Development of a Membrane Reactor System for Bioconversion of Lignocellulosic Biomass by Novel Enzymes

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Lignocellulose ranks among the most abundant renewable organic raw material in the biosphere. Its biomass accounts for approximately 50 % of biomass produced all over the world. Lignocelluloses are found in higher plants, such as wood (in the cell wall). It is of high industrial interest since it is mainly composed of the compounds cellulose, hemicelluloses, and lignin which form a complex network. The complexity is basically caused by lignin, a polydisperse aromatic polymer. Lignin is extremely recalcitrant to degradation and restricts, in terms of a barrier, the biocatalytic hydrolysis of cellulose and hemicellulose limiting the bioconversion of lignocelluloses into valuable products (e.g. for production of second-generation biofuel).Thereby, the production cost obtaining bioproducts from lignocelluloses are increased. Thus, an efficient lignin separation / decomposition is a big challenge.

In nature, the lignocellulose biodegradation underlies an extensive reaction mechanism which is not fully understood yet. The most efficient organisms involved in wood decay processes are some basidiomycetous white-rot fungi due to their ability to degrade lignin by their lignolytic extra-cellular enzymes. These enzymes are mainly heme peroxidases (H_2O_2-dependent) like lignin peroxidase (LiP), manganese peroxidase (MnP) and versatile peroxidase (VP) and the O_2-dependent phenol oxidase laccase (Lac). Accessory enzymes like H_2O_2-generating enzymes and esterase-type enzymes are also involved.

Focus of this research work was the development of a bioprocess for an efficient lignocellulose deagradation of milled poplar wood to valuable compounds for subsequent industrial processes using novel lignolytic enzymes, also in composition with commercial enzymes. Insect-associated fungi were employed as sources for the novel enzymes. Undesired reaction products, such as radicals and insoluble polymers (generated by those radicals) resulting in a loss of enzymes, have to be minimized. For this objective a membrane reactor system seems to be a promising configuration that shall be developed in combination with modern computer-aided simulation tools. Furthermore, the required analytics must be established in order to monitor crucial process parameters, e.g. substrate (S), product, enzyme (E), hydrogen peroxide, dissolved oxygen concentration. The first investigations of this project were performed in a batch mode with respect to: the optimal reaction/operational conditions (pH, temperature),the E/S/H_2O_2 ratio, the necessity of mediators and other additives (e.g. enzyme deactivation defense) and kinetics as basis for calculations considering the further reactor design and optimizations as well. Beyond this, a so called quality criterion for the operational process was also searched simultaneously.