Ethanol Based Organosolv of Wheat straw: Process Optimization and Process Product Relations

J. Wildschut

W.J.J. Huijgen

J.H. Reith

H. den Uil

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ECN
P.O. Box 1,
1755 ZG Petten
The Netherlands

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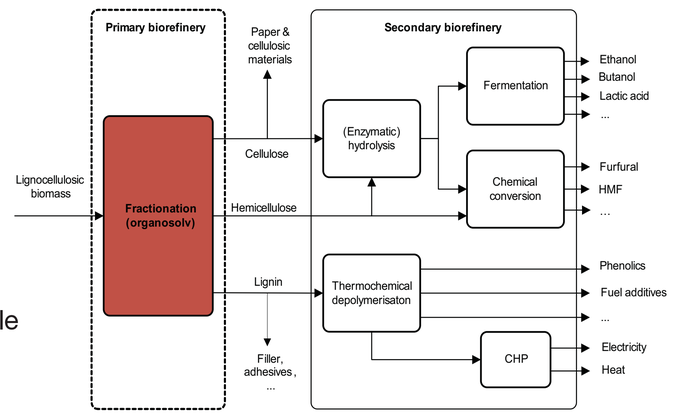
J. Wildschut, W.J.J. Huijgen*, J.H. Reith** & H. den Uil

* Corresponding author: phone: +31 224-568162, e-mail: huijgen@ecn.nl. ** Presenting author.

1. Lignocellulosic Biorefinery

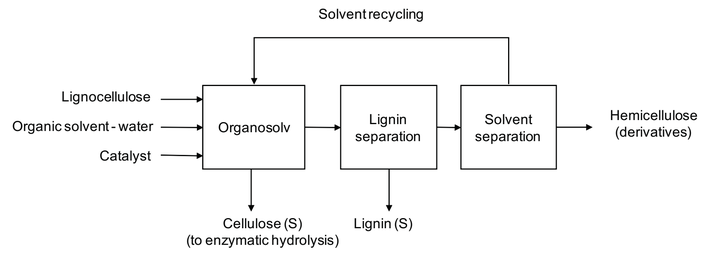
Organosolv fractionation:
- Fractionation of lignocellulosic biomass for production of materials, fuels, chemicals and energy.
- Extraction of high-purity lignin (prior to enzymatic hydrolysis).
- Enhancement enzymatic hydrolysis cellulose to fermentable sugars.



Scheme of an organosolv-based lignocellulose biorefinery

2. Organosolv Process

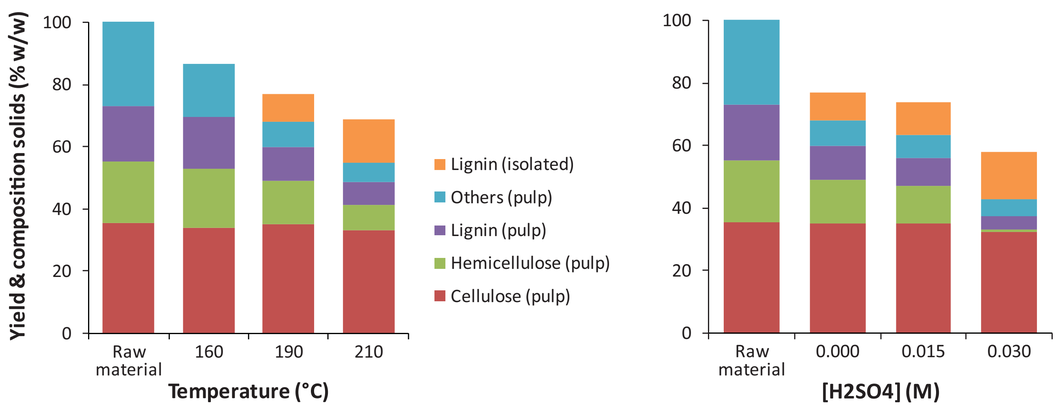
ECN process:
- Lignocellulosic biomass: focus on straw and hardwood.
- Solvents: aqueous ethanol, acetone, …
- Catalyst: H_2SO_4, ...
- Typical process conditions: 180-200 ºC, 10-40 bar, 30-120 min.



Organosolv fractionation process

Study presented:
- Wheat straw pretreatment for enzymatic cellulose hydrolysis by ethanol-based organosolv.
- Goal: identification key process parameters, process-product relations and process optimization.

3. Fractionation



Influence of temperature ([H_2SO_4] = 0 M) and catalyst added (T = 190 °C) (both: 60 min, EtOH-H_2O = 60:40% w/w, 10 L/kg).

Fractionation primarily determined by temperature, organic solvent-water ratio, and application of catalysts.
Cellulose recovered in solid (>90%), xylan removed from solid (up to 95%), and lignin extracted (up to 76%).
Lignin isolated: up to 96% of lignin in wheat straw (including condensation products).

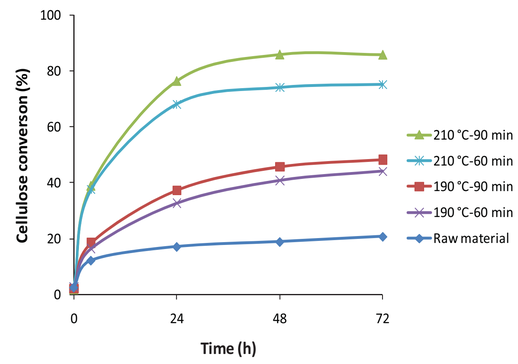
4. Enzymatic Digestibility

Enzymatic hydrolysis conditions:
- Accellerase 1500
- 20 FPU/gr dry substrate
- 3% w/v loading, pH 4.8, 50°C, 72 h

Clear improvement enzymatic digestibility by organosolv pretreatment.

Optimum enzymatic glucose yield :
Without acid: 86%.
- 210 °C, 50% w/w EtOH, 90 min.
- Delignification: 59%, xylan hydrolysis: 81%.

With acid: 89%.
- 190 °C, 60% w/w EtOH, 60 min, 30 mM H_2SO_4.
- Delignification: 76%, xylan hydrolysis: 95%.

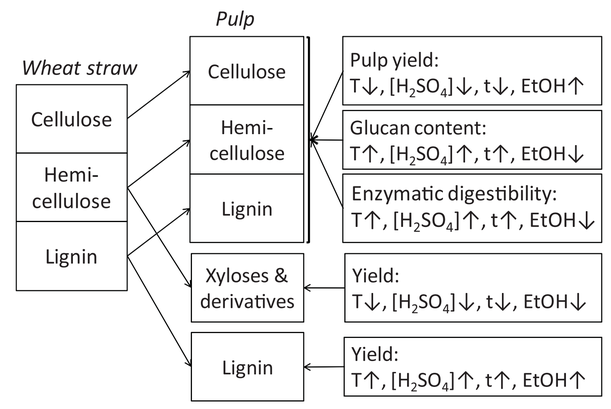


Enzymatic hydrolysis profiles of a selection of pretreated wheat straw samples (50% w/w EtOH, [H_2SO_4] = 0 M)

5. Process-Product Scheme

Effect process parameters within ranges tested:
- Temperature: 160 - 210 °C
- Time: 60 - 120 min
- EtOH:H_2O: 50 - 60% w/w
- [H_2SO_4]: 0 - 30 mM

Trade-off between lignin yield & enzymatic digestibility versus valorisation of hemicellulose:
- Fractionation improved by increased pretreatment severity, but severe loss of hemicellulose sugars.
- Formation of furfural and subsequently degradation to humins and lignin-condensation products).



Process-product relation scheme

6. Conclusions & Outlook

Conclusions:
- Organosolv is an effective fractionation and pretreatment technology for lignocellulosic biomass.
- Process-product scheme developed.
- Optimal conditions for enzymatic hydrolysis of wheat straw established.

Results other studies:
- Recycling organic solvent crucial for process feasibility.
- Lignin produced: promising characteristics, e.g. high purity, for non-CHP applications.
- 2G bio-ethanol process based on wheat straw organosolv economically feasible if lignin value >500 €/ton.

Current research within BIOCORE project:
- Application tests organosolv lignin.
- Process modifications to minimize xylose degradation.
- Development of continuous organosolv reactor.

More information on ECN organosolv research:

1. http://www.ecn.nl/units/bkm/biomass-and-coal/.
2. Huijgen WJJ, Smit AT, Reith JH, den Uil H (2011): Catalytic organosolv fractionation of willow wood and wheat straw as pretreatment for enzymatic cellulose hydrolysis, J. Chem. Tech. Biot. (in press).
3. Diaz MJ, Huijgen WJJ, van der Laan RR, Reith JH, Cara C, Castro E (2011): Organosolv pretreatment of olive tree biomass for fermentable sugars, Holzforschung 65, 177-183.
4. Huijgen WJJ, Reith JH, den Uil H (2010): Pretreatment and fractionation of wheat straw by an acetone-based organosolv process, Ind. Eng. Chem. Res. 49, 10132-10140.

References:

Wildschut J, Huijgen WJJ, Smit AT, Reith JH (2011): Ethanol-based organosolv fractionation of wheat straw: a systematic approach towards process product relations, in preparation.

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