Distinct Roles of Residual Xylan and Lignin in Limiting Enzymatic Hydrolysis of Organosolv Pretreated Biomass

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ABSTRACT

The reoccurring structure of cellulose and its close association with the lignin and hemicellulose matrix makes it highly resistant to enzymatic hydrolysis. Enzymatic hydrolysis is evaluated based on the initial hydrolysis rate and the final hydrolysis yield. The Langmuir adsorption isotherm was used to characterize enzyme affinity to the substrates and the initial hydrolysis rate. Quantitative information on enzymatic hydrolysis was established based on the initial hydrolysis rate and the final hydrolysis yield. The correlation between the amount of residual xylan and the initial hydrolysis rates, and the correlation between the amount of residual lignin and the final hydrolysis yields were established. Effects of residual xylan and lignin on ethanol yields were also compared on pretreated softwood and hardwood in the simultaneous saccharification and fermentation (SSF) process.

INTRODUCTION

1. Langmuir adsorption isotherm has been often used to characterize affinity of cellulases for substrates (2).
2. Few research has distinguished the potential different roles of xylan and lignin in limiting enzymatic hydrolysis (3).
3. The Lignin droplets on the plant cell wall do not seem to be affecting the initial hydrolysis rate of cellulose (glucan), probably the bulk lignin plays bigger role in limiting enzymatic hydrolysis in the second stage.

METHODS AND MATERIALS

METHODS

1. High lignin content (18.6%) was observed in OPLP and High xylan content (9.7) in OPSG substrates (Table 1).
2. Initial hydrolysis rate (1.45 g·L⁻¹·h⁻¹) of glucan was higher in OPLP than that (1.19 g·L⁻¹·h⁻¹) in OPSG (Fig. 2).
3. The glucan-to-glucose yield reached 60% on OPLP, and 89% on OPSG under the 10 FPU of enzyme loading per gram of glucan (Fig. 2).
4. Supplementing xylanase increased glucose yield from 60% to 67% for OPLP substrate, and from 89% to ~100% for OPSG substrate (Fig. 3).
5. OPSG showed higher ethanol yields (8.8 g·L⁻¹ and 10.3 g·L⁻¹) than OPLP (7.8 g·L⁻¹ and 8.0 g·L⁻¹) respectively for both enzyme loadings. However, the initial ethanol production rates with OPLP were 0.47 g·L⁻¹·h⁻¹ and 0.81 g·L⁻¹·h⁻¹ at 10 FPU and 20 FPU respectively (Table 4).
6. The role of xylan and lignin in limiting the initial hydrolysis rate of cellulose has been reported in a SSFCF of paper sludge (4).

RESULTS

1. In this study, we used ethanol organosolv pretreatment to fractionate loblolly pine xylan and sweet gum in an ethanol organosolv process.
2. The initial hydrolysis rates of organosolv pretreated loblolly pine (OPLP) and sweet gum (OPSG) were 1.45 g·L⁻¹·h⁻¹ and 1.19 g·L⁻¹·h⁻¹ under the enzyme loading of 20 FPU.
3. The final glucan hydrolysis yields of OPLP and OPSG at 72 h were 76.4% and 98.9%.
4. Xylan was much closer to cellulose structurally than lignin, and consequently the initial interaction between xylan and cellulases decreased the initial hydrolysis rate.

DISCUSSION

We also observed that the amount of residual xylan in substrates affects the initial hydrolysis rate (Fig.5), and the amount of lignin will affect the final hydrolysis yield because xylan effects can be removed gradually by hydrolysis of xylan.

CONCLUSIONS

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Acknowledgement

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REFERENCES


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Fig. 1 Biofuels & value added co-products production process

Table 1. Chemical composition of untreated and pretreated biomass (%)

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Total (%)</th>
<th>Xylan (%)</th>
<th>Lignin (%)</th>
<th>Hemicellulose (%)</th>
<th>Acid (as Ac)</th>
<th>Acetic acid (%)</th>
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<tbody>
<tr>
<td>Untreated</td>
<td>93.69</td>
<td>3.33</td>
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<td>9.74</td>
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<td>Loblolly pine</td>
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<tr>
<td>Sweetgum</td>
<td>3.92</td>
<td>41.19</td>
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<td>2.93</td>
<td>NA</td>
<td>0.87</td>
</tr>
<tr>
<td>OPLP</td>
<td>90.20</td>
<td>1.30</td>
<td>0.83</td>
<td>2.93</td>
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</tr>
<tr>
<td>OPSG</td>
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</table>

Fig. 2 Enzymatic hydrolysis of OPLP and OPSG

Fig. 3 Effect of xylanase on Enzymatic hydrolysis

Fig. 4. Ethanol yield in SSF process

Fig. 5. Correlation between residual Xylan and initial hydrolysis rate.