Biomass Hydrolysis: Enzyme Synergies

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Introduction

Cellulose is the principle component of plant biomass that is currently used for fuels and productions. Cellulose (Figure 1) is a polymer that must be transformed into its individual glucose molecules for subsequent fermentation to ethanol or other biofuels.

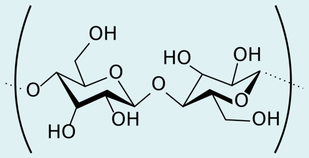


Figure 1. Cellulose

This transformation is typically performed using cellulase enzymes and is termed hydrolysis. One of the major operating costs of the biological conversion of plant biomass into ethanol is cellulase enzymes. The role of the ligninolytic enzyme manganese peroxidase (Figure 2) in reducing cellulase use was investigated.

Figure 2. Crystal structure of MnP

MnP is able to degrade lignin and may be able to reduce cellulase poisoning by lignin or increase cellulose accessibility to cellulases. The catalytic cycle of MnP includes oxidizing a Mn^{2+} to Mn^{3+}, which diffuses to the lignin substrate and then induces a degradation reaction. The Mn^{3+} is stabilized by organic acids. This unique mode of action will allow MnP to be immobilized and thereby reused in a processing strategy.

MnP Radical Cycle

$MnP(Fe^{3+}) + H_2O_2 \rightarrow MnP(Fe^{4+})O\bullet + H_2O$
Compound I

$MnP(Fe^{4+})O\bullet + chelated(Mn^{2+}) \rightarrow MnP(Fe^{4+})O + chelated(Mn^{3+})$
Compound I — Compound II

$MnP(Fe^{4+})O + Mn^{2+} \rightarrow MnP(Fe^{3+}) + H_2O + chelated(Mn^{3+})$
Compound II

Lignin Radical Initiation

$chelated(Mn^{3+}) + RH \rightarrow R\bullet + H^+ + chelated(Mn^{2+})$

Figure 3. Lignin degradation catalyzed by MnP

Methodology

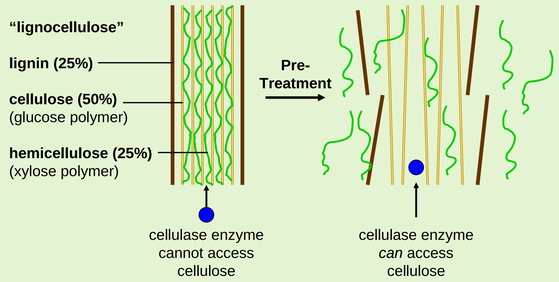


Figure 4. Wood or corn stover was pretreated using acid hydrolysis.

Figure 5. Wood chip and corn stover.

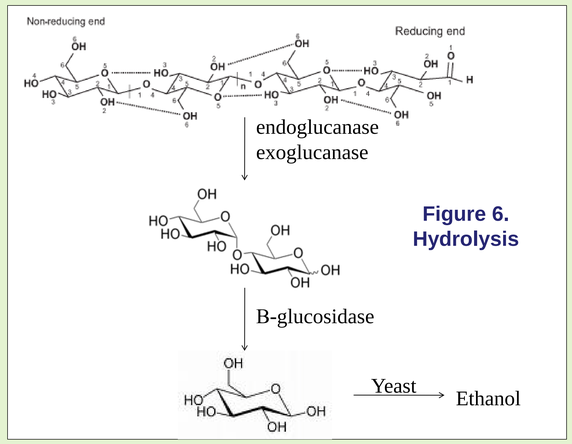


Figure 6. Hydrolysis

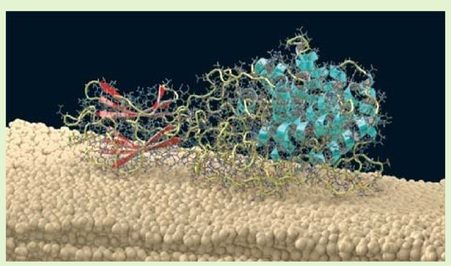


Figure 7. Cellulase Enzyme

The effect of rMnP addition to the cellulase hydrolysis of cellulose was investigated. The reaction was carried out in vials with filter paper or pretreated wood biomass as a substrate (Figure 5).

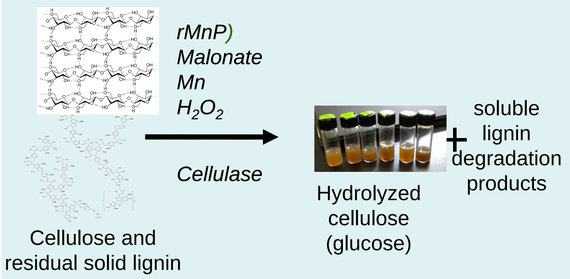
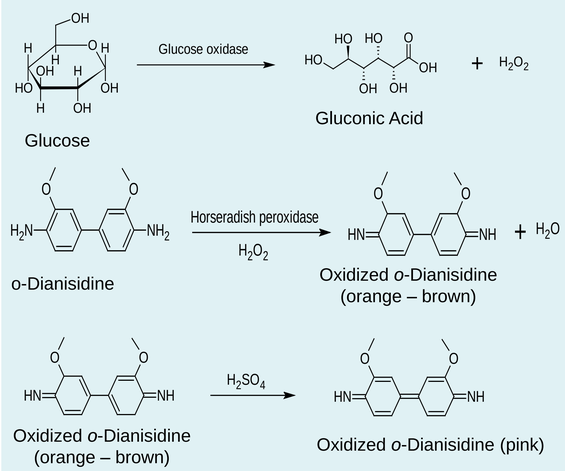


Figure 8. Enzymatic hydrolysis

rMnP was produced in bioreactor cultivation (Figure 9) and concentrated with acetone precipitation, filtration and lyophilization.

Figure 9. Bioreactor Production of rMnP



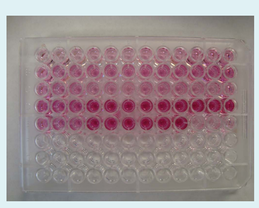


Figure 10. Reaction scheme and plate for the experimental determination of glucose in from hydrolyzed biomass

Results

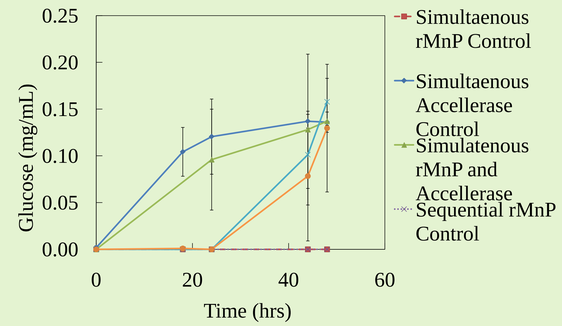


Figure 11. Sequential and simultaneous rMnP and cellulase hydrolysis of pretreated Ponderosa Pine

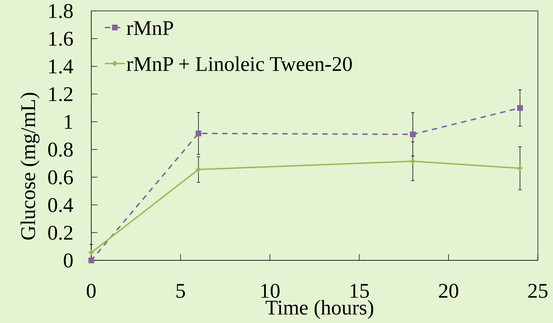


Figure 12. Sequential rMnP and cellulase hydrolysis of pretreated corn stover , with and without the redox meiator linoleic acid

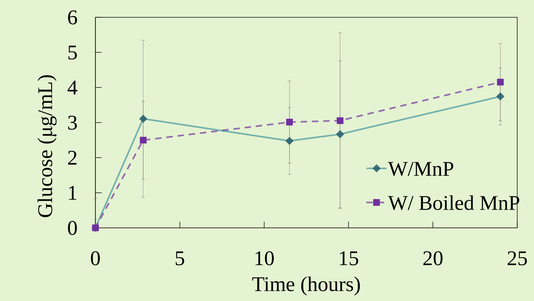


Figure 13. Sequential rMnP and cellulase hydrolysis of pretreated corn stover, with active and inactive rMnP

Acknowledgements

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