

Chapter 42

Mycoremediation of Lignocelluloses

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ABSTRACT

The most abundant aromatic biopolymer on earth Lignin is extremely recalcitrant to degradation. It creates a barrier to solutions or enzymes by linking to both hemicellulose and cellulose preventing the penetration of lignocellulolytic enzymes into the interior lignocellulosic structure. Global attention has been gained by fungi owing to the potential use of their versatile enzymes for agriculture, medicines, industries and bioremediation. The combination of extracellular ligninolytic enzymes, mediators, organic acids and accessory enzymes make some of the basidiomycete white-rot fungi to be able to degrade lignin efficiently. This review describes remediation of lignocelluloses by fungi, properties of fungi, their spatial distribution and the mechanisms of action which render them attractive candidates in biotechnological applications like biopulping, animal feed, genetic engineering and space exploration.

INTRODUCTION

Principal structural wood polymers are cellulose, hemicelluloses and lignin, which are the most abundant biopolymers in the earth's carbon cycle. These polymers form the lignocellulose complex in all woody tissues. This is a complex structure in which the cellulose is surrounded by a monolayer of hemicellulose and embedded in a matrix of hemicellulose and lignin. The highly ordered structure of cellulose microfibril aggregates which are embedded in a matrix of hemicelluloses and lignin provides the basis for the mechanical strength of the lignocelluloses (Salmén & Burgert, 2009). Furthermore lignin specifically creates a barrier to enzymatic attack (Daniel, 2003) the highly crystalline structure of cellulose is insoluble in water while hemicellulose and lignin create a protective sheath around cellulose (Karin & Manfred, 2012). Mycoremediation is a term that is applied to the use of fungi to clear the environment of contaminating substances. It can also be understood as bioremediation by fungi. Fungi perform mycoremediation by using extracellular enzymes to reduce/remove toxic wastes from the environment. Lignocellulose degradation apart from upgrading the quality of the degraded biomass

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also helps in producing variety of commercial enzymes and many additional by products which are of interest simultaneously (Sharma & Arora, 2015).

Biochemical systems to degrade the lignocelluloses to perform conversion and mineralization of wood to carbon dioxide and water have been developed only by higher fungi. Most of these fungi belong to the Basidiomycetes. Though related phylogenetically (Binder & Hibbett, 2002; Floudas et al., 2012) strategies of their wood degradation are diverse: wood polysaccharides are primarily degraded by brown-rot fungi which leave behind a polymeric but highly modified lignin, while almost all polymeric wood constituents are degraded at similar rates by white-rot fungi. Selective white-rot fungi, which lack the ability to degrade cellulose efficiently, cause extensive delignification of wood. Soft-rot decay leading to softening of wet wood is performed by Ascomycetes and Deuteromycetes.

STRUCTURE OF LIGNOCELLULOSE

Three main polymeric constituents that form wood and other lignocellulosic materials are cellulose, lignin, and hemicelluloses (Higuchi, 1997). Cellulose, a linear and highly ordered (often crystalline) polymer of cellobiose (D-glucopyranosyl- β -1, 4-D-glucopyranose) represents over 50% of wood weight. On the other hand contrastingly lignin is a three-dimensional network buildup of dimethoxylated (syringyl, S), monomethoxylated (guaiacyl, G) and non-methoxylated (*p*-hydroxyphenyl, H) phenylpropanoid units which are derived from the corresponding *p*-hydroxycinnamyl alcohols, giving rise to variety of subunits including different ether and C—C bonds. Analytical pyrolysis has enabled identification of acetylated lignin units recently identified in non-woody plants (Del Río, Gutiérrez & Martínez, 2004).

PROPERTIES OF LIGNOCELLULOSES

The word lignin is derived from Latin word ‘Lignum’ meaning wood. It embodies three components of lignocellulosic biomass in addition to cellulose and hemicellulose. Lignin, the second most abundant natural substance in nature after cellulose is produced approximately 5×10^6 metric tons annually through industrial processes (Mai, Majcherczyk, & Huttermann, 2000). Lignin, most abundant renewable source of aromatic polymers owes its degradation mandatory for carbon recycling. Lignin chemically is a cross-linked macromolecule derived from the oxidative coupling of monolignols, mainly hydroxycinnamyl alcohols which are three main components comprising of *p*-coumaryl, coniferyl and synapyl alcohols. The composition of lignin is plant-specific, with molecular weight and linkage motifs varying according to plant species and environmental factors.

Mechanical resistance to wood confers to lignin's high resistance towards chemical and biological degradation. Middle lamella is where the highest concentration of this recalcitrant polymer is found, acting as a cement between wood fibers, it is also present in the layers of the cell wall (secondary cell-wall), with hemicelluloses forming an amorphous matrix embedded with cellulose fibrils which are protected against biodegradation (Loredano, Fabio, Elena, & Rosini, 2015). Highest lignin content made up with mostly G units is found in woody gymnosperms, which are contrasted by the presence of S and G units in the lignin of woody angiosperms. Lignin composition varies between wood tissues and cell-wall layers.

The third structural component, hemicelluloses (polyoses), has an intermediate degree of complexity and is made up of different pentose and hexose residues, which are often acetylated, and generally form

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