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# Novel Enzymes Isolated from Marine-derived Fungi and its Potential Applications

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## ABSTRACT

*Marine environments provide habitats to a diverse group of microorganisms which play an important role in nutrient recycling by decomposing dead organic matters. In this regard, marine-derived fungi can be considered a great source of novel bio-active molecules of environmental and industrial importance. The morphological and taxonomical diversity of marine-derived fungi as compared to their terrestrial counterpart make it more interesting candidate to be explored and utilized in marine biotechnology. Fungi isolated from different marine habitats produce important enzymes with interesting characteristics. As marine-derived fungi have adapted well through evolution to thrive in the extreme marine conditions, they exhibited tremendous level specialization in the form of producing important secondary metabolites particularly novel enzymes which can be considered a better prospect for many future applications. This article discusses novel marine-derived enzymes, isolated from different marine fungi. From recent researches, it is cleared that marine-derived fungi have the potential to produce novel enzymes and important secondary metabolites. Lignin-degrading enzymes are one of the most important products produced by most marine-derived fungi. Future research that concentrates on culturing of rare and unique marine fungi with novel products, with an understanding of their biochemistry and physiology may pave the path for marine myco-technology.*

**Keywords:** *Marine-derived fungi, lignin, biotechnology, bioremediation, myco-technology, enzymes*

## INTRODUCTION

Marine environments (coastal, open-ocean water and sediments and the deep-sea subsurface) harbor a wide diversity of microorganisms which are involved in important biogeochemical processes. Recently, scientists showed great interest in the diversity of microorganism living in these habitats and the bioactive molecules they produced. As fungi are heterotrophic eukaryotic organisms and can be found in almost all sorts of niches such as oceans, sediments, mangroves, coastal and terrestrial regions. According to recent predictions, there are almost 5.1 million fungal species on earth and out of which more than 1500 species belong to the marine environments (Parte et al. 2017).Marine fungi are either freely floating entities or lodge onto sunken wood pieces, rocks, sand, plants, animals etc. On the basis of growth and sporulation characteristics, marine fungi are classified into two distinct groups, i.e. facultative marine fungi and obligate marine fungi. The first group has the potential to grow and reproduce both in marine and terrestrial environment(Kohlmeyer and Kohlmeyer 1979; Hawksworth and Lucking 2017) while the latter group cannot survive on land and complete their life cycles only within the sea (Kohlmeyer and Volkmann-Kohlmeyer 2003; Li and Wang 2009; Parte et al. 2017). A common term Marine-derived fungi is now used for all fungi derived from marine environments including both obligate and facultative fungi as most of the fungi isolated from marine samples are not demonstrably classified as obligate or facultative marine microorganisms (Osterhage 2001). Marine fungi have been isolated from different substrates such as, sponges, algae, wood pieces, tunicates, sediments, mollusks, corals, plants, fish etc., and their ecology, diversity, and phylogeny have been severely discussed (Jones 2000; Jones et al. 2009; Jones et al. 2011; Jones and Pang 2012; Richards et al. 2012; Bonugli-Santos et al. 2015). Similarly, a great number of fungal communities have also been recovered from the coastal habitats, like mangrove, sand, beach, water, river, and sediments, giving a strong proof of environmental influences such as winds, floods,

and air, on fungi migration from land toward marine environments. That is why marine fungi usually demonstrate morphological characteristics similar to their terrestrial counterparts (Méjanelle et al. 2000; Morrison-Gardiner 2002).

Marine-derived fungi adapted well to the extreme environment of the sea and enzymes produced by these fungi are also different from their terrestrial counterparts. Elevated pressure, salinity, low temperature, extreme pH, mineral content variation, and the partial or complete absence of light are the conditions responsible for the diversity of the enzymes produced by marine-derived fungi and homologous enzymes from terrestrial fungi (Jones 2000; Gomes et al. 2008; Rämä et al. 2014; Bonugli-Santos et al. 2015; Raghukumar 2017). As fungi found almost everywhere in nature, and have great influence onhuman in various aspects and have many advantages in the pharmaceutical, agricultural and food industries, for instance, Trichoderma reesei, Aspergillus niger, and Aspergillus oryzae have complex posttranslational processing and high protein secretion ability, therefore, widely used in industries to produce different enzymes and proteins (Calmels et al. 1991; Ward 2012; Benoit-Gelber et al. 2017).A wide range of bioactive molecules have been isolated from marine environments which have the potential to perform different activities such as, antibacterial, antiviral, anti-diabetics, anti-inflammatory, and antitumor and many of these functions are due to specific enzymes produced by marine fungi(Mayer et al. 2013).

This review will discuss novel enzymes isolated from marine-derived fungi and it's biotechnologically importance. The use of marine-derived fungi and their enzymes in different sectors will also be discussed in this review

## Fungi and the Marine Extreme Environments

Fungi have been found to colonized substrate in many extreme habitats such as extremely cold region of polar area (Robinson 2001) the outer stratosphere (Wainwright et al. 2003) deep-sea sediments (Raghukumar et al. 2004a; Edgcomb et al. 2011), deep anoxic basins (Edgcomb et al. 2009) in hot springs with temperature of almost of 60 °C (Maheshwari et al. 2000) and below the deep sub seafloor (Liu et al. 2017). One the most extreme conditions in the marine environment is the elevated hydrostatic pressure and deep-sea are considered as the home to baro-tolerant and barophilic microorganisms. Similarly, another important extreme condition is the low temperature around 2-4 °C and fungi from this environment are known to produce cold-tolerant enzymes such as low-temperature active serine protease, isolated from Aspergillus terreus (Table 1). These enzymes are found to helpful in detergents for cold-wash, waste digestion, and degradation in cold conditions, food and industrial processing to reduce the cost of heat energy.

Marine-environments provide habitat to various microorganisms including fungi; however, the origin, diversity, distribution, and important bioactive materials of marine-derived fungi have not been fully discovered. Eventhough the first enzyme isolated from marine-derived fungi was reported back in the 1980s but not studied extensively after that and in 1999 the detailed study on this topic started more frequently (Velmurugan and Lee 2012).Marine environments are considered as one of the extreme environment due to various factors such as low-temperature, salinity, low or no oxygen, high pressure, salinity, and special lighting conditions are responsible for the significant differences between the enzymes generated by marine microorganisms and homologous enzymes from terrestrial microorganisms (Zhang and Kim 2010). Marine organism develops a defense mechanism through evolution in order to survive in this harsh conditions andtherefore, theenzymes produced by marine organisms especially fungi show unique physiological properties such as hyper-thermo-stability, baro-tolerance, salt and pH tolerance, better stabilityinextreme cold conditions, and unique chemical and stereochemical properties. These novel characteristics of enzymes make these fungi to strive well in these conditions where most of similar land fungal strains cannot withstand (Saleem et al. 2007; Zhang and Kim 2010) and these unique enzymes produced by these fungi have tremendous potential for biotechnological applications.

## Important Enzymes Isolated From Marine-Derived Fungi

Fungi growing in extreme marine environment have the potential of producing industrially important extracellular novel enzymes(Synnes 2007; Dang et al. 2009) because of their great genetic and physiological diversity. Enzymes, such as proteases, laccases, amylases, xylanases

and cellulases produced by marine fungi havingmany important applications in various sectors such as: i) textile, paper, leather, pulp, biofuel, medical and pharmaceuticals, food and beverage industries (ii) Environmental applications (iii) animal feed production application(iv) and for research purposes. All the important novel enzymes isolated from marine fungi and its substrate and characteristics are listed in table 1.

Marine-fungal-derived enzymes showed novel characteristics as compared to those isolated from land species, due to their taxonomic diversity and adaptation to various marine-extreme conditions(Abe et al. 2001; Abe et al. 2006). Among enzymes from marine fungi, lignin-degrading enzymes (lignin peroxidases, manganese peroxidases, and laccases) gained much attention, as with the help of lignocellulase, fungi can degrade lignin. The application of lignocellulase to degrade lignin as a renewable source of fuel, attracted researchers the most (Kuhad et al. 1997; Raghukumar et al. 1999; D'Souza-Ticlo et al. 2009; Bonugli-Santos et al. 2010; Atalla et al. 2013).Many marine-derived fungi produce various lignin-degrading enzymes including lignin peroxidase (LiP), manganese peroxidase (MnP) and laccase. These enzymes are not only useful to degrade lignin but also helpful in modification and degradation of other environmental pollutants such as waste derived from crude oil, textile effluents, and agricultural chemicals(Kiiskinen et al. 2004; Mtui and Nakamura 2004).Fungi derived from marine mangrove are considered to be an important source of lignin-degrading enzymes (Raghukumar et al. 1994; Grant et al. 1996; Pointing et al. 1998; Pointing and Hyde 2001). It is also suggested that decaying activity in the marine environment is mainly performed by soft-rot fungi as compared to white-rot fungi (Pointing and Hyde 2001). Similarly,Raghukumar et al. (1994)mentioned that several mangroves-derived obligate and marine-derived fungi produce laccase, xylanase,andcellulase enzymes. Raghukumar et al. (1999)for the first time isolated marine-derived fungus Flavodon flavusstrain 312, which has the potential to produce all the lignin-degrading enzymes (LiP, MnP,and laccase) under specific conditions. Similarly, an other fungus isolated from decaying mangrove wood from marinehas the ability to producea high level of laccase when grown in phenolics and lignin substrates(D'Souza-Ticlo et al. 2006). Fungi and its isolates are also used to degrade and modify pollutants in different effluents. Verma et al. (2010) explained that marine-derived ascomycetes and basidiomycetes produced laccase which can be used for the decolorization and modification of pollutants in textile effluents.

Some unique and interesting enzymes were also produced by deep-sea marine fungi. Scientists isolated yeast, Cryptococcus liquefaciens strain N6, from the deep marine environment which has the potential to produce cold (0-10 °C) and high pressure (100 MPa) to lerantendopolygalacturonase (PGase)(Abe et al. 2006) which have been wildly used in food industries especially for the extraction and clarification of fruit juices. Marine-Derivedfungus, Cryptococcus strain N6, produce a high level of superoxide dismutase which showed tolerance to high concentration of copper (Abe et al. 2001). Similarly, cold tolerant and alkaline proteases have been isolated from various deep-sea marine fungi, Aspergillus ustus(Damare et al. 2006), Aureobasidium pullulans (Chi et al. 2007),Rhodotorula mucilaginosa(Duarte et al. 2013), Acremonium sp. (Nascimento et al. 2015) this enzyme also has some other beneficial properties which make it unique form its terrestrial counterpart, for example,it has a wide range of pH of 6–10, with an optimum activity at pH 9. Its optimum temperature was 45 oC and showed good activity at 2 oC, also its activity remains stable in the presence of high concentration (0.5M) of NaCl which is equal to seawater salinity. These enzymes have the potential to reduce the energy requirement for a chemical reaction by increasing the hydrostatic pressure and decreasing the temperature(Daniel et al. 2006). Enzymes like this could be very useful in the future to lower the energy cost.

Apart from the ecological role marine fungi also played an essential role in organic matter degradation and decomposition. In this regard, a great diversity of hydrolytic and oxidative enzymes has been isolated from these fungi which can be used in biotechnological processes. Velmurugan and Lee (2012)reported that fungi living in the marine environment can producesalt, pressure, metals, and heat-tolearnt enzymes.A thermo-stable metal tolerant laccases and alkaline xylanases have been isolated from marine strains of Cerrenaunicolor and Aspergillusniger(Raghukumar et al. 2004b; D'Souza-Ticlo et al. 2009). Baker et al. (2010) isolated cold tolerant endoglucanases from

several marine-derived fungi. Similarly,a cold-tolerant xylanase was reported from marine-derived Cladosporium species (Del-Cid et al. 2014). This enzyme was also produced by genetically modified marine strain(a psychrotrophic fungus from the YellowSea ;Hou et al. (2006)). Fenice et al. (1998)and (Velmurugan et al. 2011)also isolated a low-temperature active chitinase enzyme. Yeast strains isolated from different Antarctic marine samples (sediments and marine invertebrates) has the potential to produce lipases, proteases,and cellulases on solid media at 15oC(Duarte et al. 2013). Salt tolerant fungi and their enzymes especially lignin-degrading enzymes have been extensively used in the bioremediation of different environmental pollutants (Passarini et al. 2011). All important and novel enzymes isolated from marine-derived fungi are listed in table 1.

Enzymes production from marine-derived fungi mainly depends on its physiology and the composition of the culture medium (Bonugli-Santos et al. 2015). The source of carbon and nitrogen play the most important role in fungalenzymes production. The most common substrates used for marine-derived fungal enzymes production are: Soluble starch, peptone, pectin, yeast extract, malt extract, casein, wheat bran, sugarcane bagasse and xylan (Table 1). All the enzymes produced by marine-derived fungi isolated from different marine habitats are shown in Table 1. The optimal temperature of the enzymes ranges from 26 to 70°C while the optimal pH ranges from 3 to 9.

**Table1.** *Important enzymes isolated from marine-derived fungi its source optimum temperature and pH, and maximum production*

| Enzyme | Fungal source | Substrate/Medium | Characteristics of Enzymes | | | | Reference |
|---|---|---|---|---|---|---|---|
| | | | Unique property | Optimal Temperature(°C) | Optimal pH | Maximum Production | |
| Laccase | *Flavodon flavus* | Sugarcane bagasse | Salinity, thermo-stability and metal-tolerance | 26 | -- | 300 U/L | Raghukumar et al. (1999) |
| | *Cerrena unicolor* | Glycine and fructose | | 70 | 3.0 | 24,000 U/L | D'Souza-Ticlo et al. (2009) |
| | *Mucor racemosus* | Wheat bran + glucose | | -- | 5.0 | 898.15 U/L | Bonugli-Santos et al. (2010) |
| | *Trematosphaeria mangrovei* | Sucrose, peptone, yeast extract | | 25 | 6.0 | 184.84 U/mg | Atalla et al. (2013) |
| Lignin Peroxidase (LiP) | *Flavodon flavus* | Sugarcane bagasse | Salinity tolerance | 26 | -- | 380 U/L | Raghukumar et al. (1999) |
| | *Mucor racemosus* | Malt extract | | -- | 3.0 | 75,376 U/L | Bonugli-Santos et al. (2010) |
| | *Cladosporium cladosporioides* | | | 28 | -- | 17,419 U/L | |
| | *Aspergillus sclerotiorum* | | | | | 17,957 U/L | |
| Manganese Peroxidase (MnP) | *Flavodon flavus* | sugarcane bagasse | Salinity tolerance | 26 | -- | 420 U/L | Raghukumar et al. (1999) |
| | | | | -- | 4.5 | 44,84 U/L | Bonugli-Santos et al. (2010) |
| | *Mucor racemosus CBMAI 847* | Wheat bran + glucose | | | | | |
| Versatile peroxidase | *Pleurotus eryngii* | Wheat straw | Mnp and Lip properties | -- | -- | -- | Camarero et al. (1999) |
| Protease | *Aspergillus ustus* | Skim milk powder | Alkaline and cold tolerance | 45 | 9.0 | 1639 ACU $mL^{-1}$ | Damare et al. (2006) |
| | *Aureobasidium pullulans* | Starch+ $NaNO_3$ | | 45 | 9.0 | 7.2 U/ml | Chi et al. (2007) |

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| | *Rhodotorula mucilaginosa* | Sabouraud and skimm milk | Low temperature active | 25 | -- | 11.12 U/mL | Duarte et al. (2013) |
| | *Acremonium sp* | Cactus and pear | Low temperature active (10-40°C) | 50 | 8.0 | 445.48 U/mL | Nascimento et al. (2015) |
| Polygalacturonase (PGase) | *Cryptococcus liquefaciens* | Peptone, yeast extract, malt extract and glucose | Copper, cold (0-10 °C) and high pressure (100 MPa) tolerance | 50 | -- | 1.8 U/ml | Miura et al. (2001); Abe et al. (2006) |
| Xylanase | *Aspergillus niger Penicillium, Cladosporium* | Oat spelt xylan, sugarcane bagasse | Alkaline and cold tolerance | 50 | 3.5 | 580 U/L | Raghukumar et al. (2004b); Hou et al. (2006); Del-Cid et al. (2014) |
| | *Candida davisiana, Cryptococcusadeliensis, Guehomyces pullulans* | Birchwood xylan and yeast nitrogen base | Active at low temperature | 15 | -- | 0.75 U/mL<br>0.43 U/mL<br>0.43 U/mL | Duarte et al. (2013) |
| | *Phoma sp.* | beechwood xylan and peptone | salt tolerance | 45 | 5.0 | 1322.82 U/mg | Wu et al. (2018) |
| Lipases | *Penicillium Oxalicum, Aspergillus flavus, Candida intermedia, Candida parapsilosis , Lodderomyces elongisporus, Rhodotorula mucilaginosa, Aureobasidium pullulans, streptomycete* | olive oil, yeast extract, Lard, peanut oil, soybean oil | Cold tolerance | 35-40 | 6.0-8.5 | -- | Kirsh (1935); Wang et al. (2007) |
| | *Leucosporidium Scottii Cryptococcus adeliensis* | Peptone and yeast extract, olive oil | Cold tolerance | 15 | -- | 0.230 U.mL-1, 0.143 U L-1 | Duarte et al. (2013) |
| L-Glutaminase | *Penicillium brevicompactum* | Czapek Dox agar + Glucose | Thermo-stable at 70 °C, and antitumor activity | 50 | 8.5 | 869.1 U/ mg | Elshafei et al. (2014) |
| Amylase | *Mucor sp.* | Starch, Casein | Thermo-stable | 60 | 5.0 | 41,840 U/L | Mohapatra et al. (1998) |

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| | *Aureobasidium pullulans* | raw potato starch | | 60 | 4.5 | 0.5 U/ml | Li et al. (2007) |
| β-glucosidase | *Aspergillus SA 58* | Starch, pectin, cellulose, | Showed good activity at low pH | 35 | 3.0-9.0 | 80,000 U/L | Elyas et al. (2010) |
| β-D-Glucosidase | *Penicillium canescens* | Yeast extract, peptone | Thermo-stable | 70 | 5.2 | 1.86 U/ml | Dubrovskaya et al. (2012) |
| Inulinase | *Pichia guilliermondii* | Wheat bran and rice bran | High production on solid state fermentation | 30 | 6.5 | 455 U/g | Guo et al. (2009) |
| Alginate lyase | *Aspergillus oryzae* | Yeast extract, peptone | Consisted of two polypeptides with 45 and 50 kDa | 35 | 6.5 | 67.24 U/mg | Singh et al. (2011) |
| Chitinase | *Plectosphaerella sp* | Colloidal chitin andmalt extract | Active at low temperature | 37 | 3.0 | 0.22 U/ml | Velmurugan et al. (2011) |
| | *Penicillium Janthineflum* | | | 24 | 4.0 | 686 U/L | Fenice et al. (1998) |
| Nuclease | *Penicillium melinii* | glucose, peptone, soybean flour | Stable at 75°C and pH 2.5-8.0 | 37 | 3.7 | 41,250 U/mg | Balabanova et al. (2012) |
| Superoxide dismutase | *Cryptococcus* strain N6 | Yeast extract, peptone, dextrose and $CuSO_4$ | High copper tolerance | 24 | -- | 110 mU/µg | Abe et al. (2001) |
| L-asparaginase | *Aspergillus sp.* | Dextrose and ammonium sulphate | Anti-tumor activity | 35 | 7.5 | 185 U/ml | Sanjotha (2017) |
| | *Aspergillus terreus* | Dextrose and L-asparagine | | 35 | 6.0 | 33.86 U/mg | Farag et al. (2015) |
| | *Aspergillus sp.* | Glucose and asparagine | | 30 | 6.0 | 30.64 U/ml | Ahmed Mervat et al. (2015) |
| keratinase | *Colletotrichum capsici* | Dextrose and Ammonium sulfate | Alkaline in nature | -- | 7.5 | 1.858 mg/ml | Samuel et al. (2018) |
| | *Penicilliumspp.* | Czapek's agar, rice straw, and yeast extract | Stable at pH 6.0-11.0, 26-65 °C | 26 | 6.0 | 1,600 U/g | El-Gendy (2010) |
| Endoglucanases | *Various fungi isolated form marine sponge Haliclona simulans* | Cellobiose and yeast extract | Active at lower temperature | 18-60 | -- | 0.014-0.34 U/mg | Baker et al. (2010) |
| L-arginase | *Penicillium chrysogenum* | Dox's medium + L-arginine | Thermo-stable and anticancer activity | 50 | 6.8-7.9 | -- | El-Sayed et al. (2014) |

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|---|---|---|---|---|---|---|---|
| L-Arginine Deiminase | *Aspergillus fumigatus* | Glucose and L-arginine | Thermo-stable and anticancer activity | 45 | 7.0 | 22.0 U/ml | El-Sayed et al. (2015) |

## Application of Some Important Novel Fungal Enzymes

Marine-derived fungi with novel and unique properties are considered to be a good candidate of industrially important enzymes(Synnes 2007; Dang et al. 2009). Enzymes produced by marine-derived fungi have many industrial applications. Some important enzymes are given below.

### *Proteases*

Proteases are the most commonly used enzyme all over the world and have many applications in the detergents industry and lather production. It has also been used in the pharmaceutical industry as an anti-inflammatory and digestive drug(Zhang and Kim 2010). Chi et al. (2007)isolated yeast strain, Aureobasidium pullulans, from China Yellow Sea, which produced a high yield (623 U/mg) of alkaline protease. Another alkaline protease isolated from marine-derived fungus showed 45% and 25% activity at 20 0C and 15 0C, respectively, with the highest activity at pH 9.5, thus performed well under high saline condition. These features make it a good candidate for detergents used under cold conditions(Raghukumar et al. 2006). Thus proteases isolated from marine-derived fungi might prove to be a valuable source of enzymes for detergent industries.

### *Lipases*

Lipases catalyze the breakdown of oil and fats and are found in a wide variety of organism. Recently this enzyme got more attention and have been isolated from various microorganisms and also produced commercially. Lipases are mainly used in the production of detergents, paper, cosmetics, in medicine as digestive enzymes and other clinical reagents, and as a food flavoring (Seiichi et al. 1991; Kobayashi et al. 2008; Chi et al. 2009; Zhang and Kim 2010).Kirsh (1935)isolated lipase for the first time from Penicillium Oxalicum and Aspergillus flavus. The best cold-tolerant lipase was extracted from Moraxella, isolated from seawater of Antarctica, can work at a temperature of 3 0C with an optimum of 25 0C of temperature (Feller et al. 1990).Cold-active lipases have also been isolated from many deep-sea fungal species. For example Wang et al. (2007)isolated 9 lipase producing yeast strains by screening a total of 427 marine-derived yeast strains belonging to the following groups Pichia guilliermondii N12c, Candida intermedia YA01a, Candida parapsilosis3eA2,Candida quercitrusa JHSb, Lodderomyces elongisporusYF12c, Candia rugosa wl8, Rhodotorula mucilaginosaL10-2,Yarrowia lipolyticaN9a,and Aureobasidium pullulans HN2.3. Lipases form these fungi showed optimum activity at various low temperature and pHs. The optimum temperature was between 35 and 40 0C while the optimum pH was between 6.0 and 8.5.

### *Polygalacturonases*

Polygalacturonases (PGase) are enzymes usually used in food industry for clarification of fruit juices. Two unique PGase were isolated from deep-sea (4500-6500 m) marine-derived yeast extracted from the Japan Trench, showed activity at low temperature (24 0C) and high hydrostatic pressure (100 MPa)(Miura et al. 2001; Abe et al. 2006).These enzymes were also tolerant at high (50 mM) concentration of CuSO4 and showed the high activity of superoxide dismutase (superoxide radical scavenger). This pressure can shift the temperature required for a given chemical reaction towards lower temperature (Daniel et al. 2006). Thus it is possible to reduce the energy expenditure by running a chemical reaction with a mesophilic enzyme rather than thermophilic enzymes at elevated hydrostatic pressure.

## Conclusions

Even though marine fungi have been extensively studied in recent researches, our understanding and scientific knowledge of marine fungi is still very limited. Marine fungi produced unique and novel enzymes which have many industrial applications. So far the major focus was on marine bacteria and regardless of the physiological adaptability to low temperature, elevated hydro pressure, and playing important roles in the ecosystem, marine

fungal taxa have not been discovered that much. Marine-derived fungi haverevealed much promise interm of interesting enzymes with novel properties, unique metabolics, and secondary metabolites. Many biotechnological important enzymes have been produced by marine-derived fungal community isolated from a variety of marine habitats. This diversity of marine fungal products is due to genetic diversity based on taxonomy and adaptability to various extreme environmental conditions. There is still a very big scope to examine these fungi for other interesting and useful products, like extracellular polysaccharides and other secondary metabolites. Future studies should be focused on marine fungal biology to reveal interesting biochemical and physiological features useful to various new biotechnological processes, forexample, finding of new techniques to study uncultured and rare marine-derived fungi and knowing about its physiology and biochemistry will definitely pave the way for future marine mycology.

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