academicJournals

Vol. 7(10), pp. 184-196, November, 2013
DOI: 10.5897/AJBR12.068
ISSN 1996-0778 ©2013 AcademicJournals
http://www.academicjournals.org/AJBR

African Journal of Biochemistry Research

Review

Marine fungal metabolites as a rich source of bioactive compounds

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Accepted 27 May, 2013

This paper reviews the recent results of bioactive compounds derived from marine fungi, which are highly diversified and are less explored. Researchers are showing keen interest in isolating novel bioactive compounds with clinical applications. Hence, here we discussed most of the bioactive compounds isolated from marine derived fungi and their possible roles in various efficient biological activities.

Key words: Marine derived fungi, bioactive compounds, biological activities.

INTRODUCTION

The main emphasis of this review is on bioactive compound producing marine fungi and their biological active compounds. Marine secondary metabolites can easily impede other micro organisms (Jeffrey et al., 2011). Among marine microorganisms, particularly fungi have gained an important role as a source of biologically active secondary metabolites (Amira et al., 2009). Marine fungi are prolific resources of natural products. But only a limited potential of marine fungi have been investigated to an extent. True marine fungi have the ability to grow and sporulate exclusively in sea water, where facultative marine fungi are able to adapt away from their natural habitat.

Unique features of marine environment and their relevance to marine fungi

The unique properties of the marine environment are considered important for marine biotechnology for several reasons: 1) A good adaptation of ecosystem will help in development of novel genes and 2) biotechnological production processes are influenced by the special adaptations of organisms to their environment.

The physical factors that influence the marine fungi are a) salinity and pH, b) low water potential, c) high concentrations of sodium ions, d) low temperature, e) oligotrophic nutrient conditions and f) high hydrostatic pressure, the last three parameters being unique to the deep-sea environment (Raghukumar, 2008).

In recent years, marine fungi have been explored more intensely to obtain novel and biologically active compounds, when compared with marine sponges, bacteria. Marine fungi are still less explored. Nevertheless, success in marine fungi research is less. Cephalosporin C was the first bioactive compound from *Cephalosporium acremonium* which was isolated from a sewage outlet of the Sardinian coast.

Marine fungi have been explored to a much lesser extent than their terrestrial counterparts, such as those for use in treatment of human diseases as well as several others in biotechnological applications (Aline et al., 2008). Hence, we tried to review the research carried out so far regarding marine fungi and their bioactive compounds.

Previous literature shows that marine-derived fungi have been recognized as one of the tapped sources for new biologically active secondary metabolites including antitumor, antibacterial, antiviral, antifungal, anti- inflammatory and anticancer activities and enzyme inhibitor compounds. Clodepsipeptide[(1)] isolated from the marine fungus, *Clonostachys* sp. is having anti cancer activity

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(Samuel et al., 2011). Until 1991, only 321 species of obligate marine fungi had been described, of which 11 belong to the class Ascomycete, which are found in shallow waters. Facultative marine fungi have been explored to a lesser extent, and only 56 species have been described until 1999 (Aline et al., 2008). Between 2000 and 2005, approximately 100 marine fungal metabolites were described and between 2006 and 2010, a total of 690 natural products were reported as being isolated from fungi in marine habitats (Katia et al., 2012). Marine fungi have attracted great attention as considerable resources from only few decades. Recent investigations on marine filamentous fungi looking for biologically active secondary metabolites indicate their tremendous potential as a source of new medicines even at low concentrations of their secondary metabolites (Table 5) (Swathi et al., 2013).

Continuous investigations demonstrated that marine microorganisms are an unlimited source of novel biologically active secondary metabolites. Marine-derived fungi, in particular, have yielded an increasing number of biologically active natural products.

Bioactive compounds from marine derived fungi

Marine-derived fungal strains majorly produce polyketide derived alkaloids, terpenes, peptides and mixed biosynthesis compounds which are representative groups of secondary metabolites produced by fungi. Miriam et al. (2012) isolated marine-derived fungal strains, they yielded several bioactive secondary metabolites among which are *E*)-4-methoxy-5-3-methoxybut-1-enyl)-6- methyl-2*H*-pyran-2-one, a new metabolite isolated from the *Penicillium paxilli* strain MaG)K, Norliquexanthone, also known as 1, 3,6- trihydroxy-8-methyl-9H-xanthen-9-one, was isolated from the fungus *P. raistrikii* obtained from the sponge *Axinella* cf. *corrugate.*

The structure and absolute stereochemistry of *S*)-8-methoxy-3,5-dimethylisochroman-6-ol, isolated from *Penicillium steckii* obtained from an algae belonging to the genus *Sargassum*, could be established by analysis of spectroscopic data and also by comparison with literature data.

A *Penicillium* sp. strain DG M3) 6'C, isolated from the ascidian *Didemnum granulatum*, yielded 13-desoxyphomenone. Roridin A was isolated from *Trichoderma* sp. obtained from the sponge *Mucale angulos*a and also identified by analysis of spectroscopic data and comparison with literature data. The fungal strain Ma G) K, obtained from the sponge *M. angulosa* and identified as *Penicillium paxilli*, gave an extract which was cytotoxic against MDA-MB435 human mammalian cancer cells (HCT8 human colon), CNS 295 central nervous system cancer cells and HL60 leukemia cells. Fractionation of this crude extract yielded three 2-pyrones, belonging to Pyrenocines the class of pyrenocines, of which two were known and one was a new natural product, Pyrenocine J. B and A were first isolated from *Pyrenochaeta terrestris* and identified by spectroscopic and X-ray diffraction analysis (Miriam et al., 2012). Two new indole alkaloids, 2-3, 3-dimethylprop-1-ene)-costaclavine and 2-3, 3-dimethylprop-1- ene)-epicosta-clavine, together with the known compounds costaclavine, fumgaclavine A and C, were isolated from the marine-derived fungus *Aspergillus fumigates*(2) (Dahai et al., 2012). *Penicillium commune* SD-118, a fungus obtained from a deep-sea sediment sample, resulted in the isolation of a known antibacterial compound, xanthocillin X(3), and 14 other known compounds comprising three steroids, two ceramides, six aromatic compounds and three alkaloids (Table 1).

Xanthocillin X was isolated for the first time from a marine fungus. In the bioassay, xanthocillin X displayed significant cytotoxicity against MCF-7, HepG2, H460, Hela, Du145 and MDA-MB-231 cell lines. Meleagrin exhibited cytotoxicity against HepG2, Hela, Du145 and MDA-MB-231 cell lines. This is the first report on the cytotoxicity of xanthocillin X (Shang et al., 2012). Khouloud and Yousry (2012) isolated new biologically active metabolites against some virulent fish pathogens *Edwardsiella tarda, Aeromonas hydrophila, Vibrio ordalli and Vibrio angularuim*. *Aspergillus terreus var. Africanus* was identified as the most potent isolate by Khouloud and Yousry (2012). Acremolin(5), a novel modified base, was isolated from the culture broth of the marine fungus *Acremoniu strictum*. Based on combined spectroscopic analyses, the structure of this compound was that of a methyl guanine base containing an isoprene unit. In addition, the presence of a 1H-azirine moiety is unprecedented among natural products. This compound exhibited weak cytotoxicity against an A549 cell line (Elin et al., 2012).

In investigation of new bioactive natural products from marine fungi collected from the South China Sea one terrestrial fungal metabolite, chrodrimanin B, together with five new phenolic bisabolane-type sesquiterpenoids were isolated from the fermentation broth of a marine-derived fungus *Aspergillus* sp. This is the first report of the isolation of chrodrimanin B from a marine organism (Mei-Yan et al., 2011). Smetanina et al. (2011) determined that the biologically active compounds among marine isolates of microscopic fungus. *Myceliophthora lutea Costantin*, which was isolated from marine sediments of Sakhalin Bay Sea of Okhotsk), synthesizes compounds with antibacterial and cytotoxic activities. The new compounds isoacremine D and acremin were reported for the first time from the marine isolate of the fungus Myceliophthora lutea. It was found that acremine A in $CHCl_3$ was converted through the action of light into spiro compounds called as spiroacremines A and B (Smetanina, 2011). A new cyclopentanopyridine alkaloid(6), 3-hydroxy-5-methyl-5,6- dihydro-7*H* cyclopenta(*b*)pyridin- 7-one, together with 11 known aromatic compounds were isolated from the secondary metabolites of the halo tolerant fungal strain *Wallemia sebi* PXP-89 in 10% NaCl (Xiao-Ping et al., 2011). A new xanthone derivative, 8-hydroxy-

Table 1. Antibacterial compounds from marine derived fungi (Punyasloke et al., 2006).

Source	Metabolite	Class of compound
Emericella unguis	Guisinol[37]	Depside
Curvularia lunata	Lunatin 1) Cytoskyrin A 2)	Anthraquinone
Emericella variecolor	Varixanthone[39]	
E. variecolor	Shamixanthone, Tajixanthone hydrate, Terrein	
Trichoderma virens	Trichodermamide B	Dipeptide
Paraphaeosphaeria sp N-119	Modiolides A-B[34]	Macrolide
Cladosporium herbarum	Sumiki's acid, Acetyl Sumiki's acid[35]	Furan carboxylic acid
Aspergillus versicolor	Aspergillitine	Chromone derivative
Stilbella aciculosa	Fusidic acid	Steroid
Ascochyta salicorniae	Ascosalipyrrolidinone A	Alkaloid
Phoma sp	Phomadecalins A-D, Phomadecalin A, B, D	
Aspergillus ochraceus	CJ-17665 I)	Diketopiperazine & N-indole
Halocyphina villosa	Siccayne	
Penicillium sp.	7-deacetoxyyanuthone A	Polyoxygenated Farnesyl cyclohexenones
Aspergillus ostianus	8-Chloro-9-hydroxy-8, 9-deoxyasperlactone 1) 9-chloro-8-hydroxy-8, 9-deoxyasperlactone 2) 9-chloro-8-hydroxy-8, 9-deoxyaspyrone 3)	Chlorinated compounds
Kirschsteiniothelia maritima	Ascochital[36]	Aromatic aldehdye
Fusarium sp.	Enniatin B	Cyclodepsipeptide
Halorosellinia oceanica	Halorosellinic acid, Phenyl lactone[38]	Sesterterpene, Lactone
Unidentified marine-derived fungus	Seragikinone A[42]	Anthracycline related pentacyclic compound
Fusarium sp.	Neomangicol B	Sesterterpenes
Coniothyrium sp isolated from the sponge Ectyplasia perox)	2-hydroxymethyl furan)	

3-methyl-9-oxo-9H-xanthene-1-carboxylic acid methyl ether, was isolated from the co-culture broth of two mangrove fungi strain No. K38 and E33 isolated from the South China Sea coast. Primary bioassays showed that compound has inhibitory activity against microorganisms, including *Gloeasporium musae* and *Peronophthora cichoralearum*, etc. (Chunyuan et al., 2011).Three metabolites, pre-aurantiamine(7), -)-9-hydroxyhexyli-taconic acid and -)-9-hydroxyhexylitaconic acid-4-methyl ester 5, together with two known compounds, paraherquamide E and secalonic acid D, were isolated from the marine-derived fungus, *Aspergillus aculeatus* (Bassey et al., 2011). Marine sediments were collected from different coastal locations of Kanyakumari District; South India and antimicrobial activity was confirmed by crowded plate techniques. Antimicrobial activity of marine fungi isolate was evaluated against six human pathogenic bacteria viz., *Enterobacter aerogenes, Escherichia coli, Proteus mirabilis, Bacillus subtilis, Staphylococcus aureus* and *Klebsiella pneumoniae*, with different solvents like *n*-butanol, chloroform, water and acetone. Anticancer activity of the selective fungi *Aspergillus protuberus* SP1 extracts were tested and they showed activity against Hep 2 cells using MTT assay (Mathan et al., 2011). Two new metabolites, 3S*,4S*,5S*,6R*)-4,5,6-trihydroxy-3-methyl-3,4,6,7-tetrahydro-1H-isochromen- 8 5H)-one(8) and 3R*,4S*)-7-ethyl-3,4,6,8-tetrahydroxy-3,4-dihydronaphthalen-1 2H)-one(9), were isolated from the culture broth

Table 2. Antifungal compounds from marine derived fungi (Punyasloke et al., 2006).

Source	Metabolite	Type of compounds
Penicillium cf. montanense	Xestodecalactone B	
Unidentified marine fungus derived from the *Rhodophyte Ceratodictyon spongiosum*)	Seragikinone A	Anthracycline related pentacyclic compound
Paraphaeosphaeria sp.	Paraphaeosphaeria sp	Macrolide
Ascochyta salicorniae	Ascosalipyrrolidinone A 2,3-Dihydro-2-hydroxy-2, 4-dimethyl-5-transpropenyfuran-3-one	Alkaloid
Keissleriella sp. YS4108	3,6,8-trihydroxy-3-(3, 5-dimethyl-2-oxo-3 E)-heptenyl)-2, 3-dihydronaphthalen-14H)-one	
Zopfiella latipes	Zopfiella latipes	Pyrrolidinone derivative
Microsphaeropsis sp derived from he sponge Myxilla incrustans)	Microsphaeropsin[41]	Eremophilane derivative

of the aquatic fungus Delitschia corticol. The antimicrobial activities of compounds were evaluated against a panel of bacteria and fungi (Rong et al., 2011). New antioxidants and antibacterial compounds were isolated and characterized from *Curvularia tuberculata* (Venkatchalam et al., 2011). Joel et al. (2010) isolated compounds from marine fungi derived from seaweeds. They include alkaloids with anticancer activity from *Penicillium citrinum*, *Fusarium* sp., *Apiospora montagnei* and polyketide ascosali pyrrolidinone-A[40] isolated from the *Ascochyta Salicorniae* having potential antimalarial activity (Joel et al., 2010). The fungal genus *Aspergillus* has been reported to produce a considerable number of cytotoxic compounds as well as other bioactive compounds. (Table 2) Bioactive metabolites from the marine sponge-derived fungus, *Aspergillus versicolor*, yielded three polyketides. In continuation of this study, an aromatic polyketide derivative 2,4-Dihydroxy-6-*R*)-4-hydroxy-2-oxopentyl)-3-methylbenzaldehyde, two xanthones Sterigmatocystin, Dihydrosterigmatocystin and five anthraquinones Averantin, methylaverantin, averufin, nidurufin, versiconol[(10-17)], were isolated by bio activity guided fractionation (Yoon et al., 2010). To study the potential of *Trichoderma* species in controlling nematodes, fungal filtrates of 329 Trichoderma strains were evaluated for their nematicidal activity against *Panagrellus redivivus* and *Caenorhabditis elegans*. Fifteen strains exhibited nematicidal activity against *P. redivivus*, and 14 strains showed activity against *C. elegans* (Zhong-Shan et al., 2010). Fungi *Phialocephala* sp. FL30r) have strong cytotoxic activities inhibition rate of 50%. Nine cytotoxic compounds belonging to phenazine, indole, polyether and ester were isolated from them through bioassay-guided chromatography and identified by spectral methods (Xiang et al., 2010). Marine fungus *Aspergillus glaucus* produces anti-tumor polyketide compound aspergiolide A[(18)] (Xueqian et al., 2010, 2009) and statistical methodologies were employed to optimize submerged culture medium for the production of this novel compound from *Aspergillus glaucus* HB1-19 (Xueqian et al., 2009). A marine-derived fungus, *Cladosporium* sp. F14, was studied for its ability to produce antibiotic and antifouling compounds on different cultivation media. The fungus grew well on tryptone or yeast extract media, slowly on ammonium or nitrate media, and not at all on urea media. In nutrient-enriched cultivation media, this strain produced antibiotic and antifouling compounds in the presence of glucose or xylose. These bioactive compounds were rarely produced in the absence of the sugars, even though the fungal cells grew well under these conditions. Fungal extracts decreased the attachment of bryozoan larvae *Bugula neritina* and showed antibiotic activity towards 6 tested bacterial species. Metabolite profiles of the fungus revealed by gas chromatography - mass spectrometry GCeMS) showed clear differences when glucose was present in or absent from the culture medium. This study provides evidence that marine fungus has the ability to produce antibiotic and antifouling compounds (Hairong et al., 2009). Six new ergosterols, including 3β-hydroxyl-22*E*, 24*R*)-ergosta-5,8,22-trien-7,15-dione[(19)], 3β-hydroxyl-22*E*, 24*R*)-ergosta-5,8,14,22-tetraen-7-one[20], 3β,15α-dihydroxyl-22*E*, 24*R*)- ergosta-5,814),22-trien-7-one[(21)], 3β,15α-dihydroxyl-22*E*, 24*R*)-ergosta-5,814),22-trien-7- one[(22)], 3β-hydroxyl-22*E*, 24*R*)-ergosta-5,814),22-trien-7,15-dione[(23)] and 5α,8α-epidioxy-

23,24*R*)-dimethylcholesta-6,911),22-trien-3β-ol,havebeen isolated from the marine derived fungus *Rhizopus* sp., along with four known ones. The structures of the new compounds were determined on the basis of extensive spectroscopic data. All compounds were eva-luated for their cytotoxic activities against P388, A549, HL-60 and BEL-7420 cell lines by the MTT and SRB methods (Fazuo et al., 2008). Chemical investigation of the cytotoxic and anti-tuberculosis is active butanone extract obtained from the growth media of the marine-derived fungus *Beauveria felina* led to the isolation of two new destruxins, (b -Me- Pro) destruxin E chlorohydrins[24] and pseudodestruxin C[25], along with five known cyclic depsipeptides. The structures of the new destruxin derivatives were established by analysis of spectroscopic data, while the absolute configuration of the common amino acid residues was established by Marfey's analysis (Simone et al., 2006). The potential activity of domic acid, a neurotoxin released from marine fungi was studied against from Dipteral larvae (Nicolas et al., 2010). A new cytotoxic cyclodepsipeptide[26] was isolated from extracts of marine fungus *Clonostachys* sp.. The amino acid sequence was determined by spectrometric studies and the sequence was revealed to be a cyclic dimer formed by two chains of L-*N*,*N*-Me2Leu-L-Ser-L-*N*-MeLeu-L-*N*-MePhe bound by the two esters formed between the carboxylic acid of the L-*N*-MePhe and the hydroxyl function of the L-Ser. IB-01212 is highly cytotoxic to different tumour cell lines (Luis et al., 2006). The new metabolite cillifuranone[27] was isolated from *Penicillium chrysogenum* strain LF066. The structure of cillifuranone was elucidated based on 1D and 2D NMR analysis and turned out to be a previously postulated intermediate in sorbifuranone biosynthesis. Only minor antibiotic bioactivities of this compound were found so far (Jutta et al., 2011). Protulactones A and B[4], two new polyketide-derived fungal metabolites, have been isolated from an EtOAc extract of the marine-derived fungus *Aspergillus* sp. SF-5044 by various chromatographic methods (Jae and Hyuncheol, 2010). Marine fungi belonging to the genus *Aspergillus, Pencillium and Fusarium* were isolated from mangrove forest and these fungal derived compounds were tested for antibacterial activity with *E. coli, K. pneumonia* and *P. aurogenosa* and antimycobacterial activity against *M. tuberculosis* H37 RV. These fungal compounds showed best antibacterial and antimycobacterial activities when extracted with n-hexane, methanol and ethyl acetate (Punyasloke et al., 2006). Two new sesquiterpenes, one new monocyclofarnesane type 3,7,10-trihydroxy-6,11 cyclofarnesane-1-ene[28] and acorane type sesquiterpene,8-hydroxymethyl)-1-2-hydroxy-methylethyl)-4-methylspirol(4.5)-dec-8-en-7-ol[29] and three known terpenes were isolated from *Eutypella scoparia* which shows cytotoxic activities against the SF-268, MCF-7, NCL-H460 tumor cell lines (Li et al., 2012). Mohamad et al. (2007) isolated marine derived fungi that produce spiromassaritone[30] and massariphenone[31], as well as the previously reported fungal metabolites 6-epi-50- hydroxy-mycosporulone[32] and enalin A[33] from *Massarina* sp. strain CNT-016) (Mohamed et al., 2007). Marine derived fungi *Mucor racemosus* CBMAI 847 has relevant potential features producing laccase, manganese peroxidise and lignolytic enzymes (Rafaella et al., 2010). Mi-Hee et al. (2008) isolated a novel yeast strain that produce a large amount of squalene[43] and several polyunsaturated fatty acids from *Pseudozyma* sp. JCC 207 of marine fungi (Xueqian et al., 2009) (Table 3). Oda and colleagues (2005) described the pharmacology of verrucarin A, a compound isolated from the culture broth of the Palauan marine fungus *Myrothecium roridum*. Verrucarin A significantly inhibited interleukin-8 production from human promyelocytic leukemia cells, by a mechanism that involved inhibition of the activation of the mitogen activated kinases c-JUN and p38 (Alejandro et al., 2009). Wei et al. (2011) investigated a novel polyketide shimalactone A isolated from the cultured marine-derived fungus *Emericella variecolor* GF10. Shimalactone A induced neuritogenesis in a neuroblastoma Neuro 2A cell line at 10 µg/ml by a none yet undetermined mechanism (Alejandro et al., 2009). Marine fungi strains of genera Pencillium and Cladosporium show strong antibacterial activity (Ya-Nan et al., 2011). A marine fungal isolate, *Penicillium* sp. isolated from seaweed, *Ulva* sp. led to the isolation of a new chromone derivatives, 2-hydroxymethyl)-8-methoxy-3-methyl-4H-chromen-4-one chromanone A[44] which act as an active tumour anti-

Table 3. Discovery of bioactive compounds from marine fungi (Mi-Hee et al., 2008).

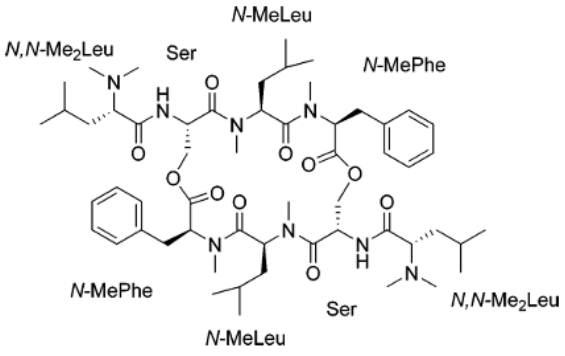
Fungi	Bioactivity
Ascomycetous	Antiviral activity
Fusarium sp.	cytotoxicity
Penicillium griseofulvum Y19-07	cytotoxicity
Penicillium Viridicatum	Antibacterial activity Anti fungal activity
Penicillium expansum	cytotoxicity
Penicillium citrinum	Cytotoxicity Anticoccidial activity
Trichoderma koningii	Anti fungal activity
Hypocrea vinosa	cytotoxicity
Penicilium citreonigrum	Neuroactivity
Phoma sp.	Neuroactivity
Phomaexigua var exigua	Neuroactivity
Scopulariopsis sp.	Neuroactivity
Chrysosporium queenslandicum	Neuroactivity
Pycnidiophora dispersa	Neuroactivity
Penicilium citreonigrum	Neuroactivity
Phoma sp.	Neuroactivity
Scopulariopsis sp.	cytotoxicity
Chrysosporium queenslandicum	Neuroactivity
Pycnidiophora dispersa	Neuroactivity cytotoxicity

Table 4. Screening bioactive compounds from marine fungal strains (Mi-Hee et al., 2008).

Fungi	Compound	Bioactivity
Chaetomium sp.	Chaetominedione	Enzyme inhibition
Ascomycetous 222	Balticolid	Antiviral
Fusarium sp.	3-O-methylfusarubin	Cytotoxicity
Penicillium griseofulvum Y19-07	4-Hydroxyphenethyl methyl succinate 4-Hydroxy-phenethyl 2-4-hydroxyphenyl)acetate	Cytotoxicity
Penicillium viridicatum	Fumigaclavine	Antibacterial Antifungal
Penicillium expansum	Expansol A Expansol B	Cytotoxicity
Penicillium citrinum	3S)-3,5-dimethyl-8-methoxy-3,4-dihydro-1H-isochromen-6-ol	Cytotoxicity Anticoccidial activity
Trichoderma koningii	Trichodermaketone A	Antifungal
Hypocrea vinosa	Chaetochromin A	Cytotoxicity
Aspergillus versicolor	Sterigmatocystin Averatin Methyl-averatin Nidurufin	Cytotoxicity Cytotoxicity Antibacterial Antibacteria Cytotoxicity Antibacterial
Cladosporium sp. *F14*	Cinnamic acid* 2-Phenylethano Cyclo-Phe-Pro) Cyclo-Val-Pro)	Antioxidant Antibacterial Antibacterial Antibacterial Antibacterial
Aspergillus fumigatus	Bismethylthio) gliotoxin 6-methoxyspirotryprostatin B	Antiparasitic
Nodulisporium sp. *CRIF1*	Nodulisporacid A Vermelhotin*	Antiplasmodial
Fusarium sp.	Fusaquinon A Fusaquinon B Fusaquinon C	Cytotoxicity
Aspergillus ostianus	Circundatin A* Circundatin B* Circundatin E* Circundatin H*	Antibacterial

*Compounds known already.

Chemical structures



1. Clodepsipeptide

initiating via modulation of carcinogen metabolizing enzymes and protection from DNA damage (Amira et al., 2009).

The marine fungi are highly diversified and their potential to produce bioactive compounds clearly demonstrates their role in clinical applications and further drug designing pharmaceuticals. New method of isolation and screening of fungi and its metabolites is essential to generate a novel compound (Table 4). The main goal of this review was to investigate the potential bioactive compounds isolated from marine fungi and their contribution towards modern medicine.

CONCLUSION

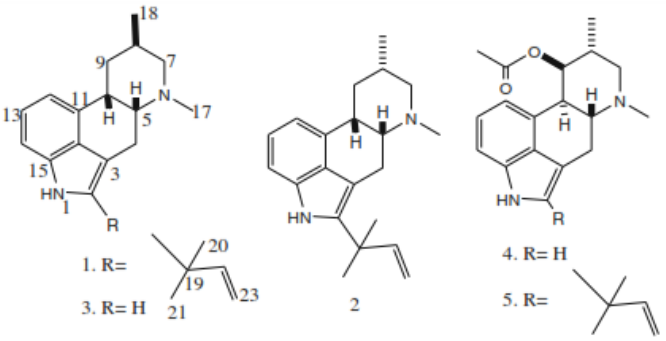
The way of screening new bioactive compounds depends

Table 4. Contd.

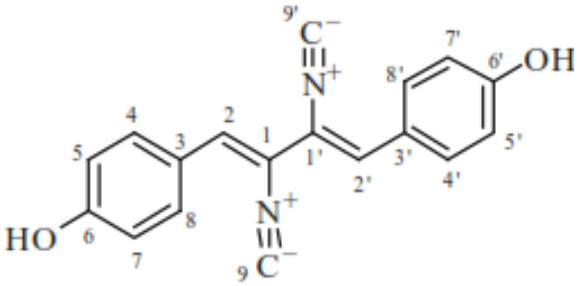
Penicillium sp.	Chromanone A	Cytotoxicity
Chrysosporium synchronum	1-O-a-Dmannopyranosyl) chlorogentisyl alcohol	Scavenging activity
Chondrostereum sp.	Hirsutanol A*	Cytotoxicity
Aspergillus sp.	Asperxanthone Asperbiphenyl	Antiviral
Rhizopus sp. *2-PDA-61*	Aspericin A Aspericin B Aspericin C	Cytotoxicity
Aspergillus flavus	Desmethylnomifensine	Antibacterial
Cladosporium sp. *F14*	Cladospolide E	Antibacterial Cytotoxicity
Aspergillus sp. *SF-5044*	Protuboxepin A	Cytotoxicity
Penicillium chrysogenum QEN-24S	Penicisteroid A	Cytotoxicity Antifungal
Phomopsis sp. *ZH-111*	3R,4S)-3,4-Dihydro-4,5,8-trihydroxy-3-methylisocoumarin	Cytotoxicity
Coniothyrium cereale	Z)-coniosclerodinol coniosclerodione coniolactone	Antibacterial
Aspergillus sp.	Aspergilone A	Cytotoxicity antifouling

Table 5. Biological activity of secondary metabolites obtained from the different species of marine fungi in the coastal area of Andhra Pradesh, India.

Isolated sp.	Activity of secondary metabolite	Low and high concentrations	Reference
Aspergillus sp.	Anti-bacterial	10-40 µg/ml	Swathi et al., 2013
Aspergillus sp.	Anti-bacterial, anti-fungal	50-200 µg/ml	Swathi et al., 2013
Curvularia sp.	Anti-bacterial	25-100 µg/ml	Swathi et al., 2013
Fusarium sp.	Anti-bacterial, anti-fungal	50-200 µg/ml	Swathi et al., 2013
Microascus sp.	Anti-bacterial, anti-fungal	20-50 µg/ml	Swathi et al., 2013

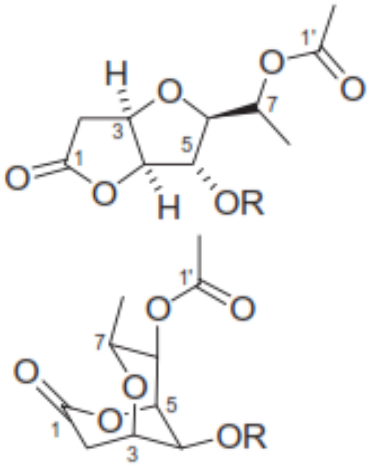


2. *Aspergillus fumigates*

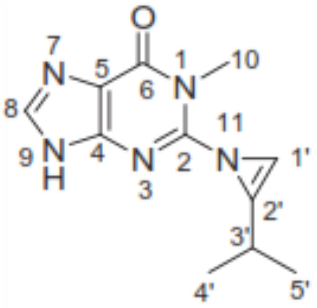


3. Xanthocillin X

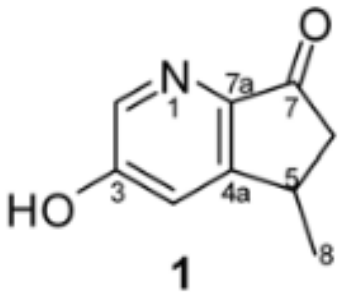
on source of sample collection and storage, cultivation, extraction and separation of compound. The collection and extraction of compound even depends on solvent used for extraction. Hence, so far, we have reviewed the



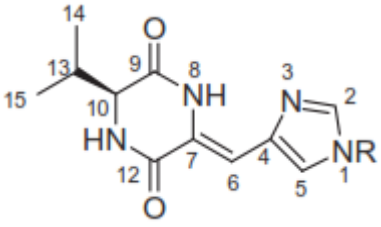
4. Protulactones A and B4



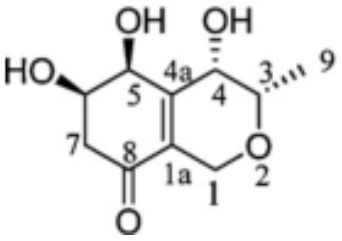
5. Acremolin



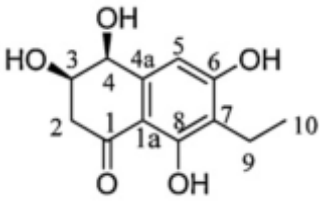
6. 3-Hydroxy-5-methyl-5,6-dihydro-7H cyclopenta(b)pyridin- 7-one



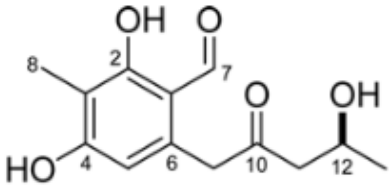
7. Pre-aurantiamine



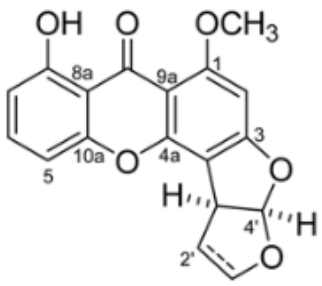
8. 3S*,4S*,5S*,6R*(-4,5,6 -trihydroxy-3-methyl-3,4,6,7-tetrahydro-1H-isochromen- 8 5H)-one



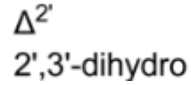
9. 3R*,4S*(-7-ethyl-3,4,6,8-tetrahydroxy-3,4-dihydronaphthalen-1 2H)-one



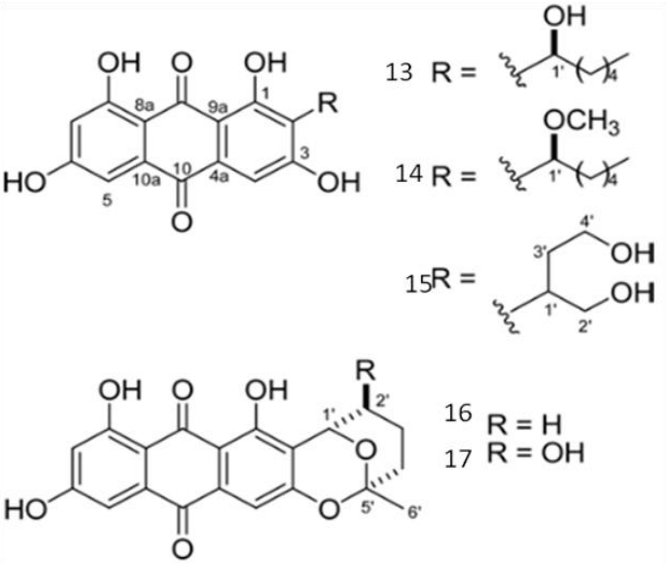
10. 2,4-Dihydroxy-6-R)-4-hydroxy-2-oxopentyl)-3-methylbenzaldehyde



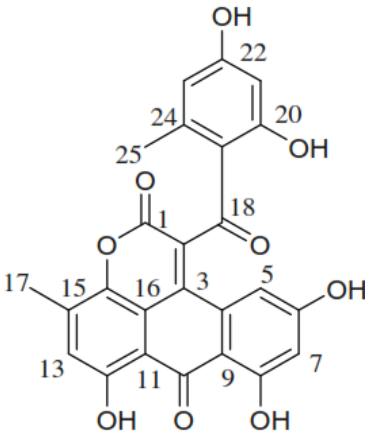
11. Sterigmatocystin



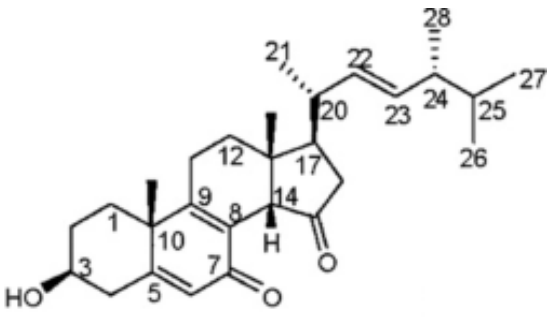
12. Dihydrosterigmatocystin



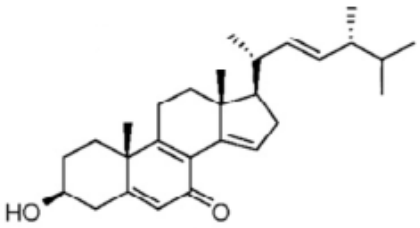
13. Averantin
14. Methyl-averantin
15. Averufin
16. Nidurufin
17. Versiconol



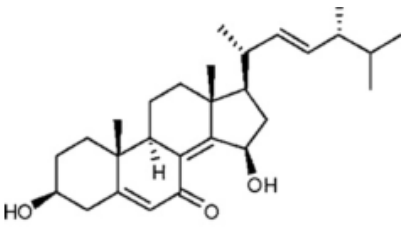
18. Aspergiolide A



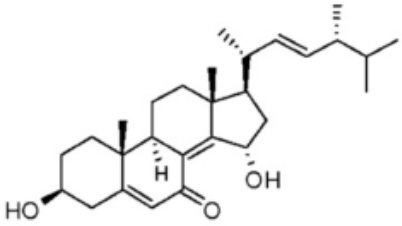
19. 3β-Hydroxyl-22*E*, 24*R*)-ergosta-5,8,22-trien-7,15-dione



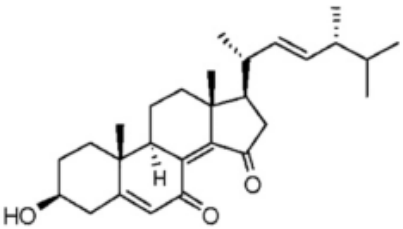
20. 3β-Hydroxyl-22*E*, 24*R*)-ergosta-5,8,14,22-tetraen-7-one



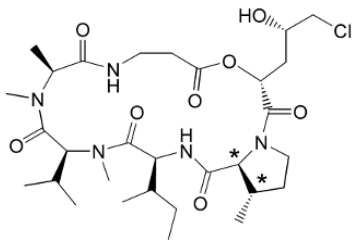
21. 3β,15α-Dihydroxyl-22*E*, 24*R*)-ergosta-5,814),22-trien-7-one



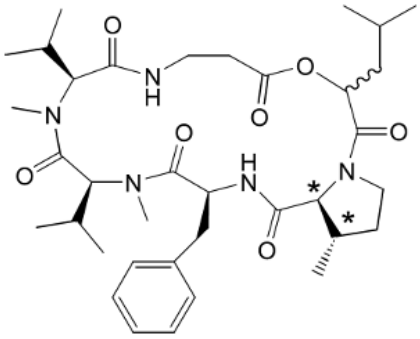
22. 3β,15α-Dihydroxyl-22*E*, 24*R*)-ergosta-5,814),22-trien-7- one



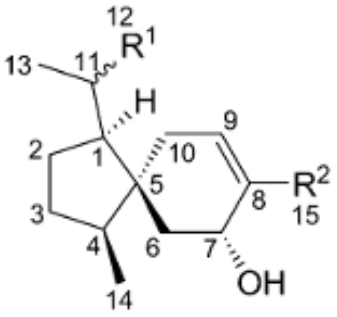
23. 3β-Hydroxyl-22*E*, 24*R*)-ergosta-5,814),22-trien-7,15-dione



24. (b -Me- Pro) destruxin E chlorohydrins

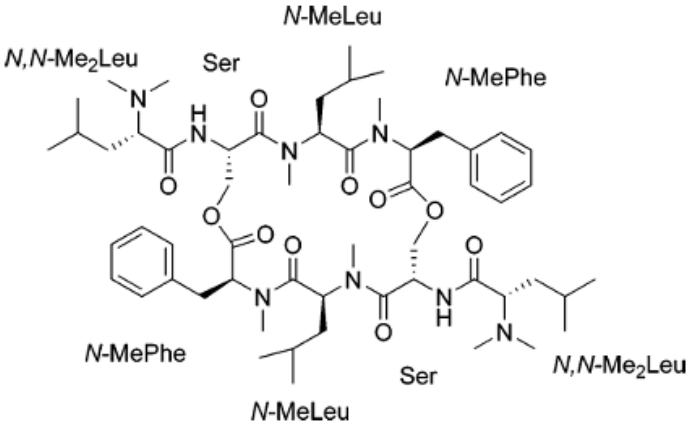


25. Pseudodestruxin C

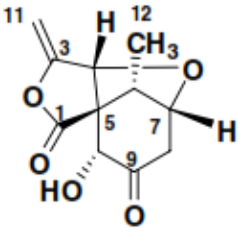


-R^1 R^2 =H0-CH_2

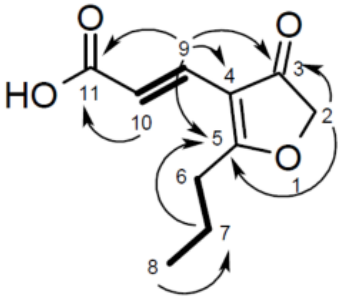
29. 8-hydroxymethyl)-1-2-hydroxy-methylethyl)-4-methylspirol(4.5)-dec-8-en-7-ol



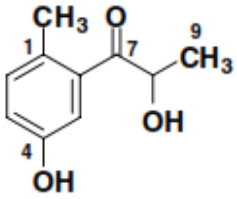
26. Cyclodepsipeptide



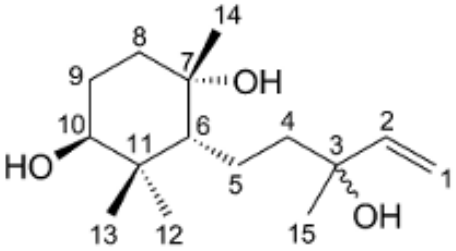
30. Spiromassaritone



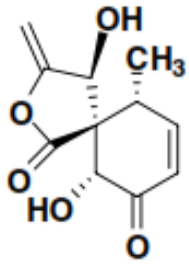
27. Cillifuranone



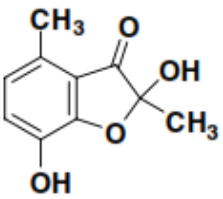
31. Massariphenone



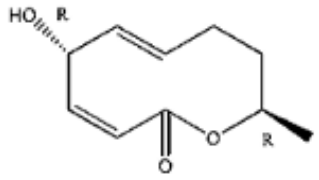
28. 3,7,10-Trihydroxy-6,11 cyclofarnesane-1-ene



32. 6-Epi-50- hydroxy-mycosporulone

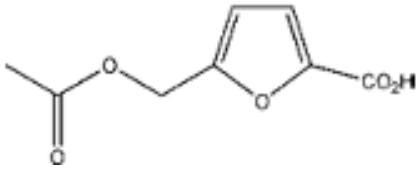


33. Enalin A

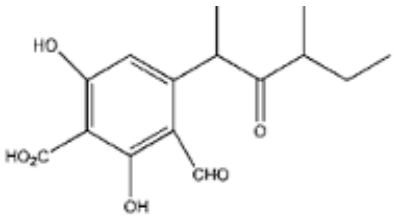


Modiolide B

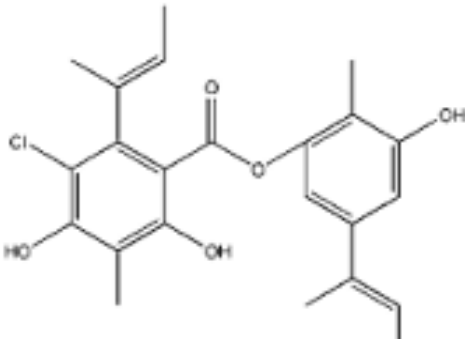
34. Modiolides A-B



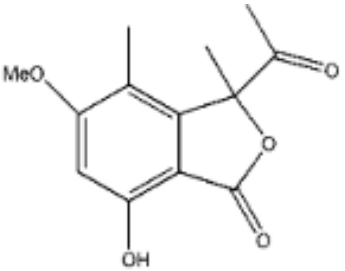
35. Acetyl Sumiki's acid



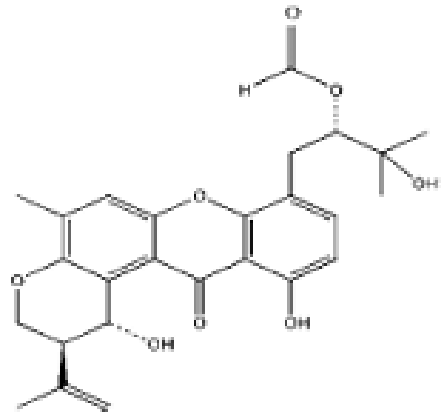
36. Ascochital



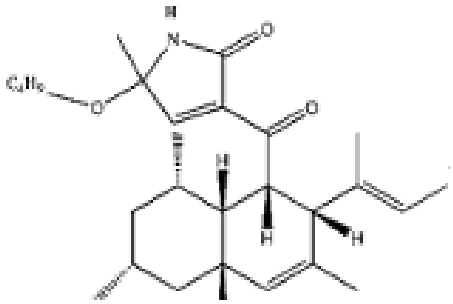
37. Guisinol



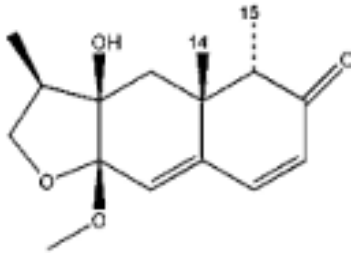
38. Phenyl lactone



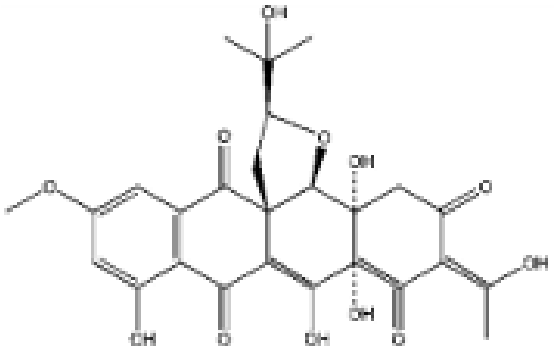
39. Varixanthone



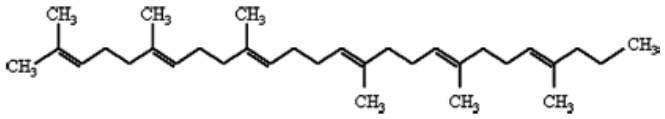
40. Polyketide ascosali pyrrolidinone-A



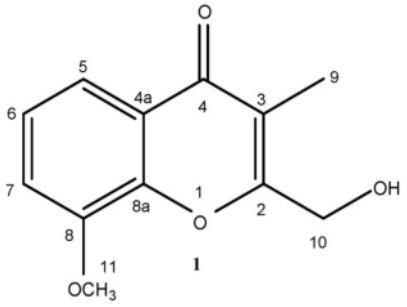
41. Microsphaeropsin



42. Seragikinone A



43. Squalene



44. 2-hydroxymethyl)-8-methoxy-3-methyl-4H-chromen-4-one chromanone A

results related to research on bioactive compounds isolated from marine derived fungi showing activities like antibacterial, antifungal, cytotoxic, anticancer, antioxidant, antimalarial, nematicidal, antitumor, antineoplastic, antifouling, larvicidal, neurotoxic, antimycobacterial, anti HIV, antiprotozoal, antiviral, antiulcer, antiparasitic, pulmonary diseases, anti-inflammatory, and also act as immunosuppressant. This review provides scope for further research on isolation and production of efficient bioactive compounds from marine fungi.

However, once the novelty of a compound is established, the extracts must be processed by the traditional approaches for subsequent purification and synthesis of the bioactive compounds.

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