Comparison of Kinetics of Xylose and Lignin Removal During Hot Water and Dilute-Acid Pretreatment of Corn Stover using a Continuous Flow-Through Reactor

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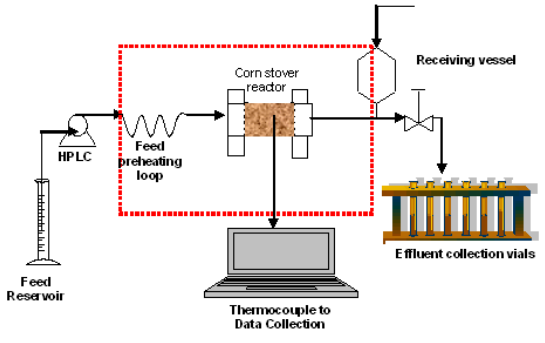
Abstract

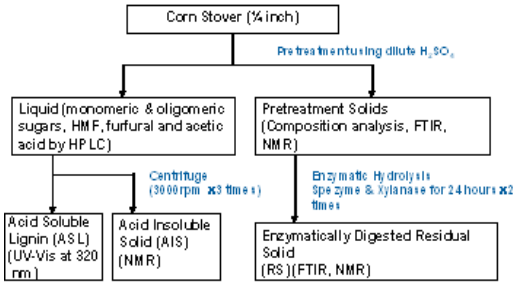
A flow through reactor (FTR) was used to determine the kinetics of xylose and lignin removal during hot water and dilute-acid pretreatment for bioethanol production. The removal rates of xylan and lignin during hot water (HW) and dilute-acid flow-through (DA) experiments with corn stover were studied between 170°C and 230°C for HW and 150°C and 210°C for DA. During all FTR pretreatments, insoluble dark precipitates were observed in the effluent and were characterized as lignin-carbohydrate complexes (LCC). Oligomeric and monomeric xylan was measured in the effluent during all of the FTR experiments. At temperatures beyond 200 °C significant xylan degradation to unknown products was observed. Total xylan removed was proportional to lignin and acetate release over the reaction time. Increases in pretreatment temperatures from 200°C to 230 °C did not significantly enhance the kinetics of xylan, lignin or acetate removal. Melting and mobilization of lignin also likely contribute to the process of xylan release. The results show that a flow through reactor is suitable for kinetics studies because the products are removed from the reaction zone, therefore less sugar degradation and lignin condensation reactions occur as compared to a batch reactor system.

Experimental Setup

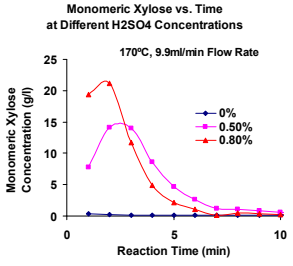
Experimental Conditions

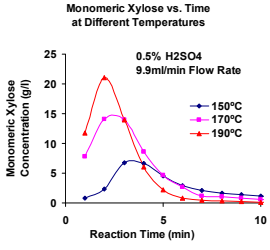
- Temperatures:170ºC~230ºC for HW, 150ºC and 210ºC for DA
- Acid concentrations: 0, 0.5 and 0.8%,
- Reaction times: 20 minutes
- Flow rate: 9.9ml/min

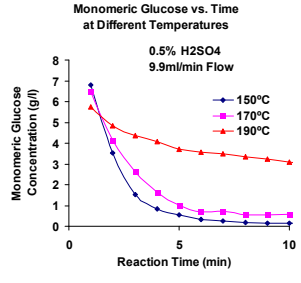


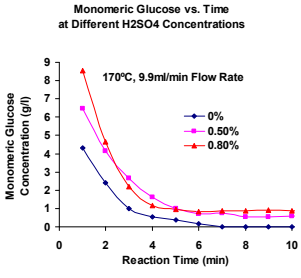


Effect of Reaction Temperature and Catalyst Concentration

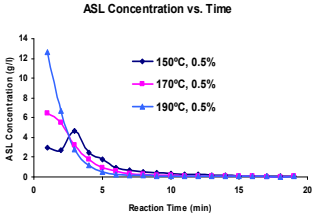


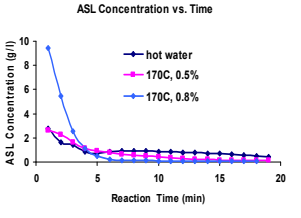






Acid Soluble Lignin





Mass Balance

Experiment	Sugar (%)	AIS (%)	ASL (%)	Inhi (%)	Solid (%)	Mass Balance (%)
0% acid, 170ºC	37.0	5.5	4.8	1.4	50.0	**98.7**
0.5% acid, 170ºC	41.3	6.1	5.0	3.9	40.0	**96.2**
0.8% acid, 170ºC	35.2	6.1	5.1	4.2	36.4	**87.1**
150ºC, 0.5% acid	43.1	4.9	4.9	2.9	46.0	**101.8**
170ºC, 0.5% acid	41.3	6.1	5.0	3.9	40.0	**96.2**
190ºC, 0.5% acid	56.0	6.1	5.2	5.7	24.5	**97.5**

Data Reduction Procedure

Inflow - Outflow + Dissolved by Reaction = Accumulated in Reactor

$$0 - \phi_v C_x(t)dt + r(t)m_c dt = V_r dC_x(t)$$

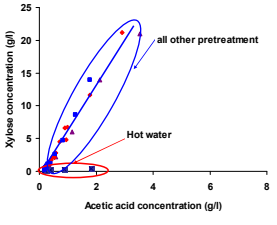
$$r(t) = \left[\phi_r C_x(t) + V_r \frac{dC_x(t)}{dt}\right]\frac{1}{m_c}$$

where **r(t) is the rate of xylose release (mg xylose/g biomass/min)**
Φ_v is the liquid flow rate (ml/min)
$C_x(t)$ is the xylose concentration at time t (mg xylose/ml)
V_r is the reactor volume (ml)
M_c is the corn stover weight (g)

Discussion and Conclusion

The results show that a flow through reactor is suitable for kinetics studies because the products are removed from the reaction zone, therefore less sugar degradation and lignin condensation reactions occur as compared to a batch reactor system.

Xylose vs. Acetic Acid



- In the pretreatment hydrolysate, the xylose concentration and acetic acid concentration has a linear relationship regardless of the pretreatment condition except hot water.
- More severe pretreatment condition will be used to verify this finding in the future.

Acknowledgement

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- Thanks to Rick Elander, Jim McMillan and other staff at the National Bioenergy Center (NBC) for their support and help with my research work.

Future Work

- Different feedstocks under different pretreatment conditions will be evaluated.
- A kinetic model will be calculated to predict biomass pretreatment behavior.

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