Determining the Effect of Densification of Pretreated Harvested Forest Residue on Enzymatic Monosaccharide Production

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Introduction

Densification of woody biomass leads to more cost-effective transportation of materials by increasing the amount of mass that can be transported for a volume of limited means, such as by train in certain parts of the U.S. Northwest. However, densification can cause hornification of chemically pretreated fibers, which refers to the pore collapse phenomenon due to hydrogen bonding upon heating or pressing of the material. This pore collapse reduces enzyme accessibility to the cellulose in woody biomass, which in turn results in reduced conversion of cellulose to sugar, and consequently, reduced yield of biofuel through fermentation.

Purpose/Goal: to determine the effect of densification of pretreated biomass on sugar (glucose) production in order to examine its effectiveness as a strategy for biomass transportation

Methods

Sulfite pretreatment to overcome recalcitrance of lignocellulose (SPORL)

- This pretreatment process aids in the conversion of biomass to sugars by overcoming the natural resistance of cell walls of lignocellulosic biomass to enzymes by partial delignification, lignin sulfunation, and hemicellulose dissolution.
- Wood chips, along with a pretreatment liquor consisting of sulfuric acid and sodium bisulfite, were placed in a stainless steel, steam-jacketed pressure vessel. The mixture in the vessel was then heated through the steam jacket and rotated at a speed of 2 rpm. The temperature inside the vessel was then raised and maintained for a specified period of time (e.g., 180 °C for 30 min)[1]
- Cold and hot presses were applied to the pretreated wood chips for densification.
- The pressed and unpressed (control) wood chips were size-reduced using a Wiley mill and a house Waring blender.
- The size-reduced substrates were then used for enzymatic hydrolysis.

Enzymatic hydrolysis

- Two types of pretreated wood samples, including beetle-killed lodgepole pine and poplar, were hydrolyzed with dilutions of commercial complex cellulase Cellic® CTec3 (enzyme) with an activity loading of 10 FPU/g cellulose, along with a sodium acetate buffer of pH 6.0 and tetracycline.
- Hydrosylates were placed in a shaking incubator (Thermo Fisher Scientific, Model 4450) at 200 rpm and 50 °C
- Samples were taken at 1, 2, 4, 24, 48 and 72 hours for glucose analysis using a commercial glucose analyzer (YSI 2700 Select)

Results

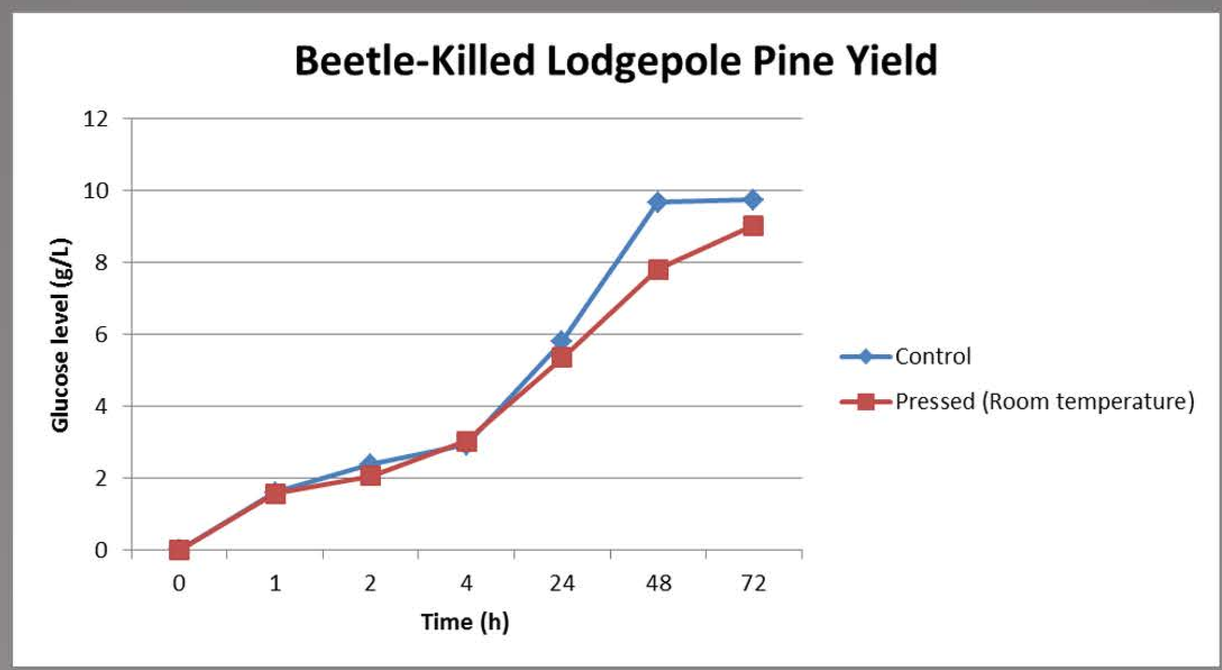

Figure 1. Glucose yield for beetle-killed lodgepole pine samples. When compared to the control, the pressed sample yielded nearly the same glucose levels across time.

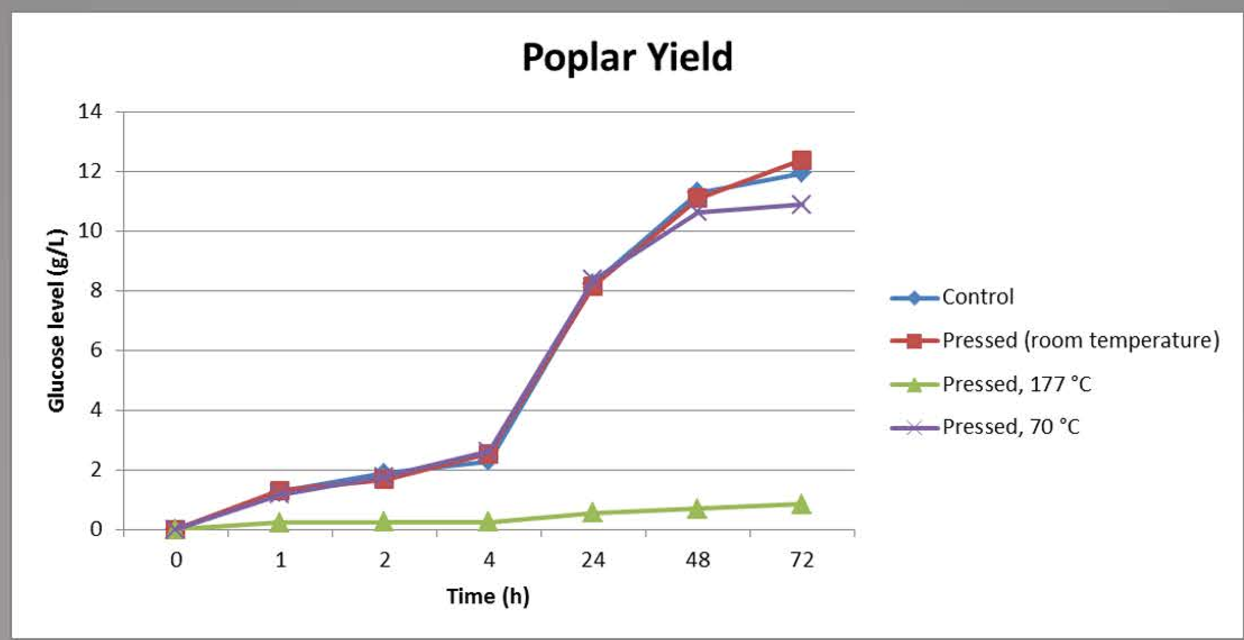

Figure 2. Glucose yield for poplar samples. All samples showed no significant differences in yield, except for samples pressed at a high temperature. When pressed at a temperature of 177 °C, glucose yield decreased significantly. Overall, glucose yield was slightly higher for poplar samples than for beetle-killed lodgepole pine samples, (except in the samples pressed at a high temperature).

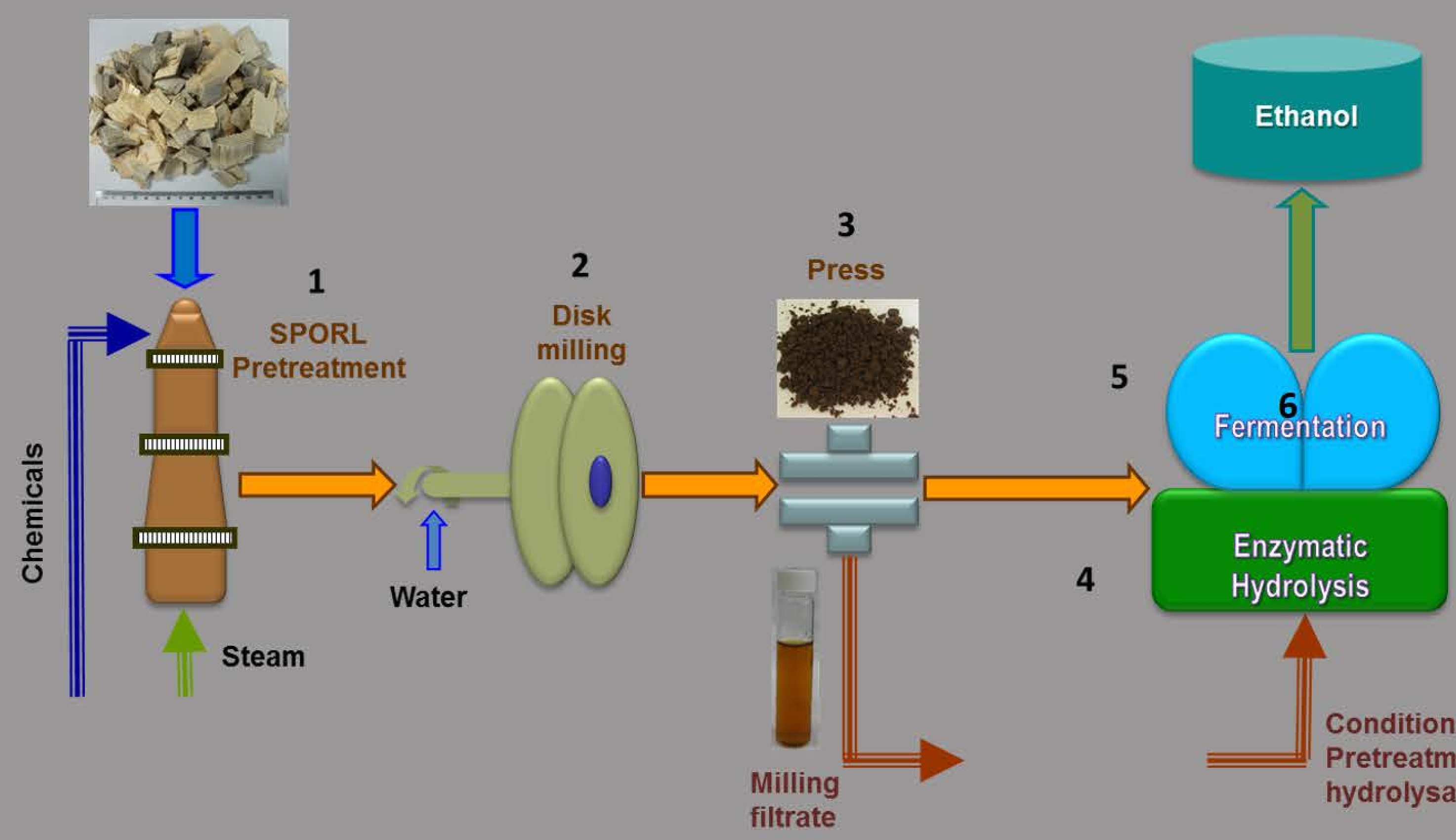

Figure 1. Overview of biofuel production process, starting with pretreatment. (Fermentation to biofuel was not done in this study)

Results

When compared to other poplar samples, the poplar sample that was pressed at a temperature of 177 °C yielded a significantly lower level of glucose. When compared to the poplar control sample, the glucose level decreased, on average, by as much as 1.0525 g/L at 1 hour, 1.6285 g/L at 2 hours, 2.0365 g/L at 4 hours, 7.692 g/L at 24 hours, 10.6135 g/L at 48 hours, and 11.0935 g/L at 72 hours. When compared to the poplar sample that was pressed at a lower temperature (70 °C), the glucose level decreased on average by 0.9475 g/L at 1 hour, 1.5135 g/L at 2 hours, 2.3515 g/L at 4 hours, 7.822 g/L at 24 hours, 9.9635 g/L at 48 hours, and 10.0435 g/L at 72 hours.

Conclusions

Densification of pretreated woody biomass does not significantly decrease sugar production, except in cases where pressing is conducted at high temperatures. Thus, densification could be used as a more efficient way of transporting forest residue while still maintaining similar sugar yields as non-densified material.

Future Directions

Since no significant effect on glucose yield was seen on poplar samples that were dried and pressed at 70 °C but an effect was seen at a much higher temperature, it would be useful to analyze samples at temperatures between 70 and 177 °C in order to determine the threshold for decrease in glucose yield.

References

1. Zhu, J.Y., Pan, X.J., Wang, G.S., Gleisner, R., Sulfite pretreatment (SPORL) for robust enzymatic saccharification of spruce and red pine, Bioresource Technology, Vol. 100, pp. 2411-2413, 2009.

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