



Unveiling the aromatic profile of marine macroalgae:
a review of the composition and bioactivity of essential oils

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Table S1 – Comparative overview of essential oil extraction methods, chemical yields, and biological activities of seaweeds.

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial [#]	
Rhodophyta												
Corallinales												
<i>Jania rubens</i> (Linnaeus) J.V.Lamouroux	Izmir, Turkey (38°45'N / 27°09'E)	Biotech	HD	4	Yes (EtOAc)	-	-	-	-	-	Inhibition Zone Disc Diffusion (0.015 µg / mL) for: a, c, n, o, p, q, t, ad, and ap.* Not Active	Karabay-Yavasoglu <i>et al.</i> 2007

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Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References	
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial *		
Bangiales													
<i>Porphyra tenera</i> Kjellman	Yamaguchi, Japan (34°53'N/ 131°42'E)	Ecology	NS	-	Yes (<i>n</i> -pentane: CH ₂ Cl ₂ 1:1)	-	0.10	Chemical cues: pheromones in the conchocellis-filaments	-	-	-	Kajiwara <i>et al.</i> 1990	
	Gyeongsan, Gyeongbuk, Korea (35°49'N/ 128°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	-	1.41	-	-	-	MIC (MBC): (µg/ mL) for ag 25000 (25000), ah (-) and ai 12500 (25000) **	Patra & Baek 2016b	
Ceramiales													
<i>Laurencia obtusa</i> (Hudson) J.V. Lamouroux	Izmir, Turkey (38°32'N/ 26°30'E)	Biotech	HD	4	NS	-	-	-	-	SEO 1.0 mg/ mL (BHA 0.1 mg/ mL): ABTS ⁺ 26.08 (97.90), β-carot 37.37 (92.85), DPPH 0.19 (87.93)	Inhibition Zone Disc Diffusion (0.1 µg/ mL) for: c (13), g (11), aj (9), o (9), s (-), r (-), af (-), au (-), al (-), m (13), w (-) and ap (11) *	Demirel <i>et al.</i> 2011	
<i>L. obtusa var. pyramidata</i> Bory ex J.Agardh	Izmir, Turkey (38°32'N/ 26°30'E)	Biotech	HD	4	NS	-	-	-	-	SEO 1.0 mg/ mL (BHA 0.1 mg/ mL): ABTS ⁺ 23.1 (97.90), β-carot 10.8 (92.85) DPPH 1.2 (87.93)	Inhibition Zone Disc Diffusion (0.1 µg/ mL) for: c, at, aj, o, s, r, au, av, al, w, m, af and ax. * Not Active	Demirel <i>et al.</i> 2011	
<i>L. dendroidea</i> J. Agardh	Anchieta, Espírito Santo, Brazil (20°48'S/ 40°36'W)	Biotech	HD	4	Yes (Et ₂ O)	-	-	-	-	SEO 500 µg/ mL DPPH (8.10). Vitamine E as positive control (Not showed)	MIC: (500 µg/ mL) for h, c, al, b, an, ae, u, p and aq.* Not active	Gressler <i>et al.</i> 2011	

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial *	
<i>Centroceras clavulatum</i> (C. Agardh) Montagne	Marrocos (31°30'N/ 9°47'W)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	-	-	-	-	-	Inhibition Zone Disc Diffusion: au, av, c, ao, ax, an, az, ar, as and at. *** Weak activity	Nafis <i>et al.</i> 2021
Chlorophyta												
Uvaes												
<i>Ulva pertusa</i> Kjellman	Yamaguchi, Japan (34°53'N/ 131°42'E)	Ecology	SD	2	Yes (<i>n</i> -pentane: CH ₂ Cl ₂ , 2:1)	0.03	-	Chemical cues: Algal sex attractant of gametes in the Phaeophyta <i>Anallipus japonicus</i>	-	-	-	Akakabe & Kajiwa 2008
<i>U. lactuca</i> Linnaeus	El jadida, Marrocos (33°24'N/ 8°49'W)	Biotech	HD	3	NS	-	0.19	-	-	-	Anticyanobacterial (<i>Microcystis aeruginosa</i>), harmful algae control - Not active	Zerrifi <i>et al.</i> 2020
<i>U. rigida</i> C. Agardh	Loutropyrgos, Greece (38°02'N/ 23°46'E)	Ecology	HD	2	Yes (CH ₂ Cl ₂)	-	-	Enviromental effects of halocarbons release-	-	-	-	Roussis <i>et al.</i> 2000
	Sinop, Turkey (42°06'N/ 35°04'E)	Biotech	HD	4	Yes (<i>n</i> -hexane)	0.05	-	-	-	-	MIC (MBC): µg/ mL for h 12 (23), aw 16 (20), d 20 (18), p 13 (20), u (22) and aq (24) *	Yücel <i>et al.</i> 2023

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial ‡	
<i>Codium fragile</i> (Suringar) Hariot	Izmir, Turkey (38°45'N / 27°09'E)	Biotech	HD	4	Yes (<i>n</i> -hexane)	-	-	-	-	-	MIC (MBC): µg/mL for c<50 (<50), f 50 (<50), n<50 (<50), ax <50 (500), m (-), s (-), r (-), au (-), w (-), av (-), al (-), af (-) and az (-)	Koz <i>et al.</i> 2009
Bryopsidales												
<i>Enteromorpha linza</i> (= <i>U. linza</i>) (Linnaeus) J.Agardh	Gyeongsan, Gyeongbuk, Korea (35°49'N / 128°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	-	-	-	-	-	MIC (MBC): µg/mL ab, ac, x and y 12500 (25000) ****	Patra <i>et al.</i> 2015a
	Gyeongsan, Gyeongbuk, Korea (35°49'N / 128°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	-	-	-	-	SEO 500 µg/mL (BHA 0.1 mg/mL): ABTS ⁺ 37.01 (97.90), superoxide scavenging activity 53.50 (91.37), β-carot 10.8 (92.85), DPPH 91.37 (87.93), OH [•] 91.37 (94.58), superoxide scavenging 53.50 (49.34), reducing power (0.90) and inhibited lipid peroxidation by 70.53%.		Patra <i>et al.</i> 2015c
	Gyeongsan, Gyeongbuk, Korea (35°49'N / 128°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	0.32	-	-	-	-	MIC (MBC): µg/mL for d 25000 (25000), e 12500 (12500), i 12500 (12500) and j 12500 (25000). SEO at 25 mg/ disc ****	Patra & Baek 2016a

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial *	
	Gyeongsan, Gyeongbuk, Korea (35°49'N/128°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	0.32	-	-	-	-	MIC (MBC): µg/mL ag 25000 (25000), ah 12500 (25000) and ai 12500 (25000) **	Patra & Baek 2016b
<i>E. compressa</i> (=U. compressa) (Linnaeus) Nees	Alexandria, Egypt (31°29'N/30°16'E)	Biotech	HD	2	NS	-	-	-	-	SEO 100 µg/mL (BHT: total antioxidant) * 40 (37.1), ABTS ⁺ 12.7 (83.6), OH ⁻ 158.18 (52.81), β-carot 14 (68), DPPH 41 (89.5) and reducing power 2.07 (18.12) *	-	Shanab <i>et al.</i> 2011
Ochrophyta												
Fucales												
<i>Sargassum muticum</i> (Yendo) Fensholt	El jadida, Marrocos (33°24'N/8°49'W)	Biotech	HD	3	NS	-	0.11	-	-	-	Anticyanobacterial (<i>Microcystis aeruginosa</i>), harmful algae control MIC 62.5 µg/mL	Zerrifi <i>et al.</i> 2020
<i>Fucus spiralis</i> Linnaeus	Sidi Bouzid-El Jadida, Marrocos (33°23'N/8°54'W)	Biotech	HD	4	NS	-	0.30	-	Anti-insective (Mediterranean adults fruit fly <i>Ceratitis capitata</i> Wiedemann (Diptera: Tephritidae): LD ₅₀ 0.239	-	-	Boutjagualt <i>et al.</i> 2022
<i>Nizamuddinia zanardinii</i> (Schiffner) P. C. Silva	Chabahar, Irā (25°27'N/60°64'E)	Chemical Profile	HD	4.5	NS	0.40	-	-	-	-	-	Firouzi <i>et al.</i> 2013

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial *	
<i>Cystoseira tamariscifolia</i> (Hudson) Papenfuss	Souiria Laqdim, Marrocos (32°04'N / 9°34'W)	Biotech	HD	3	NS	-	0.06	-	-	-	Anticyanobacterial (<i>Microcystis aeruginosa</i>), harmful algae control MIC 7.81 µg/mL	Zerrifi et al. 2020
<i>C. compressa</i> (Esper) Gerloff & Nizamuddin	C'iovo Island, Croatia (43°49'N / 16°27'E)	Chemical Profile and Ecology	HD	3	Yes (<i>n</i> -pentane:Et ₂ O, 1:1)	-	-	Seasonal changes of chemical profile	-	-	-	Mekinić et al. 2021
<i>C. crinita</i> Duby	Sinop, Turkey (42°03'N / 35°16'E)	Biotech	HD	4	Yes (<i>n</i> -hexane)	0.08	-	-	-	-	Inhibition Zone Disc Diffusion (SEO 8.61 mg/mL at DMSO): h, aw, d 14 (18), p 13 (20), u, ap (-) *	Yücel 2021
Dictyotales												
<i>Dictyota dichotoma</i> (Hudson) J. V. Lamouroux	Izmir, Turkey (38°45'N / 27°09'E)	Chemical Profile	HD	4	Yes (<i>n</i> -hexane)	-	-	-	-	-	-	Demirel et al. 2009
<i>D. dichotoma</i> var. <i>implexa</i> (Desfontaines) S. F. Gray	Izmir, Turkey (38°45'N / 27°09'E)	Chemical Profile	HD	4	Yes (<i>n</i> -hexane)	-	-	-	-	-	-	Demirel et al. 2009
<i>Dictyopteris polypodioides</i> (De Candolle) J. V. Lamouroux	Tipaza, Algeria, (36°59' N / 2°47' E)	Biotech	HD	3	NS	8.00	-	-	-	-	MIC (µg/mL) ax and <i>Agrobacterium tumefaciens</i> : (1519) and af, d, ao and au (3038) *****	Riad et al. 2020
<i>Taonia atomaria</i> (Woodward) J. Agardh	Island Vis, Croatia (43°06'N / 16°18'E)	Methodol Develop	HD	2	Yes (<i>n</i> -pentane:Et ₂ O, 1:2)	-	-	-	-	-	-	Jerković et al. 2019

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial [‡]	
<i>Padina pavonica</i> (Linnaeus) Thivy	Vis Island, Croatia (43°06'N / 16°18'E)	Methodol Develop	HD	2	Yes (<i>n</i> -pentane:Et ₂ O, 1:2)	-	-	-	-	-	-	Jerković <i>et al.</i> 2019
Ectocarpales												
<i>Petalonia fascia</i> (O. F. Müller) Kuntze	Izmir, Turkey (38°45'N / 27°09'E)	Chemical Profile	HD	4	Yes (<i>n</i> -hexane)	-	-	-	-	-	-	Demirel <i>et al.</i> 2009
<i>Scytosiphon lomentaria</i> (Lyngbye) Link	Izmir, Turkey (38°45'N / 27°09'E)	Chemical Profile	HD	4	Yes (<i>n</i> -hexane)	-	-	-	-	-	-	Demirel <i>et al.</i> 2009
	Yamaguchi, Japan (34°53'N / 131°42'E)	Chemical Profile and Ecology	SD	NS	Yes (Et ₂ O)	-	0.01	Chemical cues: Algal sex attractant of gametes in the Phaeophyta <i>Anelipus japonicu</i>	-	-	-	Kajiwarra <i>et al.</i> 1991
<i>Colpomenia sinuosa</i> (Mertens ex Roth) Derbès & Solier	Izmir, Turkey (38°45'N / 27°09'E)	Chemical Profile	HD	4	Yes (<i>n</i> -hexane)	-	-	-	-	-	-	Demirel <i>et al.</i> 2009
Laminariales												
<i>Alaria crassifolia</i> Kjellman	Hokkaido, Japan (43°95'N / 144°71'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.01	-	-	-	-	Kajiwarra <i>et al.</i> 1988

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial [‡]	
<i>Costaria costata</i> (C. Agardh) De A. Saunders	Hokkaido, Japan (43°95'N / 144°71'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.01	-	-	-	-	Kajiwarara <i>et al.</i> 1988
<i>Ecklonia cava</i> Kjellman	Yamaguchi, Japan (34°53'N / 131°42'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.01	-	-	-	-	Kajiwarara <i>et al.</i> 1988
<i>Laminaria angustata</i> Kjellman	Hokkaido, Japan (43°95'N / 144°71'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.01	-	-	-	-	Kajiwarara <i>et al.</i> 1988
<i>L. japonica</i> Areschoug	Hokkaido, Japan (43°95'N / 144°71'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.09	-	-	-	-	Kajiwarara <i>et al.</i> 1988
	Gyeongsan, Gyeongbuk, Korea (35°49'N / 128°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	-	0.85	-	-	-	MIC (MBC): µg/mL ag (-), ah 25000 (25000) and ai 25000 (25000) **	Patra & Baek 2016b
	Wando Island, Korea (34°21'N / 126°44'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	-	-	-	-	SEO 500 µg/mL (BHT 50 µg/mL): superoxide scavenging activity 53.88 (52.81), ABTS ⁺ IC ₅₀ 92.98 (19.65), OH [•] IC ₅₀ 158.18 (52.81) and DPPH 80.45 (30.31), reducing power IC _{0.5} 89.35 (12.74) and inhibited lipid peroxidation IC ₅₀ by 388.35 (35.61)	MIC (MBC): µg/mL d, h (25000) and (-) ****	Patra <i>et al.</i> 2015b
<i>Kjellmaniella crassifolia</i> Miyabe	Hokkaido, Japan (43°95'N / 144°71'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.01	-	-	-	-	Kajiwarara <i>et al.</i> 1988

Phylogeny	Collection sites (coordinates)	Approach	Extraction method			SEO Yield (%)		Biological activity				References
			Tech	Time (h)	Hydrolate (solvent extraction)	d/w	w/w	Ecological	Bioinsecticide	Antioxidant (% Activity)	Antimicrobial [#]	
<i>Undaria pinnatifida</i> (Harvey) Suringar	Yamaguchi, Japan (34°53'N/131°42'E)	Biotech	SD	-	Yes (<i>n</i> -pentane)	-	0.01	-	-	-	-	Kajiwarra <i>et al.</i> 1988
	Hokkaido, Japan (43°95'N/144°71'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	0.26	-	-	-	-	-	Patra <i>et al.</i> 2017
	Hokkaido, Japan (43°95'N/144°71'E)	Biotech	MAHD	4	Yes (CH ₂ Cl ₂)	0.26	-	-	-	-	MIC (MBC): µg/mL ag (-), ah 12500 (12500) and ai 25000 (25000) **	Patra & Baek 2016b

Biotech = Biotechnology. Methodol Develop = Methodological Development. HD = Hydrodistillation (Clevenger-type). SD = Steam Distillation. MAHD = Microwave-Assisted Hydrodistillation. NS = Technique Not Specified. d/w = Dry Weight. w/w = Wet Weight. CH₂Cl₂ = Dichloromethane. Et₂O = Ethyl ether. EtOAc = Ethyl acetate.

ABTS⁺ = ABTS⁺ (2,2'-azino-bis(3-ethylbenzenothiazoline-6-sulfonic acid) radical scavenging assay. β-carot = β-carotene bleaching assay. DPPH = (2,2-diphenyl-1-picryl-hydrazyl-hydrate) free radical scavenging assay. OH[•] = hydroxyl radical scavenging assay. BHA = Butylated Hydroxyanisole as positive control. BHT = Butylated Hydroxytoluene as positive control.

[#] MIC = Minimum Inhibitory Concentration. MBC = Minimum Bactericidal Concentration. Microbial strains = a - *Streptococcus faecalis* (ATCC 8043), b - *S. pneumoniae* (ATCC 49619), c - *Bacillus subtilis* (ATCC 6633), d - *B. cereus* (ATCC 10876), e - (ATCC 13061), f - *B. cereus*, g - *Staphylococcus aureus* (ATCC 6538), h - (ATCC 29213), i - (ATCC 12600), j - (ATCC 49444), l - (ATCC 25923), m - *S. aureus* (methicillin-oxacillin resistant), n - *S. epidermidis* (ATCC 12228), o - *S. epidermidis*, p - *Pseudomonas aeruginosa* (ATCC 27853), q - *Enterobacter cloacae* (ATCC 13047), r - *E. cloacae*, s - *E. aerogenes*, t - *Escherichia coli* (ATCC 29998), u - (ATCC 25922), v - (ATCC 3038), x - (ATCC 43889), z - (ATCC 43890), y - *E. coli* (O157:H7 ATCC 43890), w - hemorrhagic *E. coli* (-), ab - *Salmonella enterica* serovar Typhimurium (ATCC 19586), ac - (ATCC 43174), ad - (CCM 583), ae - *Salmonella typhi* (ATCC 19430), af - *S. typhimurium*, ag - *Listeria monocytogenes* (ATCC 19114), ah - (ATCC 19115), ai - (ATCC 7644), aj - *Enterococcus faecalis*, al - (ATCC 29212), al - *Proteus vulgaris*, am - *Agrobacterium tumefaciens*, an - *Klebsiella pneumoniae* (ATCC 13883), ao - *Micrococcus luteus*, ap - *Candida albicans* (ATCC 10239), aq - (ATCC 10231), ar - *C. glabrata*, as - *C. krusei*, at - *C. parapsilosis*, au - *E. coli*, av - *P. aeruginosa*, ax - *Staphylococcus aureus*, az - *C. albicans*, aw - MRSA (ATCC 67101). * Tobramycin discs (10 µg/disc) and nystatin (30 µg/disc) were used as positive controls. ** = Kanamycin (40 µg/disc) was used as positive control. *** = Ciprofloxacin and fluconazole were used by the checkerboard method. **** = Rifampicin (20 to 40 µg/disc) was used as positive control and 5 % DMSO as the negative control. ***** = Kanamycin and chloramphenicol were used as antibiotics references with MIC from 12.5 to 125.