Chapter 10
Laccase–Mediated Treatment of Pharmaceutical Wastes

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ABSTRACT

Laccases are versatile multi-copper enzymes belonging to the superfamily of oxidase enzymes, which have been known since the nineteenth century. Recent discoveries have refined investigators’ views of the potential of laccase as a magic tool for remarkable biotechnological purposes. A literature review of the capabilities of laccases, their assorted substrates, and their molecular mechanism of action now indicates the emergence of a new direction for laccase application as part of an arsenal in the fight against the contamination of water supplies by a number of frequently prescribed medications. This chapter provides a critical review of the literature and reveals the pivotal role of laccases in the elimination and detoxification of pharmaceutical contaminants in aquatic environments and wastewaters.

1. INTRODUCTION

Since the first reports of enzyme discovery in the 18th century, applications of these valuable biologically derived macromolecules have been widely developed for many biotechnological and industrial procedures (Copeland, 2000). Enzymes are non-toxic, biodegradable, and environmental friendly catalysts that speed up chemical reactions with great specificity and at mild conditions of low pressure and temperature, as well as near neutral pH (Copeland, 2000; Yagi, 2006). Consequently, these magic tools make the
Based on their mode of action, enzymes are divided into several categories that include oxidoreductases, transferases, hydrolases, isomerases, and ligases (Purich & Allison, 2002). Laccases (benzenediol:oxygen oxidoreductase, EC 1.10.3.2), which are among the oldest and most extensively studied group of oxidoreductases, have shown multipotential utilities that range from industrial and environmental purposes to synthetic and diagnostic applications (Jafari, Rezaei, Rezaie, Dilmaghani, Khoshayand, & Faramarzi, 2017; Shraddha, Shekher, Sehgal, Kamthania, & Kumar, 2011; Yang, Li, Ng, Deng, Lin, & Ye, 2017). Laccases are generally monomeric, dimeric, and/or tetrameric glycoproteins with miscellaneous substrate ranges that can be even further expanded by the use of either synthetic or natural redox mediators (Mogharabi & Faramarzi, 2014; Shraddha, Shekher, Sehgal, Kamthania, & Kumar, 2011). These copper-containing oxidases are mainly produced by white-rot basidiomycetes, where they play physiological roles in the degradation of lignin biopolymers for natural recycling (Forootanfar & Faramarzi, 2015; Rezaei, Shahverdi, & Faramarzi, 2017; Rezaee, Rezaei, Jafari, Forootanfar, Khoshayand, & Faramarzi, 2017; Yang, Li, Ng, Deng, Lin, & Ye, 2017). Their wide spectrum of substrate specificities has drawn attention and made laccases the first choice in numerous exploitations, including dye decolorization, biodegradation and bioremediation processes, the separation of lignin in paper industries, and the removal of phenolic compounds from food (Asadgol, Forootanfar, Rezaei, Mahvi, & Faramarzi, 2014; Ashrafi, Nasseri, Alimohammadi, Mahvi, & Faramarzi, 2015; Forootanfar, Rezaei, Zeinvand-Lorestani, Tahmasbi, Mogharabi, Ameri, & Faramarzi, 2016; Mirzadeh, Khezri, Rezaei, Forootanfar, Mahvi, & Faramarzi Mirzadeh, 2014; Rezaei, Tahmasbi, Mogharabi, Firuzyar, Ameri, Khoshayand, & Faramarz, 2015; Yang, Li, Ng, Deng, Lin, & Ye, 2017). Another aim of many investigations has been the use of laccases and/or laccase producing microorganisms for the elimination of pharmaceuticals and endocrine disrupting chemicals (EDCs) present as hazardous materials in wastewater (Ashrafi, Nasseri, Alimohammadi, Mahvi, & Faramarzi, 2015; Becker, Rodriguez-Mozaz, Insa, Schoevaart, Barceló, de Cazes, … Wagner, 2017; Macellaro, Pezzella, Cicatiello, Sannia, & Piscitelli, 2014; Rahmani, Faramarzi, Mahvi, Gholami, Esrafil, Forootanfar, & Farzadkia, 2015; Tahmasbi, Khoshayand, Bozorgi-Koushalshahi, Heidary, Ghazi-Khansari, & Faramarzi, 2016; Yousefi-Ahmadipour, Bozorgi-Koshalshahi, Mogharabi, Amini, Ghazi-Khansari, & Faramarzi, 2016; Zeinvand-Lorestani, Sabzevari, Setayesh, Amini, Nili-Ahmadabadi, & Faramarzi, 2015). This type of enzyme-based bioremediation can overcome problems encountered when removing pollutants with physiochemical procedures, as these can be time consuming and costly and can generate metabolites with higher toxicity than the original pollutants (Azimi, Nafissi-Varceh, Mogharabi, Faramarzi, & Aboofazeli, 2016).

This chapter considers all the above-mentioned points about the advantages of enzymatic treatment of wastewater, and takes an environmental point of view to represent how laccases are presently being employed to assist in the bioremediation, biotransformation, and removal of pharmaceutical wastes. A further goal was to provide a state-of-the-art review of the different categories of pharmaceuticals being biodegraded by laccases and to present a simplified scheme regarding their mechanisms of action. This chapter presents how far we have come and what else can be done to improve our current knowledge and to optimize laccase-mediated treatments of pharmaceutical wastes, as well as to broaden the categories of these compounds.

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