Enzyme recycling in lignocellulosic biorefineries

Commercial production of ethanol from lignocellulosic biomass is becoming a reality, but the next step is to diversify the process and produce chemicals and materials. These lignocellulosic biorefineries will in many cases rely on hydrolysis of biomass carbohydrates into monosaccharides – the sugar platform. Cellulases are the most important enzymes required in this process, but the complex nature of lignocellulose requires several other enzymes (hemicellulases and auxiliary enzymes) for efficient hydrolysis. Enzyme recycling increases the catalytic productivity of the enzymes by reusing them for several batches of hydrolysis, and thereby reduces the overall cost associated with the hydrolysis. Research on this subject has been ongoing for many years and several promising technologies and methods have been developed and demonstrated. But only in a very few cases have these technologies been upscaled and tested in industrial settings, mainly because of many difficulties with recycling of enzymes from the complex lignocellulose hydrolyzate at industrially relevant conditions, i.e., high solids loadings. The challenges are associated with the large number of different enzymes required for efficient hydrolysis, enzyme stability, and the detrimental interaction between enzyme and lignin. This review provides a comprehensive overview of the various methods for enzyme recovery and recycling, for example recycling of free enzymes, reabsorption to fresh material, recycling of solids, membrane filtration, and immobilization. Lignin is a major obstacle for successful hydrolysis and enzyme recycling. A thorough understanding of this subject and possibilities to minimize adsorption or methods to desorb the enzymes are important in order to develop the technology.

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