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Laccase sources and their applications in environmental pollution

Sarvesh Kumar Mishra*, Shailendra Kumar Srivastava, Krishna Ash

Department of Microbiology and Microbial Technology

AAIDU, Allahabad, U.P, India

ABSTRACT- Laccase is multicopper oxidases that are widely distributed among plants, insects, fungi and bacteria. Pollution increased with the time day by day, laccase is an oxido-reductase which plays a significant role in remediation. These enzyme catalyze and one-electron oxidation of a wide variety of organic and inorganic substrate including mono-, di-, and poly-phenols, amino-phenols, metho-oxyphenols, aromatic amines, and ascorbate, with the concomitant four electron reduction of oxygen to water. Present study on their use in several industrial application, includes dye decolorization, detoxification of environmental pollutants and revalorization of waste and waste water etc. this review helps to understand the properties of these improvement enzymes for efficient utilization for its biotechnological and environmental applications. Now we provide a brief discussion of this interesting group of enzymes, increase knowledge of which will promote laccase based industrial process in future.

Keywords: Laccase, Biodegradation, Bioremediation and Dye decolorization

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INTRODUCTION

Laccases (benzenediol: oxygen oxidoreductase, EC 1.10.3.2) exist widely in nature and belongs to small group of enzymes called the blue copper protein or copper oxidases (Sivakumar et al. 2010). These are multicopper oxidases that are widely distributed among plants, insects, fungi and bacteria. These proteins are characterized by containing copper atoms. One copper is placed at the T1 site, where the reducing substrate binds and other three copper are clustered in which molecular oxygen binds. Laccases have received much attention of researchers in last decades due to their ability to oxidize both phenolic and non-phenolic lignin related compounds as well as highly recalcitrant environmental pollutants so it makes these biocatalysts very useful for their application in several biotechnological processes.

Laccase occurrence

Laccase is most widely distributed in a panoramic view of higher plant, insect, fungi and bacteria (Diamantidis *et al.* 2000).

****Address for Correspondence:***

**Sarvesh Kumar Mishra*

Research Scholar

Department of Microbiology and Microbial Technology

AAIDU, Allahabad, U.P, India

sarveshmicro@gmail.com

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Plant: Laccase in plants have been identified in tree (Mango, Pine etc), cabbages, turnip, beets, apples, asparagus, potatoes, pears and various vegetables (Levine 1965). Recently laccase has been expressed in the embryo of maize (*Zea mays*).

Insect: The insect laccase is a long amino-terminal sequence characterized by unique domain consisting of several conserved cystine, aromatic and charged residues. Laccase are found in dozen of insects of genera that include *Bombyx, Calliphora, Diploptera, Drosophilla, Lucilia, Manduca, Musca, Oryctes, Papilio, Phormia, Rhodnius, Sarcophaga, Schistocerca* and *Tenebrio* (Xu 1999). Recently, two isoforms of laccase 2 gene have been found to catalyze larval, pupal and adult cuticle tanning in *Tribolium castaneum* (Arakane et al., 2005; Sharma and Kuhad 2008).

Fungi: Fungal laccase have higher redox potential than bacterial or plant. Most of the laccase described in literature was isolated from higher fungi. Laccase have been isolated from ascomycetes, deuteromycetes and basidiomycetes fungi (Assavaning et al. 1992). Laccase from *Monicillium indicum* was the first laccase to be characterized from an ascomycetes showing peroxidative activity (Thakkar et al. 1992). In fungi, ascomycetes and deuteromycetes have not been a focus for lignin degradation studies as much as the white-rot basidiomycetes. Most common laccase producers are the wood rotting fungi *Trametes versicolor, Trametes hirsute, Trametes ochracea, Trametes villosa, Trametes gallica, Cerena maxima, Coriolposis polyzona, Lentinus tigrinus, Pleurotus erynngii, Pleurotus osteatus* etc. (Morozoa et al. 2007).

Bacteria: Bacterial laccase was first reported in *Azospirrilum lipoferum* (Givaudan et al. 1993), it play a role in cell pigmentation, oxidation of phenolic compounds (Faure et al. 1994, 1995). Other name as *E. coli, Bacillus subtilis, S. lavendulae, S.cyaneus, Marinomonas mediterranea, Aquifex aceolicus, Bacillus* sp., *Bacillus halodurans, Leptotrix discophora SS1, Oceano bacilusiheynesis* (cotA), *Alpha-proteobacterium SD21, Gama-proteobacterium JB, Pseudomonas fluorescens GB-1, Pseudomonas maltophila, Xanthomonas campesteris (copA), Pseudomonas putida GB-1 (cumA), Pseudomonas syringae pv tomato(copA), Pseudomonas aerophillum (pae1888), Streptomyces antibioticus, Streptomyces griseus (epoA), Thermus thermophillus (HB27) and Streptomyces psammoticus* MTCC7334 etc. (Sharma *et al*., 2007).

APPLICATIONS

Laccase in Environmental Pollutant:

The goal of present work is to study and thoroughly compare the properties of laccase. Laccase is also used in bioremediation agent to clean up herbicides, pesticides and certain explosive in soil. Laccase is important because it oxidizes both the toxic and nontoxic substrates. It is utilized in textile industry, food processing industry, wood processing industry, pharmaceutical industry, and chemical industry. This enzyme is very specific, ecologically sustainable and a proficient catalyst.

A few laccases are at present in market for textile, food and other industries, and more candidates are being actively developed for future commercialization. A vast amount of industrial applications for laccases have been proposed and they include pulp and paper, textile, organic synthesis, environmental, food, pharmaceuticals and nano-biotechnology. Being specific, energy-saving and biodegradable, laccase-based biocatalysts fit well with the development of highly efficient, sustainable and eco-friendly industries.

Laccase in the Paper Industry

Making paper from wood requires separation of the wood fibres from each other and then reforming them into a sheet. In wood, lignin glues the fibres together. These fibres can be separated either by degradation and removal of lignin (chemical pulping), or by physically tearing the fibres apart (mechanical pulping). Chemical and mechanical pulps have different market niches. Many paper products contain both pulp types, in variable proportions depending on the required properties. Mechanical pulp is cheaper than chemical pulp because of its high yield (up to 95 % by weight of the starting material, in contrast to the yield from chemical pulping of wood is usually less than 50%), and capital cost. However the high lignin content of the mechanical pulp fibres detracts from the quality of the paper; because the fibres have little flexibility, they do not bond together, the paper has lower strength, and there is a tendency of the pulp to yellow on exposure to sunlight. In addition, mechanical pulping requires a lot of electrical energy, which in turn increases the cost.

Laccase in the Dye Decolourization

The treatment of industrial effluents containing aromatic compounds is necessary prior to final discharge to the environment (Khalifia *et al.,* 2010). Nowadays, environmental regulations in most countries require that wastewater must be decolorized before its discharge (Molianen *et al.,* 2010) to reduce environmental problem related to the effluent (Tavares *et al.,* 2009). A newly isolate deuteromycetes fungus pestalotiopsis sp. has high potential producer of industrially important laccase and decolorization of azo dye (Hao *et al.,* 2007). Laccases from the white-rot fungi *Cerrena unicolor* and *Trametes hirsuta* for their ability to decolorize simulated textile baths (Molianen *et al*., 2010).

Laccase in Waste Detoxification and Decontamination

Laccase has been used to oxidatively detoxify or remove various aromatic xenobiotics and pollutants found in industrial waste and contaminated soil or water. Laccase catalysis could result in direct degradation or polymerization/ immobilization. Reported example of direct dechlorination, cleavage of aromatic rings, and mineralization of polycyclic aromatic hydrocarbons, decolorization of pulp or cotton mill effluent and bleaching of textile dyes. The process includes polymerization among pollutants themselves or copolymerization with other nontoxic substances (such as humic materials). Polymerized pollutants often become insoluble or immobilized, thus facilitating easy removal by such means as adsorption, sedimentation or filtration (Xu 1999).

Laccase in Bioremediation and Biodegradation

Keum and li obtained laccase from *T. versicolour* and *Pleurotus ostreatus* for degradation of PCB as well as phenol. *T. versicolour* is used for the the bioremediation of atrazine in soil (Shraddha *et al.,* 2011). *T. villosa* remediates the soil by degrading 2, 4- DCP (2, 4-dichlorophenol). *Cerrena unicolor* has the capability of reducing lignin content from sugarcane bagasse (D'sauza *et al.,* 2009). Decolorization and detoxification of a textile industry effluent by laccase from *Trametes trogii* (Imran *et al.,* 2012). Large amount of polyphenol is present in the beer factory wastewater which is present in dark brown in colour and degrade by the white-rot fungus Coriolopsis gallica (Yague *et al.,* 2000). Laccase produced from Trametes sp. bioremediate the distillery wastewater generated from the sugarcane molasses fermentation with high content of organic matter (Gonzalez *et al.,* 2000).

CONCLUSIONS

Laccase are ubiquitious in nature, being produced by various source like plants, insect, fungi and also bacteria. The function of enzyme differs from organism to organism. Laccase play an important role in the carbon cycle and could help in degrading a wide range of xenoaromatics. They have many industrial applications because of their innate ability of oxidation of phenolic and nonphenolic compounds. Laccase enzyme has the property to act on a range of substrate and to detoxify a range of pollutants. They decolourize and detoxify the industrial effluents and help in wastewater treatment. They act on both phenolic and nonphenolic lignin related compounds as well as highly recalcitrant environmental pollutants which help researchers to put them in various biotechnological applications.

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