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Antibacterial properties of selected freshwater microalgae against pathogenic bacteria

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ABSTRACT

Aqueous, ethanolic and methanolic extracts from four selected freshwater microalgae, *Euglena viridis*, *Chlorella vulgaris*, *Microcystis aeruginosa* and *Spirulina platensis* were examined for antibacterial activity by single disk diffusion method. All four algae revealed antibacterial properties. Best results were shown by the ethanolic extracts of *E. viridis* against *Vibrio alginolyticus*, *Vibrio harveyi*, *Pseudomonas putida* and *Escherichia coli*. Aqueous extracts of *C. vulgaris* also possessed antibacterial properties.

Keywords: Aantibacterial properties, *Chlorella vulgaris, Euglena viridis, Microcystis aeruginosa, Spirulina platensis*

Introduction

A variety of biologically active constituents have been isolated from various species of microalgae. The increased use of antibiotics and chemotherapeutants for disease treatment leads to problems of emergence of drug resistant forms and also impact adverse effects on the ecosystem (Aoki, 1992). A decreased efficacy of antibiotics regardless of their mechanism of action, leads to the need for suitable alternatives. Microalgae are extremely diverse group of organisms yielding an almost unlimited range of chemicals. One potential commercial application of microalgae derived compounds that has, as yet, received little attention is in the area of pharmaceuticals. Both cell extracts and extracts of the growth media of various unicellular algae (*e.g., Chlorella vulgaris*, *Chlamydomonas pyrenoidosa*) have been proved to have antibacterial activity *in vitro* against both Gram-positive and Gram-negative bacteria. It has also been reported that a wide range of *in vitro* antifungal activities are obtained from extracts of green algae, diatoms and dinoflagellates. Various strains of Cyanobacteria are known to produce intracellular and extracellular metabolites with diverse biological activities such as antibacterial, antifungal, antiviral and antialgal activity (Noaman *et al*., 2004; Volk and Furkert, 2006; Valdor and Aboal, 2007; Rania *et al*., 2008).

Screening of lipophilic and hydrophilic extracts from cultured cyanobacteria or waterbloom material, isolated from German lakes and the Baltic sea for antiviral, antibiotic, immunomodulating and enzyme inhibiting activity in different *in vitro* systems revealed strains with interesting effects (Mundt *et al*., 2001). Secondary metabolites from various microalgae are associated with toxic, hormonal, antineoplastic and antibacterial effects (Patterson *et al*. 1994; Goldin, 2003). Secondary metabolites influence other organisms in the vicinity and are thought to be of phylogenetic importance. There has been an increasing interest in cyanobacteria as a potential source for new drugs (Skulberg, 2000). There are numerous reports of compounds derived from *Chlorella* with a broad range of biological activities, such as antibacterial (Pratt *et al*., 1944; Matusiak *et al.*, 1965), antiviral (Ibusuki and Minamishima, 1990), antitumor (Tanaka *et al*., 1998; Hasegawa *et al*., 2002) as well as immunomodulatory (Halperin *et al*., 2003) effects. The free radical scavenging, anti-oxidative and anti-inflammatory activities of *Chlorella* have also been discovered in *in vitro* studies (Vijayavel *et al*., 2007). *Microcystis aeruginosa* shows antibacterial activity against the Gram-positive bacterium *Staphylococcus aureus* (Ishida *et al*., 1997). The objective of the present study was to develop and apply bacterial bioassays for the observation and quantification of possible antibacterial effects from algal extracts, which are active against fish pathogenic bacteria. It should be possible to develop specific microalgal based biologically active compounds for aquaculture inorder to avoid development of resistance against antibiotics used in human medicine.

Materials and methods

Collection and culture of microalgae

Samples of freshwater algae (*Euglena* and *Microcystis*) were collected from ponds of Central Institute of Freshwater Aquaculture and from Bindusagar, Bhubaneswar, India in

the month of September and January 2008 respectively. All samples were brought to the laboratory in plastic bags containing pond water and then washed three times with distilled water to separate potential contaminants. These two algae were identified as belonging to families Euglenophyceae and Chlorococcaceae respectively following Records of Botanical Survey of India (Biswas, 1949).

Axenic cultures of *C. vulgaris* and *S. platensis* (procured from Algal Culture Unit, CIFA, Bhubaneswar) were grown in freshly prepared culture medium. For growth, a temperature of 28 ± 2^{0}C and illumination by cool white fluorescent lamps of intensity 25 Wm^{-2} was provided. The cells of 20 d old cultures were then harvested by centrifugation (5000 g) at 4 ^{0}C and washed with Millipore water.

Dry weight determination

The cells were separated from the culture filtrate by centrifugation and then washed several times with distilled water. Biomass were transferred to a pre-weighed dry filter paper using a clean spatula and placed in an oven at 60 °C overnight to reach constant weight.

Preparation of the extracts

Harvested samples were dried at room temperature and ground in an electric grinder. Resulting powder was submitted to lipid soluble polar solvents (ethanol, methanol) as well as aqueous medium for extraction, using a soxhlet extractor at 55- 60 ^{0}C. All samples were refluxed until saturation (24 h) and the respective extracts were dried in rota-evaporator. Subsequently the residual extracts were suspended in the respective solvents to a final concentration of 10 µg µl^{-1}.

Test organisms

Antibacterial sensitivity was tested against the pathogenic Gram-negative strains of *Aeromonas hydrophila* (AH1, AH2, AH3 and AH4), *Psedomonas putida* (PP1,

Table 1. Inhibition zone in mm of ethanolic extracts of freshwater microalgae

Microorganisms	Code	Algae			
		Euglena viridis	*Chlorella vulgaris*	*Microcystis aeruginosa*	*Spirulina platensis*
Pseudomonas putida	PP1	14.0 ±0.57^{a}	10.6± 0.3^{b}	11.3± 0.3^{b}	14.3± 0.3^{a}
	PP2	15.33± 0.33^{a}	12.0± 0.5^{b}	11.6± 0.3^{b}	13.0± 0.57^{b}
	ATCC(49128)	13.33± 0.3^{a}	11.6± 0.3^{b}	11.3± 0.3^{b}	14.3± 0.33^{a}
Pseudomonas aeruginosa	PA1	13.0± 1.15^{a}	09.6± 0.3^{b}	10.3± 0.3^{b}	13.3± 0.3^{a}
	PA2	13.0± 0.57^{a}	11.3± 0.3^{a}	12.6± 0.6^{a}	12.3± 0.3^{a}
	ATCC(27853)	14.6± 0.3^{a}	12.0± 0.3^{bc}	11.3± 0.3^{c}	12.6± 0.3^{b}
Pseudomonas fluorescens	PF1	10.3± 0.3^{b}	12.3± 0.3^{a}	10.3± 0.3^{b}	13.3± 0.3^{a}
	PF2	13.6± 0.3^{a}	13.0± 0.5^{a}	9.6± 0.6^{b}	12.3± 0.3^{a}
Aeromonas hydrophila	AH1	11.0± 0.5^{bc}	13.0± 1.1^{ab}	13.6± 0.3^{a}	10.0± 0.5^{c}
	AH2	12.3± 0.3^{c}	16.3± 0.3^{a}	14.3± 0.3^{b}	15.6± 0.3^{a}
	AH3	10.0± 0.5^{b}	12.0± 1.0^{b}	11.3± 0.3^{b}	14.3± 0.3^{a}
	AH4	12.3± 0.3^{b}	11.3± 0.3^{b}	12.0± 0.5^{b}	15.3± 0.3^{a}
	ATCC(49140)	12.3± 0.3^{c}	14.6± 0.3^{a}	13.6± 0.34^{b}	15.3± 0.3^{a}
	MTCC (646)	10.6± 0.45^{b}	13.6± 0.26^{a}	12.0± 0.3^{b}	10.65± 0.34^{b}
Vibrio alginolyticus	VA	20.0± 1.1^{a}	14.3± 0.3^{b}	14.3±0.3^{b}	13.3± 0.3^{b}
Vibrio parahaemolyticus	VP	16.6± 0.3^{a}	12.0± 1.0^{b}	15.6± 0.3^{a}	13.3± 0.3^{b}
Vibrio harveyi	VH	21.0± 0.5^{a}	13.0± 1.1^{b}	11.6± 0.6^{b}	11.6± 0.3^{b}
Vibrio fluvialis	VF	10.0± 0.5^{d}	14.3± 0.3^{b}	16.3± 0.3^{a}	11.6± 0.3^{c}
Vibrio fisheri	VFS	19.0± 1.1^{a}	11.3± 0.6^{c}	9.6± 0.3^{c}	15.3± 0.3^{b}
Vibrio anguillarum	VAN	16.33± 0.3^{ab}	15.3± 0.3^{b}	16.3± 0.3^{a}	15.3± 0.3^{b}
Escherischia coli	O1	16.6± 0.3^{a}	15.3± 0.3^{b}	10.3± 0.3^{d}	15.6± 0.3^{ab}
	O115	17.6± 0.3^{a}	14.3± 0.3^{c}	11.3± 0.3^{d}	15.6± 0.3^{b}
	O156	13.3± 0.3^{a}	13.3± 0.3^{a}	12.3± 0.3^{ab}	11.3± 0.3^{b}
	O164	09.3± 0.3^{c}	12.0± 0.0^{b}	9.6± 0.3^{c}	13.3± 0.1^{a}
	O111	18.3± 0.3^{a}	10.6± 0.3^{b}	10.3± 0.3^{b}	-
	O109	17.6± 0.3^{a}	12.3± 0.3^{b}	4.3± 0.2^{c}	-
Edwardsiella tarda	ETA	12.3±0.3^{a}	11.3± 0.3^{a}	11.3± 0.3^{a}	12.3± 0.3^{a}

Values represent mean±S.D.,

Values bearing common superscript are not significantly different ($p<0.05$)

PP2), *Pseudonoms fluorescens* (PF1, PF2), *Pseudomonas aeruginosa* (PA1, PA2), *Vibrio alginolyticus* (VA), *Vibrio anguillarum* (VAN), *Vibrio fluvialis* (VF), *Vibrio parahaemolyticus* (VP), *Vibrio harveyi* (VH), *Vibrio fisheri* (VFS), *Escherichia coli* (O115, O1, O156, O164, O111 and O109) and *Edwardsiella tarda*.

Inhibitory effect by the disc diffusion method

Single disc diffusion method as described by Chabbert (1963), was used for antibacterial sensitivity test of the above selected algal extracts. The bacterial pathogens used in this work (other than *E. coli*) were isolated from diseased fish and prawns which are being maintained the Fish Health Management Division, Central Institute of Freshwaters Aquaculture (CIFA), Bhubaneswar.

All bacteria were grown in nutrient broth (10^7 cells ml^{-1}), incubated at 37 ^{0}C for 24 h and plated using a sterile swab, on to petridishes containing Antibiotic Assay Medium (Hi media, Mumbai). At the same time, sterile discs of

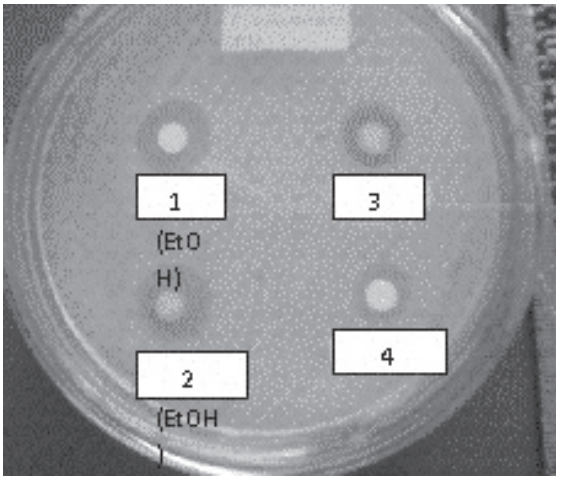

Fig. 1. Antibacterial activity of ethanolic extracts of *Euglena* (1), *Microcystis* (2) *Chlorella* (3) and Control (4) against *P. aeruginosa* (PA2)

Table 2. Inhibition zone in mm of aqueous extracts of freshwater microalgae

Microorganisms	Code	Algae			
		Euglena viridis	*Chlorella vulgaris*	*Microcystis aeruginosa*	*Spirulina platensis*
Pseudomonas putida	PP1	7.6± 0.3^b	8.6± 0.3^a	-	-
	PP2	-	9.3± 0.3^a	-	-
	ATCC(49128)	7.0± 0.5^b	9.3± 0.3^a	-	-
Pseudomonas aeruginosa	PA1	-	12.6± 0.3^a	-	8.6± 0.3^b
	PA2	-	13.6± 0.3^a	-	-
	ATCC(27853)	-	13.6± 0.3^a	-	9.6± 0.3^b
Pseudomonas fluorescens	PF1	-	10.3± 0.3^a	-	8.3± 0.3^b
	PF2	6.01± 0.01^b	10.6± 0.3^a	-	-
Aeromonas hydrophila	AH1	-	11.6± 0.3^a	-	-
	AH2	-	11.0± 0.5^a	-	9.6± 0.3^b
	AH3	-	15.0± 0.5^a	-	10.3± 0.3^b
	AH4	7.3± 0.3^c	15.3± 0.3^a	6.3± 0.3^c	8.6± 0.3^b
	ATCC(49140)	-	12.3± 0.3^a	-	-
	MTCC (646)	-	14.3± 0.3^a	-	10.0± 0.5^b
Vibrio alginolyticus	VA	0	-	-	-
Vibrio parahaemolyticus	VP	7.3±0.3^b	11.3± 0.3^a	-	-
Vibrio harveyi	VH	8.0± 0.3^b	6.3± 0.3^c	7.3± 0.3^{bc}	11.3± 0.3^a
Vibrio fluvialis	VF	-	-	-	9.6± 0.3^a
Vibrio fisheri	VFS	-	-	-	-
Vibrio anguillarum	VAN	7.6± 0.3^b	12.0± 0.5^a	-	-
Escherischia coli	O1	-	-	10.0± 0.0^a	-
	O115	-	-	11.0± 0.5^a	-
	O156	7.6± 0.3^{bc}	7.3± 0.3^c	12.3± 0.3^a	8.6± 0.3^b
	O164	-	-	10.3± 0.3^a	10.0± 0.5^a
	O111	-	-	10.3± 0.3^a	-
	O109	-	-	-	-
Edwardsiella tarda	ETA	8.6± 0.0^b	-	10.3± 0.3^a	-

Values represent mean±S.D.

Values bearing common superscripts are not significantly different ($p<0.05$)

5 mm diameter were embedded with 10 µl of the algal solvent extracts. After solvent evaporation, the discs were put on the above agar plates inoculated with the test bacteria and incubated at 37 ^{0}C. Discs with solvent (10 µl) used for dissolution were taken as control after evaporation of the solvent. Activity of the microalgae extracts against bacterial pathogens was determined after 24 h at 37 ^{0}C by measuring the diameter of the halo around the discs (Izzo *et al*., 1995). The results were analyzed using one way analysis of variance (ANOVA) and significant difference among the four microalgae were compared using Duncan's multiple range test (DMRT) (Duncan, 1955). The antibacterial activities of algal extracts were compared with inhibition zones around three commercial antibacterial discs *i.e.,* Clotrimazole, Tetracycline and Furazolodone (Hi Media, India) that were used as references.

Results and discussion

From the screening test conducted it was observed that the ethanolic extract of *E. viridis* showed the highest zone of inhibition against VH (21 mm) followed by VA, VFS and two serotypes of *E. coli i.e.,* O111 and O115 (Table 1). Aqueous extract of *E. viridis* was not effective against the above selected pathogens. In the case of *C. vulgaris*, both ethanolic as well as aqueous extracts were active against these pathogens (Table 2, Fig.1). Ethanolic extract of *C. vulgaris* showed maximum zone of inhibition (15.3-16.3mm) against *A. hydrophila* (AH2), *V. anguillarum* (VAN) and *E. coli* (O1), whereas, aqueous extract of *Chlorella* was also highly active (15.3mm) against *A. hydrophila* (AH3, AH4). It was found that ethanolic extracts of the other two groups of algae (*M. aeruginosa* and *S. platensis*) showed maximum zone size, ranging from 15.6 to 16.3 mm against AH2, VF, VAN and two strains of *E. coli* (O1, O115). Aqueous extract of *Microcystis* showed antibacterial activity against five strains of *E. coli*, whereas the other selected pathogens were resistant to the above extract. It was further noticed (Table 1) that the antibacterial activity of ethanolic extracts of all the four microalgae tested were significantly different ($p< 0.05$) from each other, when tested against VFS and *E. coli* (O115).

Several different organic solvents have been used for screening algae for antibacterial activity. Recently, Das *et al.* (2005) reported the antibacterial activity in the chloroform, acetone, methanol and ethanol extracts of *E. viridis* against different fish pathogens. Singh *et al*. (2001) and Mian *et al*. (2003) reported antibacterial and antialgal activities from terrestrial and freshwater Cyanobacteria. Antiherpes and antiinfluenza activities have also been reported (Serkedjieva, 2000; Serkedjieva *et al.*, 2000). Sastry *et al*. (1994), showed antibacterial activities against Gram-negative pathogenic strains after successive extraction of marine algae with benzene, chloroform and methanol. Likewise, Naviner *et al*. (1999) have shown antibacterial activity in organic extracts of *Skeletonema costatum* against nine fish pathogens. Recently, Pradhan *et al*. (2004) reported antibacterial activities of *Chlorella vulgaris* against various strains of fish and shellfish pathogens. Antimicrobial effects from Cyanobacterial aqueous and organic extracts were visualized in bioassays using selected microorganisms (*Micrococcus luteus*, *Bacillus subtilis*, *Bacillus cereus* and *E. coli*) as test organisms (Frankmolle *et al*., 1992; Falch *et al*., 1995).

The chemical nature of active principles in lipid soluble extracts of algae is not so far totally identified. Udea *et al*. (1991) noticed methyl jasmonate and jasmonic acid in *Chlorella* and *Spirulina*, which were found to be plant inhibitors. Our preliminary results suggest that antibacterial activity observed in ethanolic extract of four microalgae against Gram-negative bacteria could be due to more than one active principle. Purification of the crude ethanolic and aqueous extracts by fractionation or chromatography would be beneficial in the long run for preparing commercial microalgae based products. The use of natural products in disease control is recommended these days, in preference to antibiotics and chemotherapeutants. Most synthetic chemicals are more hazardous due to their long persistence, non-target toxicity and carcinogenic as well as mutagenic activities.

Some of the crude algal extracts, have shown better antibacterial activity than selected commercial antibiotics in the present study (Table 3). These bioactive compounds could become promising agents for disease control in aquaculture.

Table 3. Antibacterial sensitivity of different antibiotics against fish bacterial pathogens (inhibition zone in mm)

Antibiotics	Bacterial strain						
	AH1	AH2	PA1	PP1	PF1	VP	VAN
Clotrimazole (10 mcg)	11	11	10	10	10	10	10
Tetracycline (25 mcg)	20	29	19	15	19	19	19
Furazolodone (50 mcg)	23	23	18	15	15	ND	ND

ND-Not detected; VAN: *Vibrio anguillarum;* VP: *Vibrio parahaemolyticus;* PA: *Pseudomonas aeruginosa*; PP: *Pseudomonas putida;* AH: *Aeromonas hydrophila*

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References

Aoki, T. 1992. Chemotherapy and drug resistance in fish farms in Japan. In: Shariff, M., Subasinghe, R. P. and Arthur, J. R. (Eds.), *Diseases in Asian Aquaculture* I, *Proceedings of the first symposium on Diseases in Asian Aquaculture*, November, Bali, Indonesia, p. 519-529.

Biswas, K. 1949. Common fresh and brackish water algal flora of India and Burma, Part I. *Records of the Botanical Survey of India,* p. 15.

Chabbert, Y. A. 1963. *L' antibiogramme. Sensibilite et resistance des bacteries aux antibiotiques.* De la Tourelle, 257 pp.

Das, B. K., Pradhan, J., Pattnaik, P. K., Samantray, B. R. and Samal, S. K. 2005. Production of antibacterials from the freshwater alga *Euglena viridis* (Ehern). *World J. Microbiol. Biotech*., 21: 45-50.

Duncan, D. B. 1955. Multiple range and multiple 'F' tests. *Biometrics*, 11: 1-42.

Falch, B. S., Konig, G. M. and Wright, A. D. 1995. Biological activites of cyanobacteria: evaluation of extracts and pure compounds. *Planta Medica*, 61: 321-328.

Frankmolle, W. P., Larsen, L. K. and Caplan, F. R. 1992. Antifungal cyclic peptides from the terrestrial blue-green alga. *Anabaena laxa. J. Antibio*., 45: 1451-1457.

Goldin, E. B. 2003. Antibacterial activity of pure cultures of cyanobacteria and algae. *Mikrobiol Z*., 65(4): 68-76.

Halperin, S. A., Smith, B., Nolan, C., Shay, J. and Kralovec, J. 2003. Safety and immunoenhancing effect of a *Chlorella*-derived dietary supplement in healthy adults undergoing influenza vaccination: randomized, double-blind, placebo-controlled trial. *Canadian Med. Ass. J.,* 169(2): 111-117.

Hasegawa, T., Matsuguchi, T. Noda, K., Tanaka, K., Kumamoto, S., Shoyama, Y. and Yoshikai, Y. 2002. Toll- like receptor 2 is at least partly involved in the antitumor activity of glycoprotein from *Chlorella vulgaris*. *Int. Immunopharmacol.,* 2 (4): 579-589.

Ibusuki, K. and Minamishima, Y. 1990. Effect of *Chlorella vulgaris* extracts on murine cytomegalovirus infections. *Nat. Immun. Cell Growth Regul.*, 9(2): 121-128.

Ishida, K., Matsuda, H., Murakami, M. and Yamaguchi, K. 1997. Kawaguchipeptin B, an antibacterial cyclic undecapeptide from the cyanobacterium *Microcystis aeruginosa*. *J. Nat. Prod*., 60(7): 724-726.

Izzo, A. A., Di Carlo, G., Biscardi, D. and De Fusco, R. 1995. Biological screening of Italian medicinal plants for antibacterial activity. *Phyto. Res*., 9: 281-286.

Matusiak, K., Jaroszyñska, T. and Krzywicka, A. 1965. Activity of antibacterial substance in *Chlorella vulgaris* and *Chlorella pyrenoidosa* at various stages of their development cycle and the influence of light on the process. *Bull. Acad. Pol. Sci. Biol*., 13(11): 667-671.

Mian, P., Heilmann, J., Burgii, H. R. and Sticher, O. 2003. Biological screening of terrestrial and freshwater cyanobacteria for antimicrobial activity, brine shrimp lethality and cytotoxicity. *Pharm. Biol*., 41(4): 243-247.

Mundt, S., Kreitlow, S., Nowotny, A. and Effmert, U. 2001. Biochemical and pharmacological investigations of selected cyanobacteria. *Int. J. Hyg. Environ Health*., 203(4): 327-334.

Naviner, M., Berge, J. P., Durand, P. and Le Bris, H. 1999. Antibacterial activity of the marine diatom, *Skeletonema costatum*, against aquacultural pathogens. *Aquaculture*, 174: 15-24.

Noaman, N. H., Fattah, A., Khaleafa, M. and Zaky, S.H. 2004. Factors affecting antimicrobial activity of *Synechococcus leopoliensis*. *Microbiol. Res*., 159: 395-402.

Patterson, G. M. L., Larsen, L. K. and Moore, R. E. 1994. Bioactive natural products from blue green algae. *J. Appl. Phyco.*, 6: 151-157.

Pradhan, J., Das, B. K., Samantaray, B. R. and Samal, S. K. 2004. Effect of chlorella extracts on growth inhibition of fish pathogenic bacteria. In: *Proceedings of the National Seminar on responsible fisheries and aquaculture*, College of Fisheries, Orissa University of Agriculture and technology, Berhampur, Orissa, during 12-13 February, RFA-43

Pratt, R., Daniels, T. C., Eiler, J. J., Gunnison, J. B., Kumler, W. D., Oneto, J. F., Strait, L. A., Spoehr, H. A., Hardin, G. J., Milner, H. W., Smith, J. H. and Strain, H. H. 1944. Chlorellin, an antibacterial substance from Chlorella. *Science*, 99(2574): 351-352.

Rania, M., Abedin, A. and Taha Hala, M. 2008. Antibacterial and antifungal activity of Cyanobacteria and green microalgae: Evaluation of medium components by Plackett-Burman design for antimicrobial activity of *Spirulina platensis*. *Global J. Biotechnol. Biochem*., 3(1): 22-31.

Sastry, V. M. V. S. and Rao, G. R. K. 1994. Antibacterial substances from marine algae: successive extraction using benzene, chloroform and methanol. *Bot. Mar.*, 37: 357-360.

Serkedjieva, J. 2000. Anti-herpesvirus effect of the red marine alga *Polysiphonia denudata*. *Z. Naturforsch*., 55(9-10): 830-835.

Serkedjieva, J., Konaklieva, M., Dimitrova-Konaklieva, S., Ivanova, V., Stefanov, K. and Popov, S. 2000. Antiinfluenza virus effect of extracts from marine algae and invertebrates. *Z. Naturforsch*., 55(1-2): 87-93.

Singh, D. P., Tyagi, M. B., Kumar, A., Thakur, J. K. and Kumar, A. 2001. Antialgal activity of a hepatotoxin-producing cyanobacterium, *Microcystis aeruginosa*. *World J. Microbiol. Biotech.,* 17(1): 15-22.

Skulberg, Olav, M. 2000. Micro-algae as a source of bioactive molecules - experience from cyanophyte research. *J. Appl. Phycol*., 12 (3-5): 341-348.

Tanaka, K., Yamada, A., Noda, K., Hasegawa, T., Okuda, M., Shoyama, Y. and Nomoto, K. 1998. A novel glycoprotein obtained from *Chlorella vulgaris* strain CK22 shows antimetastatic immunopotentiation. *Cancer Immunol. Immunother.*, 45(6): 313-320.

Ueda, J., Miyamoto, K. T. and Sato, Y. 1991. Momotani, Identification of jasmonic acid from *Euglena gracilis* Z as a plant growth regulator. *Agric. Biol. Chem*., 55: 275-276.

Valdor, R. and Aboal, M. 2007. Effects of living cyanobacteria, cyanobacterial extracts and pure microcystins on growth and ultrastructure of microalgae and bacteria. *Toxicon*., 49(6): 769-779.

Vijayavel, K., Anbuselvam, C. and Balasubramanian, M. P. 2007. Antioxidant effect of the marine algae *Chlorella vulgaris* against napthalene-induced oxidative stress in the albino rats. *Mol. Cell Biochem*., 303(1-2): 39-44.

Volk, R. B. and Furkert, F. H. 2006. Antialgal, antibacterial and antifungal activity of two metabolites produced and excreted by cyanobacteria during growth. *Microbiol. Re*s., 161 (2): 180-186.

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