Advance Journal of Food Science and Technology 7(7): 490-495, 2015
DOI:10.19026/ajfst.7.1346
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: August 31, 2014 Accepted: September 20, 2014 Published: March 05, 2015

Research Article

Investigation of Anti-bacterial Activity against Food-borne Pathogens among Korean Domestic Algae

[1]Ki-hyo Jang and [2]Je-hyuk Lee
[1]Department of Food and Nutrition, Kangwon National University, Samcheok, Gangwon, 245-905, Korea
[2]Department of Food and Nutrition, Kongju National University, Yesan, Chungnam, 340-702, Korea

Abstract: The aim of this study is to explore algal species with anti-bacterial activity against six food-borne pathogens. Among 51 marine algae, *Laurencia okamurae* Yamada and *Dictyopteris undulata* Holmes was elucidated to have a potent anti-bacterial activity against food-borne pathogens. *Laurencia okamurae* Yamada showed the clear zone around agar well on *B. cereus*, *S. aureusand L. monocytogenes*-spreading agar plate. *Dictyopteris undulata* Holmes had the anti-bacterial activity against *S. chorelaesuis*, *B. cereus*, *S. aureus* and *L. monocytogenes* on bacterial spreading agar plates. Antibacterial activity of *L. okamurae* Yamada and *D. undulata* Holmes had specifically susceptibility for *B. cereus*, *S. aureus* and *L. monocytogenes* and were superior to streptomycin, the authentic antibiotics. It is anticipated that new food preservatives can be explored and developed on the basis of this study.

Keywords: Algae, anti-bacterial activity, *Dictyopteris undulata* Holmes, food-borne pathogens, *Laurencia okamurae* Yamada

INTRODUCTION

Foodborne diseases are still a major concern in the world. In 2005, it was reported that 1.8 million people died from diarrhoeal diseases, largely attributable to contaminated food and drinking water by World Health Organization (WHO). This is not just an underdeveloped world problem. About 76 million cases of food-borne diseases, resulting in 325,000 hospitalizations and 5000 deaths, are estimated to occur each year in the United States of America (USA) alone (Mead *et al*., 1999). According to the reports regarding foodborne microorganisms outbreak, *Salmonella enterica*, *Staphylococcus aureus*, *Bacillus cereus* and *Clostridium botulinum* were found in eggs, beef, chickenand dairy products in the U.S.A. and the European Union (Tauxe, 2002; Greig and Ravel, 2009).

Due to the worldwide awareness on chemical preservatives, the food industry is now reflected by the consumer opinions for safer additives and thus is focusing on natural safe preservatives (Dillon and Board, 1994). Some plant materials are used as natural antimicrobials in food systems, as well as to prevent the growth of foodborne bacteria and molds resulting in shelf-life extension of processed foods. Fruits, vegetables, grains and food constituents can be contaminated by various microorganisms and their hazardous toxic metabolites. Enterotoxins produced by *Escherichia coli*, *S. pyogenes*, *Salmonella*, *Yersinia* and *Clostridium* species are responsible for toxicity in the intestinal tract causing vomiting, diarrhea, etc. Moreover, microorganisms are also associated with food spoilage causing economical loss (Harris, 1988; Rocourt *et al*., 2003). Although most healthy humans are not significantly affected by low doses of the bacteria, the pathogen can be more harmful for people with weak immune systems or during pregnancy. Among severe infections, even listeriosis by *Listeria* sp., has been associated with high mortality rate (Datta, 2003).

Seaweeds are considered as a source of bioactive compounds as they are able to produce a great variety of secondary metabolites characterized by a broad spectrum of biological activities. Compounds with cytostatic, antiviral, anthelmintic, antifungal and antibacterial activities have been detected in green, brown and red algae (Lindequist and Schweder, 2001; Newman *et al*., 2003). There are numerous reports concerning the inhibiting activities from macro-algae against human pathogens, fungi and yeasts (Sridhar and Vidyavathi, 1991; Mahasneh *et al*., 1995; De Val *et al*., 2001; Liao *et al*., 2003). It was reported that bromophenol, dolabellane derivatives, phloroglycinand hydroquinone derivatives were isolated as anti-bacterial compounds from red algae, Rhodomelaceae, *Dictyota dichotoma*, *Fucus versiculosus* and *Dictyopteris zonarioides* (Choi *et al*., 2000; Amico *et al*., 1980). However, little attention has been given to the research

Corresponding Author: Je-Hyuk Lee, Department of Food and Nutrition, Kongju National University, Yesan, Chungnam, 340-702, Korea

Table 1: Agar diffusion susceptibility of foodborne pathogens to Korea domestic algae extract

Sea algae	JBRI coll. No.[a]	Clear zone (mm)[b]					
		S. choleraesuis	*S. enterica*	*B. cereus*	*B. subtilis*	*S. aureus*	*L. monocytogenes*
Endarachne binghamiae J. Agardh	10173	-[c]	0.5±0.1	-	-	0.5±0.1	-
Dictyopteris prolifera (Okamura) Okamura	10242	0.5±0.1	-	-	-	0.5±0.1	0.5±0.1
Sargassum nipponium Yendo	10250	-	-	0.5±0.1	-	0.5±0.1	0.5±0.1
Ulva pertusa Kjellman	10253	-	-	-	-	0.5±0.1	0.5±0.1
Dictyopteris divaricata (Okamura) Okamura	10254	-	-	-	-	0.5±0.1	-
Dictyota asiatica Hwang et al.	10255	-	-	-	-	0.5±0.1	0.5±0.1
Padina arborescens Holmes	10258	0.5±0.1	-	0.5±0.1	0.5±0.1	1	-
Sargassum muticum (Yendo) Fensholt	10261	0.5±0.1	-	0.5±0.1	0.5±0.1	0.5±0.1	-
Myelophycus simplex (Harvey) Papenfuss	10262	-	-	1	0.5±0.1	-	-
Chondria crassicaulis Harvey	10264	-	-	0.5±0.1	-	-	0.5±0.1
Dictyopteris pacifica (Yendo) Hwang et Kim comb. Nov.	10265	0.5±0.1	-	1	-	0.5±0.1	-
Lomentaria hakodatensis Yendo	10266	0.5±0.1	0.5±0.1	1	-	1	0.5±0.1
Sargassum sp.	10269	0.5±0.1	-	1	-	-	0.5±0.1
Chondracanthus tenellus (Harvey) Homm. in Homm.	10270	0.5±0.1	-	1	-	0.5±0.1	-
Dictyopteris prolifera (Okamura) *Okamura*	10271	0.5±0.1	-	1	-	1	-
Prionitis cornea (*Okamura*) Dawson	10272	0.5±0.1	-	1	-	-	0.5±0.1
Ishige okamurae Yendo	10276	-	-	0.5±0.1	-	0.5±0.1	-
Bonnemaisonia hamifera Hariot	10278	0.5±0.1	-	-	-	0.5±0.1	0.5±0.1
Laurencia intricata Lamourx	10280	-	-	0.5±0.1	-	0.5±0.1	1.0±0.5
Sargarssum fulvellum (Turner) C. Agardh	10281	-	-	0.5±0.1	-	-	-
Ecklonia cava Kjellman	10282	0.5±0.1	-	0.5±0.1	-	0.5±0.1	-
Scytosiphon lomentaria (Lyngbye) Link	10350	0.5±0.1	-	1	-	0.5±0.1	-
Laurencia intermedia Lamouroux	10351	-	-	-	-	0.5±0.1	-
Grateloupia filicina (Lamouroux) C. Agardh	10352	-	-	1	-	0.5±0.1	-
Callophyllis crispata Okamura	10353	0.5±0.1	-	0.5±0.1	-	-	-
Laurencia okamurae Yamada	10354	-	-	4	-	3	2.6±0.5
Colpomenia sinusa (Mertens ex Roth) Derbes et Solier in Castagne	10355	-	-	-	-	0.5±0.1	-
Polyopes affinis (Harvey) Kawaguch *et Wang in Kawaguchi*, *Wang*, Horiguchi	10359	-	-	0.5±0.1	-	0.5±0.1	0.5±0.1
Lethesia difformis (Linnaeus) Areschoug	10363	0.5±0.1	-	0.5±0.1	-	-	-
Chondrus ocellatus Holmes	10364	-	-	0.5±0.1	-	-	-
Polysiphonia morrowii Harvey	10365	-	-	0.5±0.1	-	-	0.5±0.1
Hydroclathrus clathratus (C. Agardh) Howe	10366	-	0.5±0.1	0.5±0.1	-	2	-
Sargassum thunbergii (Mertens es Roth) Kuntze	10367	0.5±0.1	-	1.5	-	0.5±0.1	-
Hizikia fusiformis (Harvey) Okamura	10495	-	-	1.5	-	0.5±0.1	-
Grateloupia elliptica Holmes	10513	0.5±0.1	-	1.5	-	0.5±0.1	-
Scytosiphon gracilis Kogame	10517	0.5±0.1	-	1.5	-	1	-
Sargassum micracanthum (Kuntze) Endlicher	10519	0.5±0.1	-	-	-	0.5±0.1	-
Chondrus crispus Stackhouse	10520	-	-	2	-	0.5±0.1	0.5±0.1
Gloioperltis complanta (Harvey) Yamada	10527	-	-	2	-	0.5±0.1	-
Gloioperltis furcata (Postels et Ruprecht) J. Agardh	10530	-	-	2	-	0.5±0.1	0.5±0.1
Grateloupia lanceolata (Okamura) Kawaguchi	10559	-	0.5±0.1	0.5±0.1	-	2	-
Gelidium amansii (Lam.) Lamouroux	10560	-	-	-	-	0.5±0.1	-
Dictyopteris undulata Holmes	10656	0.5±0.1	-	5	-	4	9.0±1.0
Sargassm micracanthum (Kutzing) Endlicher	10682	-	0.5±0.1	2	-	1	-
Ecklonia stolonifera Okamura	10692	-	-	2	-	-	-
Sargassum confusum C. Agardh f. validum Yendo	10696	-	0.5±0.1	-	-	-	0.5±0.1
Sargassum sagamianum Yendo	10697	-	0.5±0.1	2	-	-	0.5±0.1

Table 1: (Continue)

Sea algae	JBRI coll. No. [a]	Clear zone (mm)					
		S. choleraesuis	*S. enterica*	*B. cereus*	*B. subtilis*	*S. aureus*	*L. monocytogenes*
Gracilaria verrucosa (*Hudson*) Papenfuss	10698	-	-	1	-	0.5±0.1	-
Sargassum horneri (Turner) C. Agardh	20040	0.5±0.1	0.5±0.1	-	-	1	0.5±0.1
Sargassm patens C. Agardh	10066	0.5±0.1	-	1	-	0.5±0.1	-
Sargassum macrocarpum C. Agarch	10069	-	0.5±0.1	1.5	-	1	-
Streptomycin		5.0±1.0	6.93±0.8	10.0±1.3	6.25±1.9	3.93±1.2	4.8±1.0

The antimicrobial activities were determined by agar-well diffusion assay; After 50 μL of each bacterial suspension (OD600 = 0.2-0.3, approximately 1×10^7 cfu/mL) were spread uniformly onto the surface of each agar plate (1.5%); The well was cut into the set agar using a sterile cork-borer (5 mm diameter); Sea weeds extracts (10 μg/well) were dispensed into the wells; After 24 h incubation, the inhibition zones around wells were measured in mm using a caliper; [a]: Jeju Biodiversity Research Institute (JBRI) collection number; [b]: Semi-diameter (mm) of clear zone, expressed by average±standard deviation from triplicate trials; [c] -: Not detected

of Korean domestic algae for noble anti-foodborne pathogens.

In this report, we focused on the studies for the investigation of anti-bacterial activities of Korean domestic algae against foodborne pathogens, which were highly issued recently in South Korea. It is anticipated that new food preservatives can be explored and developed on the basis of this study.

MATERIALS AND METHODS

Sea weeds materials: All sea weed was collected in sea near Jeju island Korea, authenticated by Jeju Biodiversity Research Institute (JBRI), Jeju, Korea and deposited as the voucher specimen (Table 1) to JBRI.

Each sea weed was washed, dried by freeze drier and crushed. Crushed weeds were extracted with 70% methanol (in water) at room temperature. Extracts were filtered through Whatman No. 1 filter paper and were concentrated by evaporator under reduced pressure. Sea weed-extract was redissolved in DMSO to 100 mg/mL, stored at -20°C and used it as a stock.

Microorganisms and growth conditions: Four gram-positive (*S. aureus*, *B. cereus*, *B. subtilis* and *Listeria monocytogenes*) and two gram-negative foodborne pathogens (*S. choleraesuis* and *S. enterica*) were used in the experiments. *S. aureus* American Tissue Culture Collection (ATCC) 6538P, *S. choleraesuis* ATCC 13312 and *B. cereus* ATCC 14579 were purchased from ATCC and *L. monocytogenes* KCTC 3710, *B. subtilis* KCTC 3726 and *S. enterica* KCTC 12400 were obtained from the Korean Collection for Type Cultures (KCTC, Daejon, Korea). Stock cultures of bacteria were kept in 35% glycerol phosphate buffered saline at -70°C. All bacterial strains were cultured by inoculating 100 mL of the thawed microbial stock suspensions into 5 mL Nutrient Broth (Difco, Detroit, MI) in 100 rpm shaking incubator at 37°C for 24 h in aerobic condition.

Agar-well diffusion assay: The antimicrobial activities of sea weeds extracts were evaluated by agar-well diffusion assay. The assay was carried out according to the method (Owen and Palombo, 2007) of with some modifications. After 50 mL of each bacterial suspension (OD600 = 0.2-0.3, approximately 1×10^7 cfu/mL) were spread uniformly onto the surface of each agar plate (1.5%), the well was cut into the set agar using a sterile cork-borer (5 mm diameter). Sea weeds extracts (10 μg/well) were dispensed into the wells. Agar plates were left at room temperature for 30 min to allow the liquid to diffuse into the agar before overnight incubation at 37°C. All assays were carried out in triplicate. A clear zone of the inhibited microbial growth surrounded substances was considered positive exhibiting antibacterial properties. The solvent system used for the preparation of sea weeds extract samples was used for blank well. After incubation, the inhibition zones around wells were measured in mm using a caliper (Fazeli *et al*., 2007). Ampicillin and streptomycin (10 μg/well) were used as positive controls.

Statistical assay: All result was expressed as mean±Standard Deviation (S.D.) and were analyzed using one way Analysis of Variance (ANOVA) and Dunnett's multiple comparison test for individual comparisons. Results were considered statistically significant when p-values were $p<0.05$.

RESULTS AND DISCUSSION

Anti-bacterial activity of marine algal extracts against food-borne pathogens: The huge number of marine algal species inhabit in the coast of Jeju-island, Korea (Lee, 2008). Fifty one algae collected from seashore of Jeju-island were investigated for anti-bacterial activity against food-borne pathogens. The aim of this study is to explore algal species with anti-bacterial activity against six food-borne pathogens issued in Korea recently. Antibacterial activity of marine algae was determined by agar well diffusion assay. Control treatment (DMSO) showed no clear zone around agar-wells against any of pathogens (Fig. 1).

Among 51 marine algae, *Laurencia okamurae* Yamada and *Dictyopteris undulata* Holmes was elucidated to have a potent anti-bacterial activity against food-borne pathogens (Fig. 1 and Table 1).

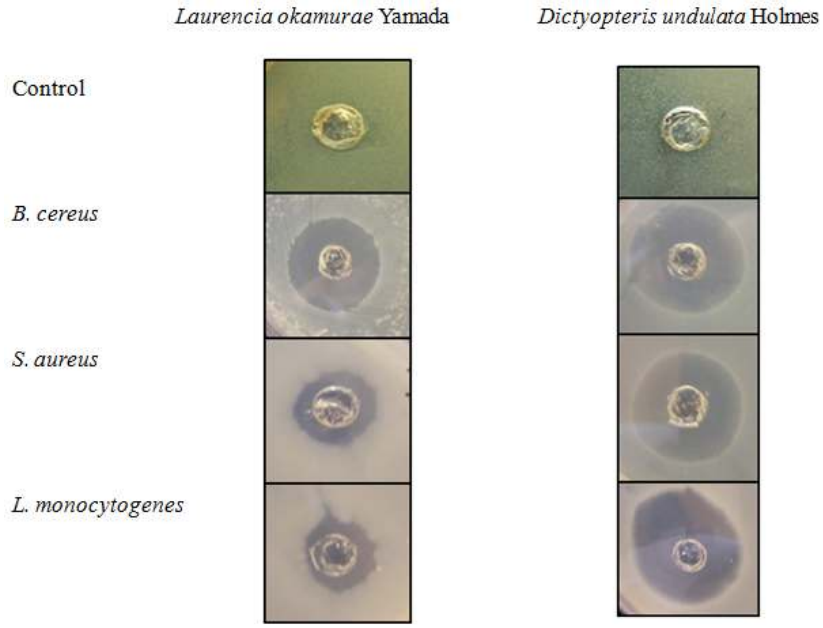

Fig. 1: Anti-bacterial activities of *Laurencia okamurae* Yamada and *Dictyopteris undulata* Holmes against food-borne pathogens. After 50 μL of *B. cereus*, *L. monocytogenes* and *S. aureus* culture suspension (OD600 = 0.2-0.3, approximately 1×10^7 cfu/mL) were spread uniformly onto the surface of each agar plate (1.5%), the well was cut into the set agar using a sterile cork-borer (5 mm diameter). The Solvent system (DMSO) used for the preparation of extract samples was used for control. Extracts (10 μg/well) of *Laurencia okamurae* Yamada and *Dictyopteris undulata* Holmes were dispensed into the wells. After 24 h incubation, the inhibition zones around wells were measured

Laurencia okamurae Yamada showed the inhibition zone of approximately 4.0±0.2 mm around agar well on *B. cereus*-spreading agar plate. In addition, *L. okamurae* Yamada had antibacterial activities against *S. aureus* and *L. monocytogenes* with approximately 3.0±0.3 and 2.6±0.5 mm, respectively. Another marine algae, *Dictyopteris undulata* Holmes had the anti-bacterial activity against *S. chorelaesuis* with approximately 0.5±0.1 mm, *B. cereus* with approximately 5.0±0.2 mm, *S. aureus* with approximately 4.0±0.3 mm and *L. monocytogenes* with approximately 9.0±1.0 mm clear zones on bacterial spreading agar plates. Antibacterial activity of *L. okamurae* Yamada and *D. undulata* Holmes had specifically susceptibility for *B. cereus*, *S. aureus* and *L. monocytogenes* and were superior to streptomycin, the authentic antibiotics. However, streptomycin, which is a broad-spectrum antibiotics, showed the clear zone for all tested food-borne pathogens.

Great attention has been focusing on the marine seaweeds as potential and promising sources of bioactive compounds in recent years. Seaweeds are able to produce a great variety of secondary metabolites with versatile activities, such as antiviral, anthelmintic, antifungal and antibacterial activities (Lindequist and Schweder, 2001; Newman *et al*., 2003). Red algal genus *Laurencia* (Rhodomelaceae, Ceramiales) produces the numerous specialized secondary metabolites with diverse structural features. Its three major classes, which are sesquiterpenes, diterpenes and acetylenes, have not yet been encountered in other terrestrial organisms (Vairappan, 2003; Erikson, 1983; Fenical, 1975). Most of these metabolites are characterized by the presence of halogen atoms in their chemical formula. Bromine-containing compounds are more abundant than either chlorine- or iodine-containing ones. Halogenated compounds and metabolites from *Laurencia* sp., have been investigated to be due to antimicrobial, insecticidal, cytotoxic and feeding-deterrent activities (Konig and Wright, 1997; Hay *et al*., 1987).

Due to increases in bacterial resistance against commercial antibiotics, there is a growing need, not only in human but also in veterinary medicine, for new antibacterial compounds that are active against pathogenic bacteria. It is reasonable to suggest some of these compounds as seaweed′s defense chemicals to protect themselves against pathogens and survive in the marine ecosystem to potential anti-bacterial agents. It was reported that metabolites isolated from Malaysian *Laurencia majuscula* could inhibit its surface bacteria, suggesting the presence of an inherently available antibacterial defense mechanism (Vairappan *et al*., 2001). Some halogenated metabolites from *Laurencia* have been shown to have antibacterial activity against terrestrial bacteria (Vairappan *et al*., 2001), thus suggesting that halogenated compounds have the potential to function as chemical defense substances

against pathogenic bacteria. Isolated metabolites including halogenated metabolites, such as 10-acetoxyangasiol, aplysiadiol, cupalaurenol, 10-acetoxyangasiol, aplysidiol, cupalaurenol and chamigrane epoxide, exhibited potent antibacterial activities against clinical bacteria, *Staphylococcus aureus*, *Staphylococcus* sp., *Streptococcus pyogenes*, *Salmonella* sp. and *Vibrio cholerae.* To date, there has been minimal research regarding the anti-bacterial activity against food-borne pathogens.

Brown algae, *Phaeophyceae*, are a class of almost exclusively marine organisms that have been explored for the bioactivity potential of its metabolic products, especially those of the representative family Dictyotaceae. Dictyotaceae natural products include a rich production of terpenoids of different origins and are therefore important in studies of metabolites of marine origin (Vallim *et al*., 2010). The most bioactive products have three or four isoprenoid units, corresponding to the sesquiterpenes and diterpenes, respectively. These two classes of terpenoids can have many different structures and variants, including the addition of halogen atoms or fragments from other biogenic pathways. Halogenated sesquiterpenes in which a phloroglucinol unit were reported in *Dictyopteris divaricata* (Ji *et al*., 2009) and *D. undulata* (Song *et al*., 2004a). The sesquiterpenes of these genera are known to exhibit activity as an inhibitor of herbivores and antifungal, cytotoxic, antibiotic and ichthyotoxic activities. In addition, the cytotoxic activities were evaluated in several human tumor cell lines for sesquiterpenes from *Dictyopteris* (Fenical *et al*., 1973) and also the antifungal activity was found only for sesquiterpenes from *Dictyopteris*. Therefore a polysaccharide-rich extracts from *Dictyopteris* sp., are expected to exhibit assorted biological activities, including anticoagulant, antiproliferative and antioxidant activities.

CONCLUSION

This result is able to provide a fundamental data of screening for marine algae with anti-bacterial activity against food-borne pathogens. *Laurencia okamurae* Yamada and *Dictyopteris undulata* Holmes was investigated to have a potent anti-bacterial activity against food-borne pathogens. And it is expected to be possible to develop a novel and natural food preservative using extracts of *Laurencia okamurae* Yamada and *Dictyopteris undulata* Holmes.

REFERENCES

Amico, V., G. Oriente, M. Piatelli, C. Tringali, E. Fattorusso, S. Mango and L. Mayol, 1980. Diterpenes based on the dolabellane skeleton from *Dictyota dichotoma*. Tetrahedron, 36(10): 1409-1414.

Choi, J.S., H.J. Park, H.A. Jung, H.Y. Chung, J.H. Jung and W.C. Choi, 2000. A cyclohexanonyl bromophenol from the red alga *Symphyocladia latiuscula*. J. Nat. Prod., 63(12): 1705-1706.

Datta, A.R., 2003. Listeria Monocytogenes. In: Miliotis, M.D. and J.W. Bier (Eds.), International Handbook of Foodborne Pathogens. Marcel Dekker Inc., New York, USA, pp: 105-121.

De Val, A.G., G. Platas, A. Basilio, A. Cabello, J. Gorrochategui, I. Suay, F. Vicente, E. Portilllo, M.J. del Rio, G.G. Reina and F. Peláez, 2001. Screening of antimicrobial activities in red, green and brown macroalgae from Gran Canaria (Canary Islands, Spain). Int. Microbiol., 4(1): 35-40.

Dillon, V.M. and R.G. Board, 1994. Future Prospects for Natural Antimicrobial Food Preservation Systems. In: Dillon, V.M. (Ed.), Natural Antimicrobial Systems and Food Preservation. CAB, Wallingford, UK, pp: 297-305.

Erikson, K.L., 1983. Marine Natural Products: Chemical and Biological Perspectives. Academic Press, New York, USA, Vol. 5.

Fazeli, M.R., G. Amin, M.M.A. Attari, H. Ashtiani, H. Jamalifar and N. Samadi, 2007. Antimicrobial activities of Iranian sumac and avishane shirazi (*Zataria multiflora*) against some food-borne bacteria. Food Control, 18(6): 646-649.

Fenical, W., 1975. Halogenation in the Rhodophyta. J. Phycol., 11(3): 245-259.

Fenical, W., J.J. Sims, D. Squatrito, R.M. Wing and P. Radlick, 1973. Zonarol and isozonarol, fungi toxic hydroquinones from the brown seaweed *Dictyopteris zonarioides.* J. Org. Chem., 38(13): 2383-2386.

Greig, J.D. and A. Ravel, 2009. Analysis of foodborne outbreak data reported internationally for source attribution. Int. J. Food Microbiol., 130(2): 77-87.

Harris, R.C., 1988. Review of selected bacterial enterotoxins and their role in gastroenteritis. Ann. Clin. Lab. Sci., 18(2): 102-108.

Hay, M.E., W. Fenical and K. Gustafson, 1987. Chemical defense against diverse coral-reef Herbivores. Ecology, 68(6): 1581-1591.

Ji, N.Y., W. Wen, X.M. Li, Q.Z. Xue, H.L. Xiao and B.G. Wang, 2009. Brominated selinane sesquiterpenes from the marine brown alga *Dictyopteris divaricata.* Mar. Drugs, 7(3): 355-360.

Konig, G.M. and A.D. Wright, 1997. *Laurencia rigida*: Chemical investigations of its antifouling dichloromethane extract. J. Nat. Prod., 60(10): 967-970.

Lee, Y.P., 2008. Marine Algae of Jeju. Academy Books Inc., Seoul, Korea.

Liao, W.R., J.Y. Lin, W.Y. Shieh and W.L. Jeng, 2003. Antibiotic activity of lectins from marine algae against marine vibrios. J. Ind. Microbiol. Biot., 30(7): 433-439.

Lindequist, U. and T. Schweder, 2001. Marine Biotechnology. In: Rehm, H.J. and G. Reed (Eds.), Biotechnology. Wiley-VCH, Weinheim, 10: 441-484.

Mahasneh, I., M. Jamal, M. Kashashneh and M. Zibdeh, 1995. Antibiotic activity of marine algae against multiantibiotic resistant bacteria. Microbios, 83(334): 23-26.

Mead, P.S., L. Slutsker, V. Dietz, L.F. McCaig, J.S. Bresee, C. Shapiro, P.M. Griffin and R.V. Tauxe, 1999. Food-related illness and death in the United States. Emerg. Infect. Dis., 5(5): 607-625.

Newman, D.J., G.M. Cragg and K.M. Snader, 2003. Natural products as source of new drugs over the period 1981-2002. J. Nat. Prod., 66(7): 1022-1037.

Owen, R.J. and E.A. Palombo, 2007. Anti-listerial activity of ethanolic extracts of medicinal plants, *Eremophila alternifolia* and *Eremophila duttonii*, in food homogenates and milk. Food Control, 18(5): 387-390.

Rocourt, J., G. Moy, K. Vierk and J. Schlundt, 2003. The Present State of Foodborne Disease in OECD Countries. Food Safety Department, World Health Organization, Geneva, Switzerland, pp: 1-39.

Song, F., X. Fan, X.L. Xu, J.L. Zhao, Y. Yang and J.G. Shi, 2004a. Cadinane sesquiterpenes from the brown alga *Dictyopteris divaricata*. J. Nat. Prod., 67(10): 1644-1649.

Sridhar, K.R. and N. Vidyavathi, 1991. Antimicrobial activity of seaweeds. Acta Hydroch. Hydrob., 19(5): 455-496.

Tauxe, R.V., 2002. Emerging foodborne pathogens. Int. J. Food Microbiol., 78(1-2): 31-41.

Vairappan, C.S., 2003. Potent antibacterial activity of halogenated metabolites from Malaysian red algae, *Laurencia majuscula* (*Rhodomelaceae*, *Ceramiales*). Biomol. Eng., 20(4-6): 255-259.

Vairappan, C.S., M. Daitoh, M. Suzuki, T. Abe and M. Masuda, 2001. Antibacterial halogenated metabolites from the Malaysian *Laurencia* species. Phytochemistry, 58(2): 291-297.

Vallim, M.A., J.E. Barbosa, D.N. Cavalcanti, J.C. De Paula, V.A.G.G. Silva, V.L. Teixeira and I.C.N.P. Paixão, 2010. *In vitro* antiviral activity of diterpenes isolated from the Brazilian brown alga *Canistrocarpus cervicornis*. J. Med. Plants Res., 4(22): 2379-2382.