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Recent Advances in Myco-remediation of Xenobiotics : Review

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ABSTRACT

A xenobiotic is a class of chemical substances which usually are not produced within an organism naturally or expected to be present within. It can also cover substances that are present in much higher concentrations than are usual.

The term xenobiotics, however, is very often used as synonym of pollutants such as dioxins and polychlorinated biphenyls, because xenobiotics are considered as substances which are not found in entire biological system, i.e. synthetic substances, which did not exist in nature or purely manmade. Degradation of such compounds by physical and/or chemical processes is costly and often produces undesirable products which are toxic. Biological methods, being eco-friendly and cost cheap techniques, were proposed for xenobiotic degradation purposes in order to overcome these problems. Compared to bacteria, most of the fungi are robust organisms and generally more tolerant to high concentrations of pollutants. It explains why they have been extensively investigated since the mid-1980s for their bioremediation capacities.

A wide number of fungal species have shown incredible abilities to degrade a growing list of persistent and toxic industrial waste products and chemical contaminants to less toxic form or non-toxic form. Fungi posses' very peculiar mode of metabolizing their substrate by using array of enzyme systems. Extracellular nature of these enzymes proven superiority over any other enzyme system in nature.

The potential of fungal enzymes can be harnessed for remediation of the environment. In depth knowledge and understanding about these enzymes will surely revolutionize the waste treatment in near future.

Key words: Xenobiotics, Myco-remediation, Fungi, Biodegradation

INTRODUCTION

A xenobiotic is a class of chemical substances which usually are not produced within an organism naturally or expected to be present within. It can also cover substances that are present in much higher concentrations than are usual.

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Fungi possess very special mode of metabolizing their substrate by using array of enzyme systems. Extracellular nature of these enzymes has proven superiority over any other enzyme system in nature. The potential of fungal enzymes can be harnessed for remediation of the environment. In depth knowledge and understanding about these enzymes will surely revolutionize the waste treatment in near future.

MATERIALS AND METHODS

White Rot Fungi in mycoremediation

A wide number of fungal species have shown incredible abilities to degrade a toxic industrial waste products and chemical contaminants to less toxic form or non-toxic form. Mycelium reduces toxins by different enzymatic actions to restore the natural pollutant free environment. White rot fungi have successfully been utilized in degradation of environmental pollutant like polyaromatic compounds, pesticides etc. Prakash (2017). Use of White rot fungi for degradation was reported as early as in1991 Higson FK (1991), White rot fungi were among the organisms tried for degrading xenobiotics. This group of fungi includes many saprophytic and few parasitic fungi like honey fungi.

White rot fungi such as *P. chrysosporium* was tried for degrading the non-repeating, non-stereo selective, insoluble polymer lignin under conditions of nutrient limitation Higson FK (1991). The attack on lignin principally involved extracellular enzymes like peroxidases (ligninases) and hydrogen peroxide. The *P. chrysosporium* system reported to be active against diverse substrates as DDT, lindane, PCBs, TNT and crystal violet. Some like biphenyl and triphenylmethane dyes are structurally related to lignin substructures. Normally less toxic intermediates were generated. Methods of optimizing ligninase activity in fungal reactors have been described, such as the addition of surfactants and veratryl alcohol to the medium. This work initiated the search for bio remediating activity of white rot fungi Higson FK (1991).

Among biological processes for degradation of xenobiotics, fungal degradation, being eco-friendly and cost effective, have been investigated extensively because most of basidiomycetes are more tolerant to high concentrations of pollutants Ellouze and Sami (2016). Fungal bioremediation is a promising technology using their metabolic potential to remove or reduce xenobiotics. Basidiomycetes are the unique microorganisms that show high capacities of degrading a wide range of toxic xenobiotics. They act via the extracellular ligninolytic enzymes, including laccase, manganese peroxidase, and lignin peroxidase. Their capacities to remove xenobiotic substances and produce polymeric products make them a useful tool for bioremediation purposes. During fungal remediation, they utilize hazardous compounds, even the insoluble ones, as the nutrient source and convert them to simple fragmented forms.

Bioremediation is an attractive technology that utilizes the metabolic potential of microorganisms in order to clean up the environmental pollutants to the less hazardous or non-hazardous forms with less input of chemicals, energy and time. White rot fungi are unique organisms that show the capacities of degrading and mineralizing lignin as well as organic, highly toxic and recalcitrant compounds. The key enzymes of their metabolism are extracellular lignolytic enzymes that enable fungi to tolerate a relatively high concentration of toxic substrates. Tišma *et al*. (2010) gave a brief review of many aspects concerning the application of white-rot fungi with the purpose of the industrial contaminants removal.

A wide number of fungal species have shown incredible abilities to degrade a growing list of persistent and toxic industrial waste products and chemical contaminants to less toxic form or non-toxic form Prakash (2017). Mycelium reduces toxins by different enzymatic mechanism to restore the natural flora and fauna. White rot fungi have successfully been utilized in degradation of environmental pollutant like polyaromatic compounds, pesticides etc. The present review gives a insights on degradation aspects of heavy metals, PAH especially using different fungal species. White rot fungi has potential to degrade contaminants using wide range of enzymes. Mycoremediation is promising alternative to replace or supplement present treatment processes.

Bhattacharya *et al*. (2012) reported mycoremediation of Benzol [a] pyrene by *Pleurotus ostreatus*. Benzo[a]pyrene (BaP) is a ubiquitous environmentally significant compound which is considered as persistent bioaccumulative toxin. The present study was carried on to determine the degradation potentials of three natural isolates of the white rot fungi *Pleurotus ostreatus* towards BaP.

Use of Mushrooms in Degrading Xenobiotics

Mushrooms posses mycoremediation potential Kulshreshtha *et al*. (2014). Mushroom uses different methods to decontaminate polluted spots and stimulate the environment. These methods include - Biodegradation, Biosorption and Bioconversion. Mushrooms are known to produce extracellular enzymes such as peroxidases, ligninase (lignin peroxidase, manganese peroxidase and laccase), cellulases, pectinases, xylanases and oxidases. These enzymes are able to oxidize many of the pollutants. Activities of these enzymes are typically induced by their substrates.

In recent times as there is an advancement in the knowledge about fungal interactions with pollutants. Khan *et al*. (2017) shown that some of the white rot fungi like *T. versicolor* and *P. ostreatus* have been recognized to be the major decomposers of biopolymers via laccase-mediated transformation. Moreover, the ligninolytic fungal strains carrying enzyme Mn-peroxidase activity demonstrated the maximum degradation of naphthalene (69 %). They have shown that biotransformation of the hazardous pollutants to less toxic substances or their complete mineralization represents an economical substitute to clean up soil and water. Fungi possess an array of extracellular enzymes which is capable of biodegrading any naturally existing biopolymers and some of the synthetic polymers as well. Degradation of polymers is largely dependent on the fungal extracellular enzymes, namely, oxidoreductases and hydrolases. Many non-ligninolytic species degrade polycyclic aromatic hydrocarbons (PAHs). Remediation of nitro-aromatics has been described by utilizing fungal species such as *Phanerochaete chrysosporium* or *Pseudomonas* sp. The need for discovering the new beneficial fungal strains and isolation, engineering, and sequencing of new useful enzymes is highlighted. This may speed up the remediation of contaminated soil.

Tiberius and Cătălin (2013) reported that ligninolytic fungi are seen with the ability to degrade the synthetic dyes, a class of xenobiotics, resistant to biological degradation. The degradation strategies can be planned according to the category and nutrients present. *Bjerkandera adusta* and *Trametes hirsuta*, were tested on different structural classes of dyes: azo, thiazine and arylmethane.

The use of white-rot fungi was also reported way back in 1995 by Paszczynski and Crawford (1995). Since this group produces an unusual enzyme system, characterized by a specialized group of peroxidases, that catalyzes the degradation of the complex plant polymer lignin. This ligninolytic system shows a high degree of non-specificity and oxidizes a very large variety of compounds in addition to lignin. Among these compounds are numerous environmental pollutants. The white-rot fungi show considerable activity as bioremediation agents for use in the remediation of xenobiotic molecules. One such white-rot fungus, *Phanerochaete chrysosporium*, has been studied and reported for their ligninolytic enzymes system and the degradation of xenobiotics. It has been widely promoted as a bioremediation agent. This article examines literature concerning the degradation of xenobiotic compounds by *Phanerochaete chrysosporium* and attempts to critically assess this organism's real potential as a bioremediation tool.

Rabinovich *et al* (2004) had reported in their detailed review about transformation of natural and synthetic aromatic compounds by fungi (causative agents of white rot, brown rot, and soft rot, as well as soil filamentous fungi). Major enzyme types, their role in the transformation of lignin and aromatic xenobiotics. The article refers aspects like activity regulation under the conditions of secondary metabolism and oxidative stress. Coupling of systems degrading polysaccharides and lignin and non-phenolic lignin structures is analyzed, together with nonenzymatic mechanisms. Metabolic pathways resulting in the formation of aromatic and haloaromatic compounds in fungi are described. Consideration is given to the mechanisms of fungal adaptation to aromatic xenobiotics.

CONCLUSION

The ability of fungi to use various substrates as carbon and energy sources can be exploited for elaboration of cost effective strategies for the mycoremediation of xenobiotics using cheap materials such as agricultural residues. Mycoremediation is promising alternative to replace or supplement present treatment processes.

White rot fungi have potential to degrade contaminants using wide range of enzymes. These enzymes have potential applications in a large number of fields, including the chemical, fuel, food, agricultural, paper, textile, and cosmetic industrial sectors. Their capacities to remove xenobiotic substances and to produce others, which are less or non-toxic, make them a useful tool for bioremediation purposes. The white-rot fungi show considerable promise as bioremediation agents for use in the restoration of environments contaminated by xenobiotic molecules.

Mushroom cultivation used in mycoremediation may help in subsiding the the world's major problem i.e. waste accumulation. There is a need for further research towards exploring potential of mushroom as bioremediation tool. The safety issues involved in consuming mushrooms as product need to be addressed.

The potential of white-rot fungi can be harnessed thanks to emerging knowledge of the physiology and morphology of these microorganisms. This knowledge could be transformed into reliable and robust waste treatment processes. The importance of high extracellular levels of these enzymes to enable the efficient degradation of xenobiotic compounds.

Importance of white-rot ligninolytic fungal strains such as *T. versicolor* and *P. ostreatus* have been recognized to be the major decomposers of biopolymers via laccase-mediated transformation. Utilization of fungal species such as *Phanerochaete chrysosporium* may be of great use. This underlines importance of white rot fungi in developing new techniques in future.

Conflicts of interest: The authors stated that no conflicts of interest.

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