Production of water-soluble carbohydrates from aspen wood flour with hydrogen chloride gas

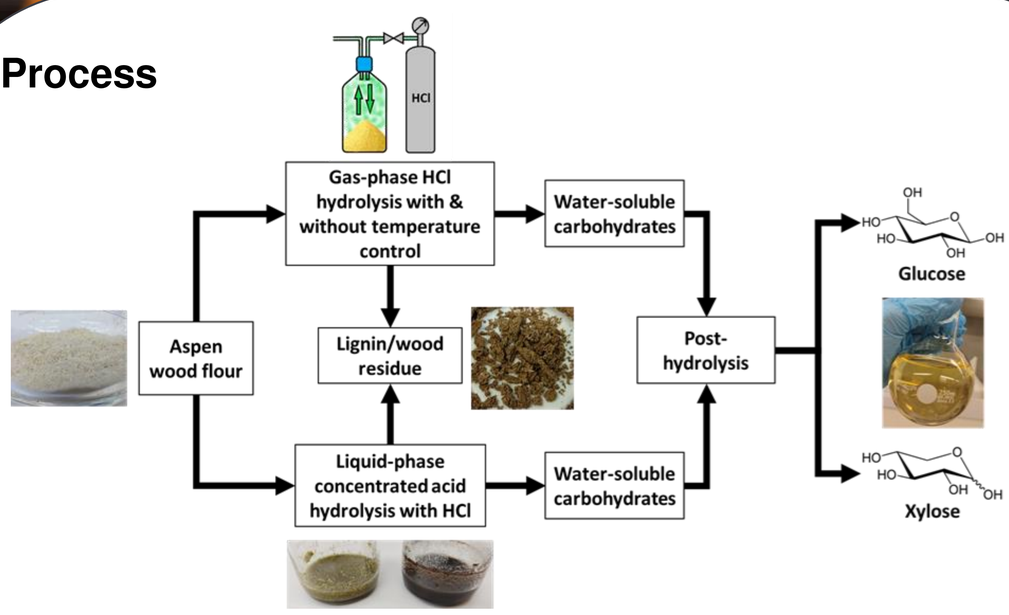
Aalto University
School of Chemical Engineering

Antti Kilpinen & Eero Kontturi
Department of Bioproducts and Biosystems, Aalto University

Introduction

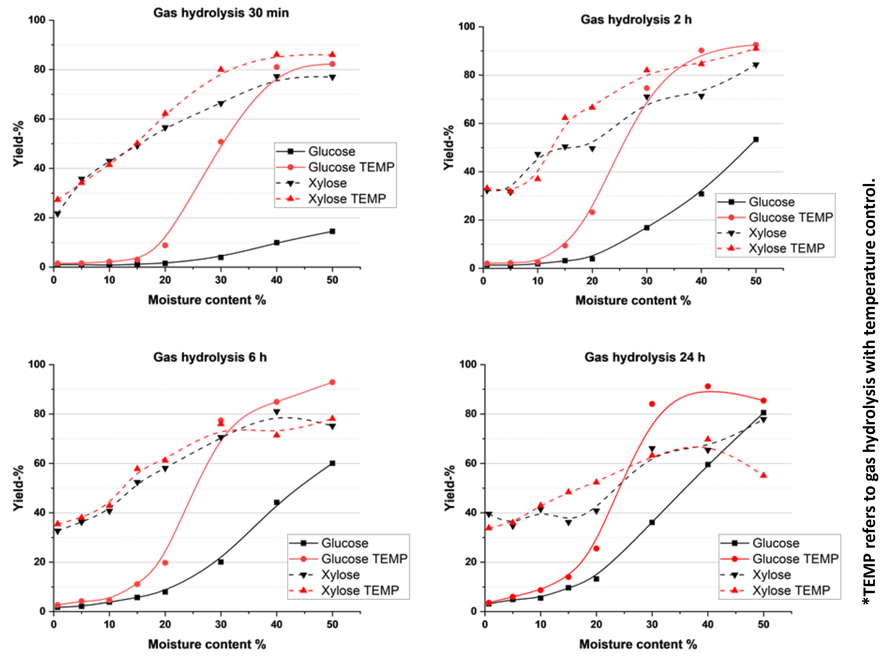
- The overall aim of this study was to optimize the reaction conditions for concentrated acid hydrolysis of aspen wood flour by employing anhydrous hydrogen chloride gas to produce fermentable sugars.
- Wood flour from aspen (*Populus Tremula*) was hydrolyzed both with concentrated hydrochloric acid and gas-phase HCl by employing the gas hydrolysis reactor used by Pääkkönen *et al.* in 2018.

Process



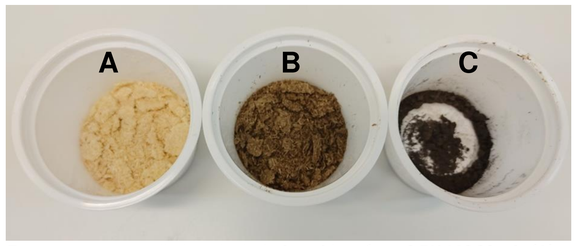
- Liquid-phase hydrolysis with concentrated hydrochloric acid in concentrations of 32%-42% and 15 min to 24 h reaction times.
- Gas hydrolysis with HCl was conducted both with and without temperature control during the hydrolysis under relatively low pressure of 1 bar.
- Process parameters for HCl gas hydrolysis included the moisture content of aspen wood flour (0.7-50 %) and reaction time under pressure (30 minutes to 24 hours).
- Temperature control during gas hydrolysis was used to prevent excess degradation of C5-sugars during the gas application phase via cooling in ice bath and to speed up the hydrolysis reaction during the last 10 minutes via heating to 50°C.

Hydrolysis with anhydrous HCl gas



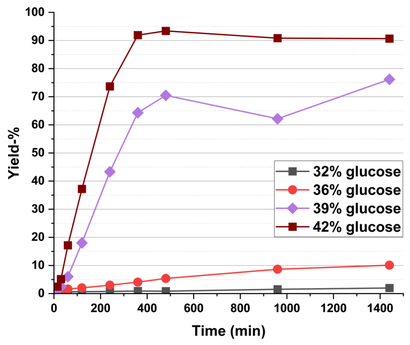
*TEMP refers to gas hydrolysis with temperature control.

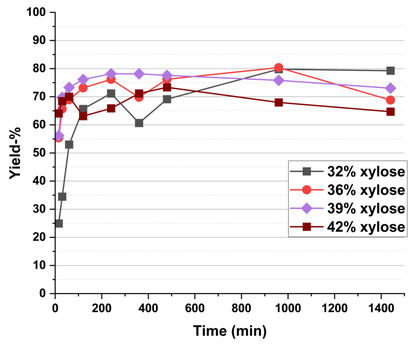
- In gas hydrolysis without temperature control, the yield of glucose and xylose increases with reaction time and moisture content. However, without temperature control the glucose yield starts to rise over 80% only with longer reaction time of 24 h and moisture content of 50%.
- With temperature control the hydrolysis efficiency is significantly improved and over 80% yields for both glucose and xylose are achieved already after 30 minutes of hydrolysis in moisture contents of 40% and 50%.
- Longer reaction times than 30 minutes increase the glucose yields to over 90%, but the xylose yield starts to go down with increased reaction time due to sugar degradation.

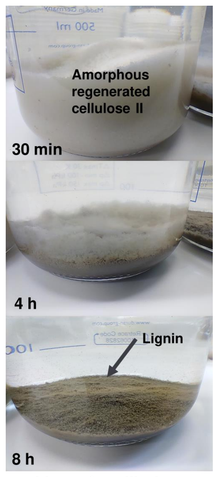


Temperature-controlled gas hydrolysis residues from 0.7% MC 30 min (A), 10% MC 6 h (B) & 40% MC 6 h (C).

Hydrolysis with concentrated hydrochloric acid







Residues after dilution from 42 % HCl hydrolysis

- With HCl concentrations of 32% and 36% mainly the hemicellulose fraction is hydrolyzed along with some degradation of disordered regions of cellulose.
- When the HCl concentration is increased to 39%, around 70% of the cellulose is hydrolyzed to water-soluble oligosaccharides after 6 hours.
- After the HCl concentration is further increased to 42%, the yield of glucose rises to over 90 % after 6 h. This indicates that almost all crystalline cellulose has dissolved and broken down to water-soluble mono- and oligosaccharides during the hydrolysis.
- The maximum yield of xylose eventually plateaus to 60-80% after 2 hours of hydrolysis with all acid concentrations.

Conclusions

- It was possible to gain high yields of water-soluble carbohydrates from aspen wood flour both with liquid and gaseous HCl hydrolyses without pre-hydrolysis step.
- Temperature-controlled gas hydrolysis produced high yields for both xylose and glucose, even with relatively low pressure of 1 bar.
- The highest water-soluble carbohydrate yield from available xylan and glucan were 91% and 92%. This was achieved with temperature-controlled gas hydrolysis at 50% moisture content using 2 h reaction time.
- Results are in line with previous research employing anhydrous HCl gas for hydrolysis.

Acknowledgements

IMPRESS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869993.

Contact information

MSc Antti Kilpinen
antti.kilpinen@aalto.fi
Department of Bioproducts and Biosystems, Aalto University

Pääkkönen, T., Spiliopoulos, P., Knuts, A., Nieminen, K., Johansson, L. S., Enqvist, E., & Kontturi, E. (2018). From vapour to gas: optimising cellulose degradation with gaseous HCl. Reaction Chemistry & Engineering, 3(3), 312-318.