_3H_7NO_2$	89.094
28.	20.569	N-Methylglucamine	$C_7H_{17}NO_5$	195.215
29.	22.946	1-Propanone	$C_6H_7NO_2$	125.127
30.	23.475	2-Piperidinone	C_5H_9NO	99.133
31.	23.6	Benzenemethanol	C_7H_8O	108.14
32.	23.946	5-Aminoisoxazole	$C_3H_4N_2O$	84.078

Table 3 — GC Chromatogram of bioactive compound of *H. venusta*

Peak No	Retention time	Name	Molecular formula	Molecular weight (g/mol)
1.	5.083	Adenosine	$C_{10}H_{13}N_5O_4$	267.245
2.	5.81	Acetamide	C_2H_5NO	59.068
3.	10.818	Phenyl 3-pyridyl ketone	$C_{12}H_9NO$	183.21
4.	13.154	Eicosane	$C_{20}H_{42}$	282.556
5.	17.65	2-Mercaptobenzothiazole	$C_7H_5NS_2$	167.244
6.	18.908	m-Tolyl isothiocyanate	C_8H_7NS	149.211
7.	20.317	5-Nitro-3-cyano-2	$C_6H_3N_3O_3$	165.108
8.	20.575	L-Leucine	$C_6H_{13}NO_2$	131.175
9.	21.26	4-Piperidinecarboxamide	$C_6H_{12}N_2O$	128.175
10.	23.9	5,5-Dibutylnonane	$C_{17}H_{36}$	240.475
11.	24.344	n-Butyl myristate	$C_{18}H_{36}O_2$	284.484
12.	25.533	Pyrrolidine	C_4H_9N	71.123
13.	31.139	Fumaric acid	$C_4H_4O_4$	116.072
14.	32.541	Trifluoroacetate	$C_2F_3O_2$	113.015
15.	36.742	L-Alanine	$C_3H_7NO_2$	89.094
16.	37.282	N-cyclobutylcarbonyl	$C_7H_{11}NO_3$	157.169
17.	38.384	Benzenesulfonate	$C_{12}H_{16}O_8S$	320.312
18.	39.049	Diisopropylidene	$C_{24}H_{26}O_2$	346.47
19.	40.475	Bupropion	$C_{13}H_{18}C_lNO$	239.743

Table 4 — GC- MS analysis of bioactive compound of *U. lactuca*

Peak No	Retention time	Name	Molecular formula	Molecular weight (g/mol)
1.	8.846	Methyl salicylate	$C_8H_8O_3$	152.149
2.	9.608	Propanoic acid	$C_3H_6O_2$	74.079
3.	12.258	2, 1, 3-Benzothiadiazole	$C_6H_4N_2S$	136.172
4.	14.222	Diethyl Phthalate	$C_{12}H_{14}O_4$	222.24
5.	16.985	Ethylene Bromohydrin	C_2H_5BrO	124.965
6.	17.729	Dibutyl phthalate	$C_{16}H_{22}O_4$	278.348
7.	19.671	Phytol	$C_{20}H_{40}O$	296.539
8.	23.272	Isooctyl Phthalate	$C_{24}H_{38}O_4$	390.564

Table 5 — GC-MS analysis of bioactive compounds of *P. gymnospora*

Peak Number	Retention time	Compound name	Molecular formula	Molecular weight (g/mol)
1.	9.568	1,2,4-Triazolo[4,3-b]pyridazin-8-ol	$C_6H_7N_5O$	165.15
2.	9.670	Tetradecanoic acid	$C_{28}H_{56}O_4$	456.7
3.	10.583	3-Octyne	C_8H_{14}	110.2
4.	11.524	9-octadecenoic acid	$C_{18}H_{34}O_2$	282.5
5.	11.744	*n*-Hexadecanoic acid	$C_{16}H_{32}O_2$	256.43
6.	12.028	Octadecyl ester	$C_{32}H_{64}O_2$	480.8
7.	13.172	Citronellyl isobutyrate	$C_{14}H_{26}O_2$	226.35
8.	13.335	9,12-Octadecadien-1-ol	$C_{18}H_{34}O$	266.5
9.	16.402	Octasiloxane	$C_{18}H_{54}O_7Si_8$	607.3
10.	16.488	Methyltris(trimethylsiloxy)silane	$C_{10}H_{30}O_3Si_4$	310.68
11.	16.819	4-(1,1-Dimethylpropyl)phenol	$C_{11}H_{16}O$	164.24
12.	17.168	2-Ethylacridine	$C_{15}H_{13}N$	207.27
13.	18.010	Cyclotrisiloxane	$H_6O_3Si_3$	138.3
14.	18.993	1H-Indole	C_8H_7N	117.15

of phytoconstituents such as alkaloids, phenol, saponins, flavonoids, steroids, terpenoids, tannins, carbohydrates, protein and lipid were recorded.

Normally, the phenolic compounds are involved in several biological activities especially for antioxidant properties due to their interaction with phenolic hydroxyl group in π-electrons benzene ring which is also responsible for the antimicrobial, anti-inflammatory, anti-feedant, anti-viral, anticancer and vasodilatory actions[12]. Alkaloids exhibit cytotoxic activity against cancer cell line due to the presence of microtubule interfering agent which bind to the ß-tubulin, thus inhibiting the formation of the mitotic spindle fiber required for cell division[13]. Saponins are considered as a major phytoconstituents used for several biological properties especially for reduced acute and chronic inflammation and it is also used to develop several commercialized product and as a dietary supplement in various industries[14]. Steroids of macro-algae are considered as insecticidal, antiparasitic and cardiotonic drug as it plays an important role for nutrition, medicine and cosmetics in human and animals[15]. Tannins are used as a therapeutical product *i.e.* anantiviral, antibacterial, antiulcer and antioxidant agents. In recent years it has been used also to treat piles, inflammation, burns and as astringen[14].

The occurrence varied types of such phytochemical compounds in all the four macro-algal species obviously indicate their utility value in multiple pharmacological applications. In GC-MS analysis, numbers of volatile compounds are recorded from *H. edulis*, *H. venusta*, *U. lactuca* and *P. gymnospora*. All these identified compounds could be of therapeutic values for several acute and chronic diseases and disorders. The pharmaceutical applications of these compounds are wide and have been summarized in Tables 6 – 9. Occurrence of these compounds in marine macroalgae could be addition of new sources to the pharmaceutical industry. Majority of these compounds possess high bioactive potentials to prevent pathogenicity as well as regulation of many physiological processes[81]. There is expanding perception towards bioactive compounds related to their different biological activities. Though all the four species of macro-algae inhabited in the same habitat, GC-MS screening of their extracts showed considerable variations with regard to number of phytochemical compounds they possess. Similar to present study, Cyril *et al.*[82] reported rich content of

Table 6 — Pharmacological properties of bioactive compounds from *H. edulis*

Peak No.	Name	Pharmacological properties	Reference
1.	N-(cyclohexylcarbonyl)	Cytotoxic Activity	16
2.	Glycine	Neuroprotective Effects	17
3.	Nitro-L-arginine	Antioxidant and Cytotoxic Properties	18
4.	dl-Phenylephrine	Septic shock	19
5.	Actinobolin	Antiviral and Antimicrobial activity	20
6.	Hydrazine	Antidepressants and Antineoplastic Agents	21
7.	[3-d-ribofuranosyl]	Antiviral & Antimicrobial activity	22
8.	1,6-dicarboxylic acid	Antidiabetic Compounds	23
9.	Cyanoacetylurea	Antiviral and Anticancer activity	24
10.	17-Octadecen-14-ynoic	Antibacterial activity	25
11.	2-Hydrazinopyridine	Antimicrobial and Anticancer activity	26
12.	Norephedrine	Antiinflammatory and Anticancer properties	27
13.	2(1H)-Pyridone	Antifungal, Antimicrobial and Antioxidant activity	28
14.	3-Hydroxypiperidine	Antimicrobial, Anticancer activity	29
15.	2-Pyrroline, 1,2-dimethyl-	Antitumour properties	30
16.	1-Methyldecylamine	Antimicrobial, Anticancer activity	31
17.	Akuammilan-17-ol	Cytotoxic Properties	32
18.	l-Guanidinosuccinimide	Antiinflammatory and Anticancer acivity	33
19.	(2-Aziridinylethyl)amine	Antiviral Properties	34
20.	Actinobolin	Antiherpes activity	35
21.	Piperidine, 3-methyl-	Anticoagulant activity	36
22.	dl-leucine	Anticancer Activity	37
23.	N-dl-Alanylglycine	Anticancer activity	38
24.	Thiophene-3-ol	Anticancer, Antioxidant	39
25.	Glutaraldehyde	Food Ulcer, Antimicrobial	40
26.	dl-Alanyl-l-alanine	Antibacterial and Cytotoxic Propetierties	41
27.	l-alanine	Antidiabetic, cardioprotective activity	42
28.	N-Methylglucamine	Antidiabetic activity, Inhibition of Alpha Amylase	43
29.	1-Propanone	AntiDiabetic Activity	44
30.	2-Piperidinone	Hepatoprotective, Anticancer Activity	45
31.	Benzenemethanol	Antibacterial and Cytotoxic Propetierties	46
32.	5-Aminoisoxazole	Antiprotozoal and cytotoxic agents	47

Table 7 — Pharmacological properties of bioactive compounds from *H. venusta*

Peak No	Name	Pharmacological properties	Reference
1.	Adenosine	Antiarrhythmic Activity,	48
2.	Acetamide	Inhibition of Bloom's syndrome	49
3.	Phenyl 3-pyridyl ketone	Hypocholesteremic activity	50
4.	Eicosane	Anticancer Properties	51
5.	2-Mercaptobenzothiazole	Antiinflammatory	52
6.	m-Tolyl isothiocyanate	Antiinflammatory	53
7.	5-Nitro-3-cyano-2	Unidentified	-
8.	L-Leucine	Unidentified	-
9.	4-Piperidinecarboxamide	Unidentified	-
10.	5,5-Dibutylnonane	Unidentified	-
11.	n-Butyl myristate	Antifungal Activity	54
12.	Pyrrolidine	HCV and Antiviral activity	55
13.	Fumaric acid	Immunomodulatory effect	56
14.	Trifluoroacetate	Antioxidant Activity	57
15.	L-Alanine	Antidiabetic, cardioprotective activity	58
16.	N-cyclobutylcarbonyl	Unidentified	-
17.	Benzenesulfonate	Unidentified	-
18.	Diisopropylidene	Unidentified	-
19.	Bupropion	Antidepressant and Antioxidant	59

Table 8 — Pharmacological properties of bioactive compounds from *U. lactuca*

Peak No	Name	Pharmacological properties	Reference
1.	Methyl salicylate	Antirheumatic Agents, Antiinflamatory activity	60
2.	Propanoic acid	Antiinflammatory and Anticancer	61
3.	2, 1, 3-Benzothiadiazole	Antiinflammatory	62
4.	Diethyl Phthalate	Antimicrobial, Antiinflammatory and Anticancer activity	63
5.	Ethylene Bromohydrin	Antifungal and Antiinflammatory and Cytotoxic Activity	64
6.	Dibutyl phthalate	Anti-androgenic, Anticancer activity	65
7.	Phytol	Antitubercular, Antimycobacterial and Antivral Activity	66
8.	Isooctyl Phthalate	Antimicrobial and Cytotoxic Activity	67

Table 9 — Pharmacological Properties of *P. gymnospora*

Peak No	Compound name	Biological properties	References
1.	1,2,4-Triazolo[4,3-b]pyridazin-8-ol	-Unidentified-	
2.	Tetradecanoic acid	Anticancer	68
		Anti obesity	69
3.	3-Octyne	Antioxidant activity	70
		Antimicrobial activity	71
4.	9-octadecenoic acid	Antihyperlipidemic and hepatoprotective activity	72
		Anticancer activity	73
5.	*n*-Hexadecanoic acid	Anti-inflammatory Antioxidant activity	74
6.	Octadecyl ester	Antioxidant and Anti malaria	75
7.	Citronellyl isobutyrate	Antimicrobial activity	76
8.	9,12-Octadecadien-1-ol	Antioxidant activity	77
9.	Octasiloxane	-Unidentified-	
10.	Methyltris(trimethylsiloxy)silane	-Unidentified-	
11.	4-(1,1-Dimethylpropyl)phenol	-Unidentified-	
12.	2-Ethylacridine	Hepatoprotective activity and Anticancer Activity	78
13.	Cyclotrisiloxane	Anticancer activity	79
14.	^{1}H-Indole	Antimicrobial activity	80

secondary metabolites and variation pertaining to their number in two other marine macroalgae, namely, *Sargassum wightii* and *Gracilaria verrucosa*. Bioactive compounds from the seaweed *Caulerpara cemosa* is believed to possess high medicinal property especially in treating diabetes and rheumatoid arthritis[83]. Applications of bioactive compounds from seaweeds in controlling pathogenicity of aquaculture organisms will lead to eco-friendly economic activity[83-84]. Recent report on pro-mineralogenic compounds from two green macroalgae *Codium fragile* and *Cladophora rupestris* exhibited mineralogenic and osteogenic activities. The quantitative analysis of operculum formation in zebrafish larvae further established mineralogenic activity of bioactive compounds from seaweeds[85]. Due to the rich content of vital bioactive compounds there should be more investigations on utilization of bioactive compounds of seaweeds in human health and other related applications.

Conclusion

Present study enumerates new secondary metabolites from marine macroalgae using phytochemical and GC-MS analysis. These secondary metabolites from natural sources could be effective compounds in the pharmaceutical applications. The compounds such as 1,6-dicarboxylic acid, adenosine, propanoic acid, and tetradecanoic acid could be alternative to synthetic compounds used for metabolic disorders. Further usage of these compounds in therapeutics will have minimum side effects.

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Conflict of Interest

The authors have no conflict of interest.

Ethical Statement

Not applicable for this study.

Author Contributions

All the authors contributed equally to this research work.

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