Optimization the Process Variables for Pretreatment of Rape Straw by a Continuous Twin Screw-driven Reactor (CTSR)

Kyeong Keun Oh*, Hyun Jin Ryu, Jin Young Hong
Department of Applied Chemical Engineering, Dankook University, Cheonan, Chungnam, 330-714, Korea

Introduction

CTSR process might be a viable continuous pretreatment when compared to other methods due to its unique advantages such as high shear, rapid mixing, varying residence time, moderate barrel temperature, adaptability to process modification, and above all it is a continuous operation. Considering its advantages, many researchers have explored extrusion process as one of the viable continuous biomass pretreatment methods. The reason attributed for the high sugar recovery in CTSR pretreatment are increase in surface area, pore size, and the decrease in cellulose crystallinity, all of these facilitate the access of enzymes to cellulose. Rape straw was used as a model biomass for the CTSR process with a dilute acid. This study focused on establishment of the continuous pretreatment feasibility to increase cellulose fraction in fractionated rape straw and xylose concentration in hydrolyzate, and investigation of the effect of operating variables such as barrel temperature, catalyst concentration, and solid/liquid ratio, which is controlled by solid loadings and liquid flow rate. The CTSR pretreatment conditions were liquid feeding rate of 13.4 mL/min, biomass feeding rate of 1.0 g/min, temperatures ranged from 160℃ to 175℃, acid concentrations ranged from 1.0% (w/v) to 5.0% (w/v), and screw speeds of 30, 40, 50 rpm for the optimization for sugar recovery. The enzymatic digestibility of the fractionated rape straw through CTSR processing was significantly increased over that of the untreated rape straw.

Materials & Methods

Biomass

By HPLC (Breeze HPLC system, Waters, USA) with a Refractive Index detector; Column : Aminex HPX-87H (Bio-rad, USA), Column temperature : 60℃, Mobile phase : 5 mM H2SO4, Flow rate : 0.50 mL/min

Enzymatic digestibility

- Cellulase : Celluclast 1.5L (Novozyme, Denmark)
- β-glucosidase : Novozym-188 (Novozyme, Denmark)
- Enzyme loading : 30 FPU/g-glucan, 70 pNPGU/g-glucan
- Saccharification conditions : 50℃, 150 rpm, pH 4.8

Equipment

Continuous Twin Screw-driven Reactor (CTSR)

Table 1. Remaining solid and changes of sugar contents in pretreated solid residue and liquid hydrolyzate, and mass closure for CTSR pretreatment of rape straw with various screw configurations

<table>
<thead>
<tr>
<th>Screw config.</th>
<th>Sample</th>
<th>Pretreatment</th>
<th>Enzyme concentr. (%)</th>
<th>Glucose (%)</th>
<th>xmg (%)</th>
<th>Cellulose (%)</th>
<th>XMG (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Config. 1</td>
<td>Pretreated</td>
<td>48.92</td>
<td>55.56</td>
<td>1.72</td>
<td>2.72</td>
<td>90.99</td>
<td>92.49</td>
</tr>
<tr>
<td>Config. 2</td>
<td>Pretreated</td>
<td>42.03</td>
<td>59.93</td>
<td>4.73</td>
<td>6.45</td>
<td>96.30</td>
<td>91.03</td>
</tr>
<tr>
<td>Config. 3</td>
<td>Pretreated</td>
<td>45.36</td>
<td>67.09</td>
<td>9.48</td>
<td>1.42</td>
<td>92.53</td>
<td>97.30</td>
</tr>
</tbody>
</table>

Corresponding author : Kyeong Keun Oh (TEL. +82-41-550-3558 E-Mail : kkoh@dankook.ac.kr)

Biomass Research Lab., Dankook University

Conclusion

CTSR process, a continuous pretreatment of biomass, has great potential for increasing the efficiencies; fractionation of hemicellulosic sugars, enhancing enzymatic hydrolysis, and low labor intensity, and high energy efficiency.

- The optimum condition resulting in the highest xylose yield (72.1%) in hydrolyzate fractionation and cellulose content (67.1%) in CTSR (with screw Config. 3) pretreated rape straw were: 165℃, 30 rpm, 3.0 (w/v)% H2SO4, 1 g/min (biomass), 13.42 mL/min (liquid catalyst).
- The different CTSR screw configurations in the CTSR process may be a major factor affecting.
- According to the three screw configurations. The glucose yields from enzymatic hydrolysis were 70.1%, 72.9%, and 78.7% for screw Configs. 1, 2, and 3, respectively.
- Further efforts have to be devoted to the optimization the CTSR process variables to find a most economical constraints; sugar yield, and enzyme dosage.