Effects of Different Milling Processes on Properties of Douglas-fir Forest Residuals

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Introduction

Lignocellulosic biomass is composed of cellulose, hemicellulose, and lignin. In order to gain more digestible cellulose for enzymatic hydrolysis, lignin and hemicellulose which are interconnected with cellulose have to be detached from cellulose for better enzyme accessibility. Ball milling is one of the common means to reduce biomass crystallinity as well as particle size to increase surface area. These factors help boost enzyme contact for bioconversion, degrading cellulose to sugar. This results in a decreased degree of polymerization and hydrolysis time, while increasing the recovery of sugar from lignocellulosic biomass.

Objective

Operation costs of milling processes for biofuel from lignocellulosic biomass demands high specific energy consumption costs due to the grinding process. This process breaks down biomass into fine particle sizes, leading to high digestible lignocellulosic resources. Therefore, the objective in this study is to develop a milling process with low energy consumption while decreasing particle size and crystallinity of Douglas-fir Forest Residuals.

Total Energy Consumption

Table 2. Energy consumption of each process (kWh/kg).

<table>
<thead>
<tr>
<th>Process</th>
<th>Hammer Mill</th>
<th>Air Classifier Mill</th>
<th>Ball Mill</th>
<th>Total Energy Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM1-ACM1</td>
<td>0.23</td>
<td>2.31</td>
<td>-</td>
<td>2.54</td>
</tr>
<tr>
<td>HM2-ACM2</td>
<td>0.07</td>
<td>0.50</td>
<td>0.47</td>
<td>1.04</td>
</tr>
<tr>
<td>HM2-ACM2-BM7</td>
<td>0.07</td>
<td>0.50</td>
<td>0.54</td>
<td>1.11</td>
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<tr>
<td>HM2-ACM2-BM10</td>
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<td>0.50</td>
<td>0.68</td>
<td>1.35</td>
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<tr>
<td>HM2-ACM2-BM20</td>
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<td>0.50</td>
<td>1.37</td>
<td>1.94</td>
</tr>
<tr>
<td>HM2-ACM2-BM30</td>
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<td>0.50</td>
<td>2.04</td>
<td>2.61</td>
</tr>
</tbody>
</table>

X-ray Diffraction Analysis (XRD)

Fig. 6. Effect of milling processes and ball milling time on x-ray diffraction of wood residuals.

Fig. 7. Effect of different milling strategies on total energy consumption, median particle size, and crystallinity index.

Effect of Milling Strategies

- HM2-ACM2-BM8 wood powder showed lower energy consumption compared to that of HM1-ACM1, even though HM2-ACM2-BM8 has a smaller particle size (35.4 μm) than that of HM1-ACM1 (37.8 μm).
- HM2-ACM2-BM20 wood powder showed lower crystallinity (CrI=15.88%) than HM1-ACM1 (CrI=35.26%) although HM2-ACM2-BM20 consumed 1.94 kWh/kg, which is higher energy than HM1-ACM1 (2.54 kWh/kg).
- SEM images showed changes in wood particle size with different milling processes.

Conclusion

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