CPERI Chemical Process and Energy Resources Institute

CERTH Centre for Research and Technology Hellas

Mild oxidative organosolv pretreatment of lignocelullosic biomass residues for high added value chemicals and food additives via fermentation processes

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Presentation Layout

1 Introduction – Purpose of the work

2 Experimental units and procedures

3 Experimental results

4 Conclusions

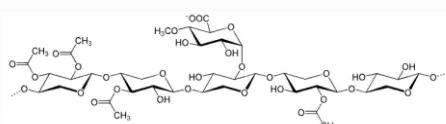
NoWasteBioTech Objectives


corn stover

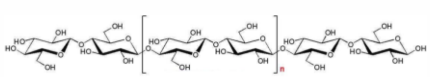
corn cob

Biomass

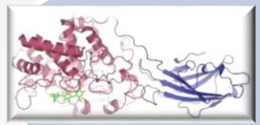
- solid **cellulose** pulp
- aqueous **hemicellulose** oligo-sugars solution



xylan structure



cellulose structure

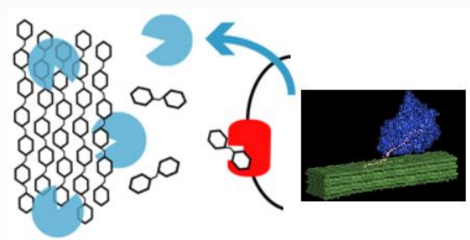


cellulase

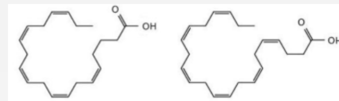
xylanase

Saccharification

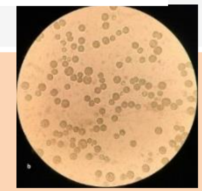
- **enzymatic production** of sugars
- **cellulases/hemice-llulases**



cellulose/hemicellulose hydrolysis



ω-3 fatty acids

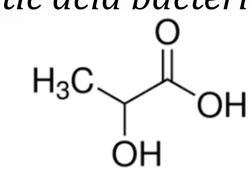



microalgae cells

Fermentation

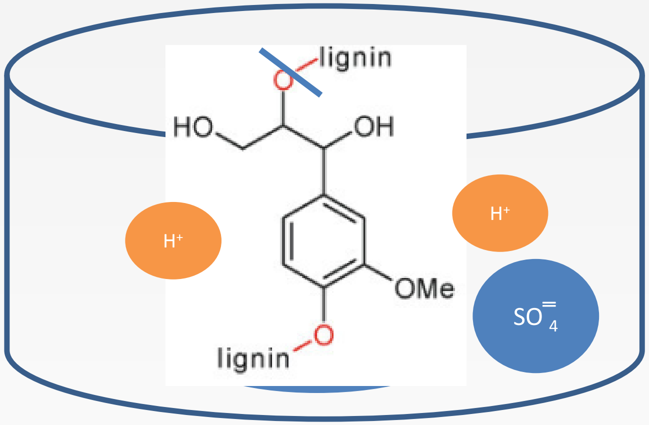
- **ω-3 fatty acids**
- **lactic acid**


lactic acid bacteria

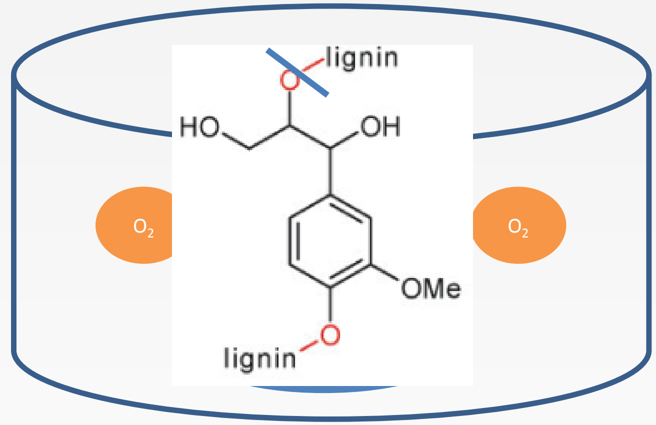


lactic acid

Acid Organosolv Delignification



Oxidative Organosolv Delignification

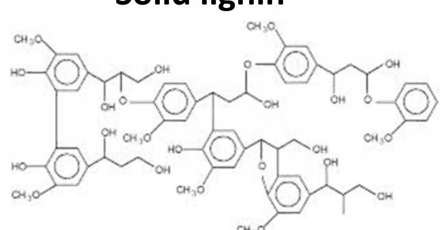


H_2O/Acetone/Lignin one phase liquid

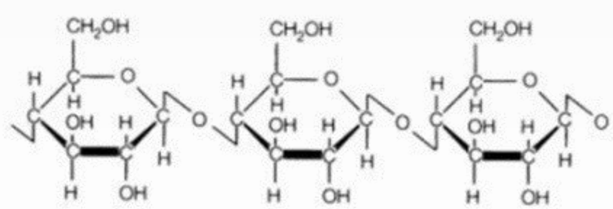
Vacuum distillation

Aqueous hemicellulose byproducts solution

Solid lignin



Solid delignified pulp



Experimental results – Main parameters

Biomass used was Lignocel HBS 150/500 which is a Beechwood sawdust

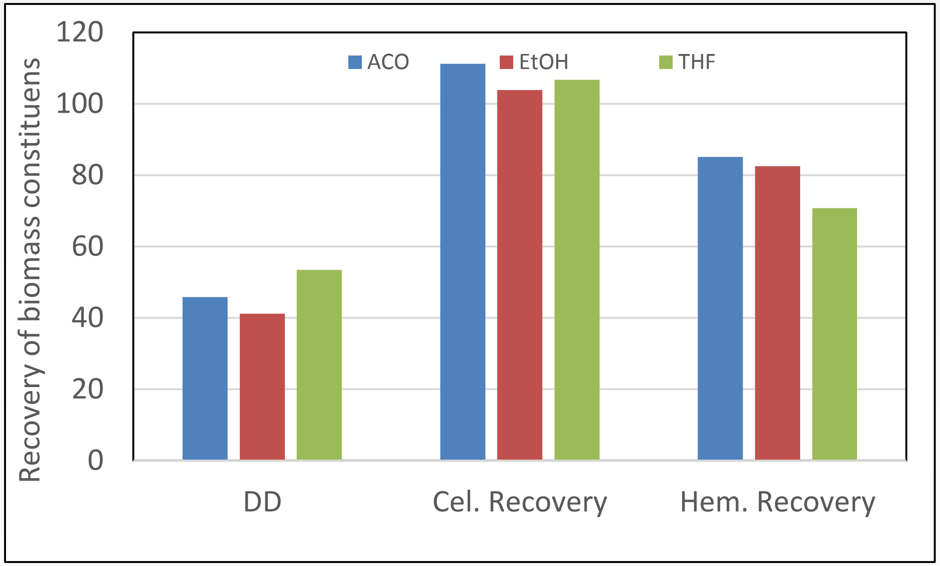
Extracts	A.I. Lignin	A.S. Lignin	Cellulose	Hemicellulose
3.7	21.7	2.5	47.6	21.2

Main Parameters

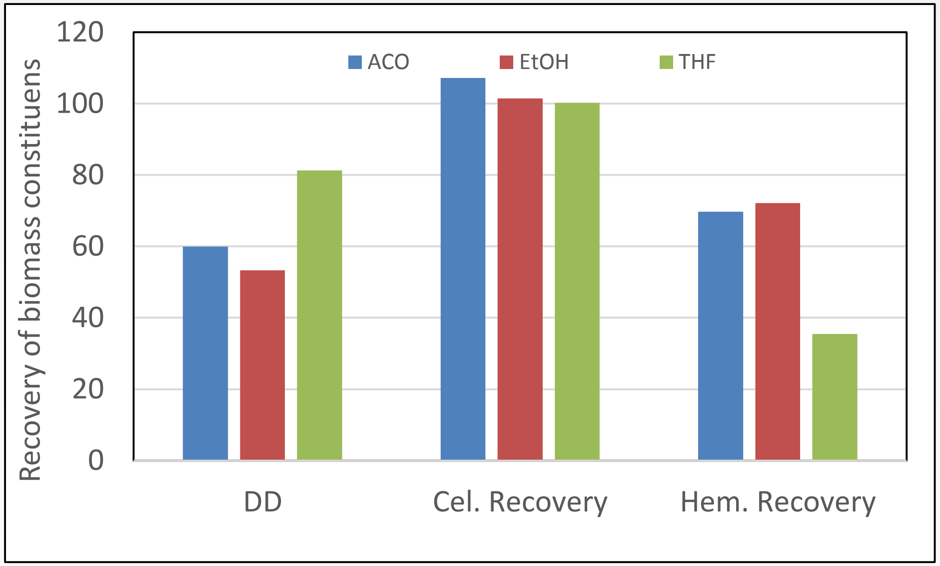
- Solvent
- Pressure
- Time
- Temperature

Solvent effect

❑ 60 min



❑ 120 min



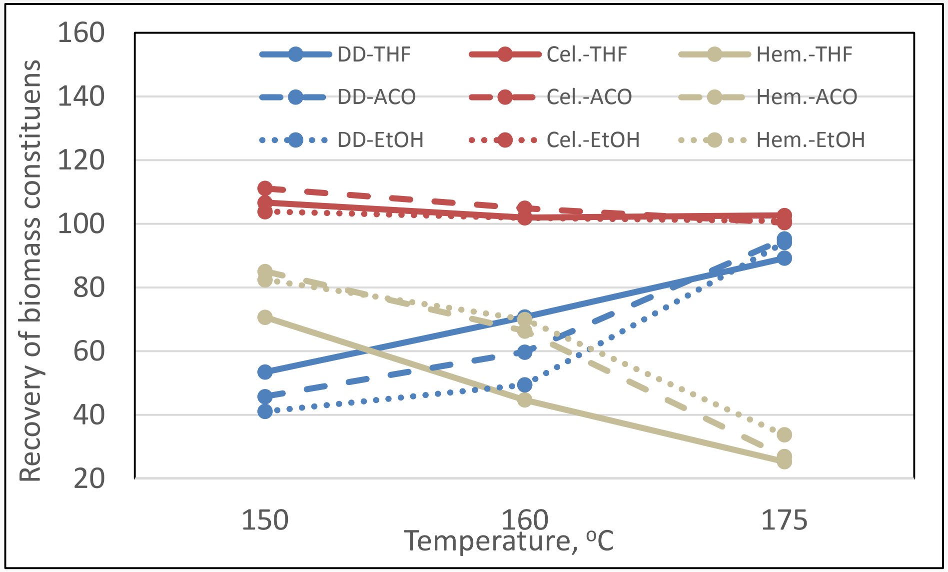
Main Parameters

- ❑ LSR=10
- ❑ Solvent wt.%=50
- ❑ 100% O_2 use
- ❑ T=150 °C

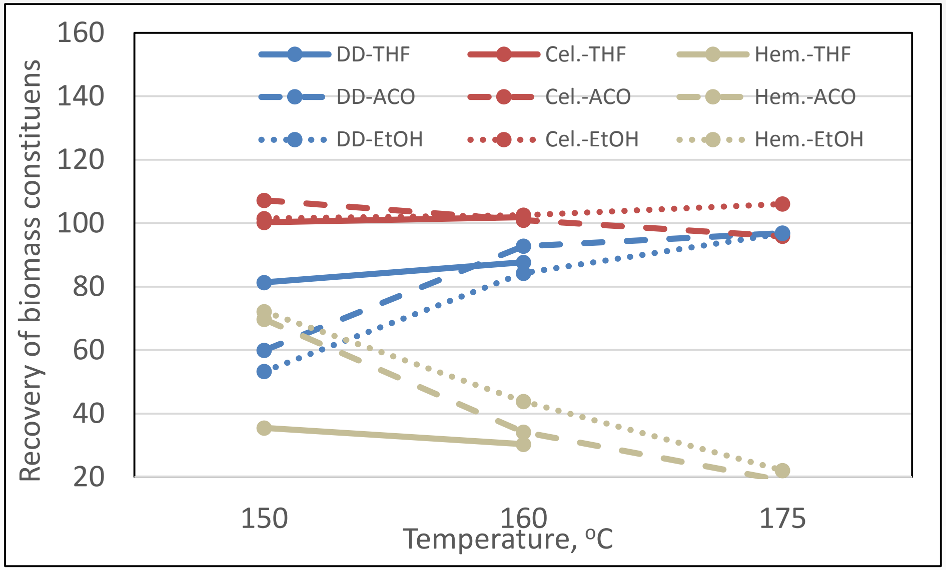
- Solvent effect is significant, Acetone and THF very efficient, EtOH does not achieve high DD at low T
- At higher reaction time, differences more pronounced
- Cellulose recovery excellent in all cases (100%)

Temperature effect

❑ t=60 min



❑ t=120 min



Main Parameters

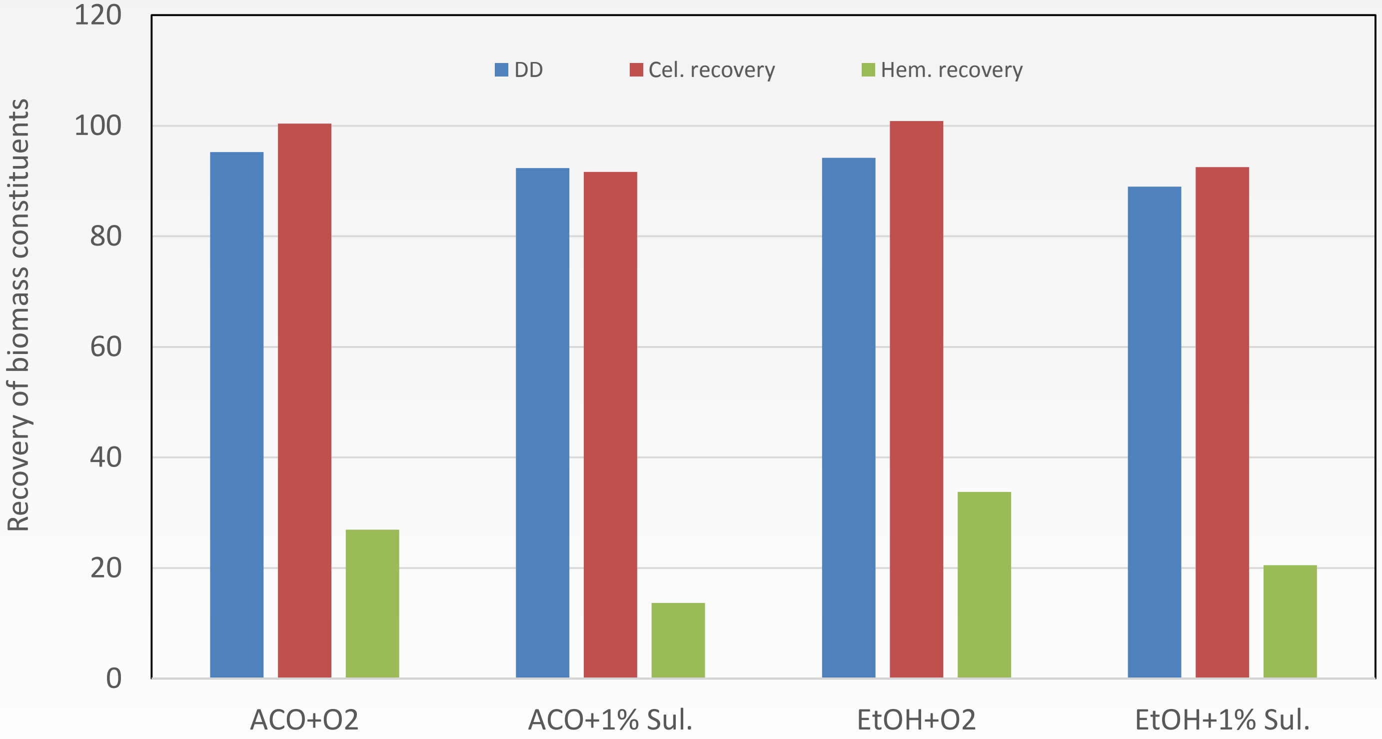
❑ LSR=10

❑ 100% O_2 use

❑ t=60, 120 min

- Temperature has significant effect, especially at reaction time of 60 min
- 25 °C increase resulted in doubling of DD (~46 → 95 %) at 60 min
- At 120 min even a 10 °C increase is enough to increase DD from 60 to 92%
- Cellulose recovery at 100% regardless of T

Acidic vs Oxidative Organosolv Delignification



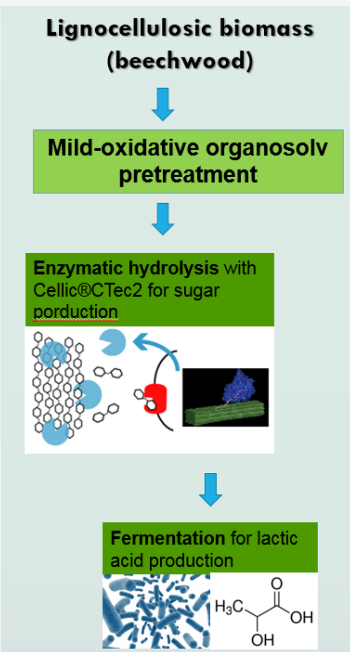
Main Parameters

- LSR=10
- Solvent wt.%=50
- T=175 °C
- t=60 min

- Use of O_2 instead of acids enhances delignification, up to 95% of lignin removed
- Cellulose recovery at 100% under O_2 delignification as opposed to ~92% under acidic delignification
- Hemicellulose recovery in pulp also increased with O_2 delignification due to less severe pretreatment

Fermentation to lactic acid

Simultaneous saccharification and fermentation (SSF) of ***cellulose-rich biomass fractions*** (>65% w/w cellulose) by *Lactobacillus debruenckii sp. bulgaricus*, following pretreatment



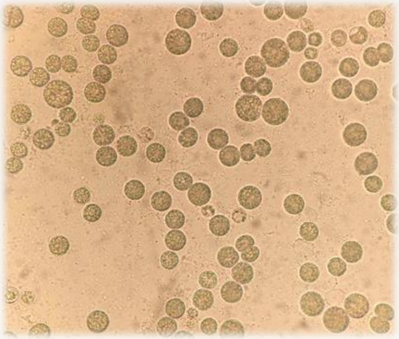
Biomass pretreatment	Cellulose %	Hemicellulose %	Lactic acid (g/lt)	mg lactic acid/ g biomass	% theoretical yield
H_2O/ACO (50/50%), O_2 8 bar, 160°C, 120min	66.77	18,36	77.11	756	79.60 ± 8.16
H_2O/ACO (50/50%), O_2 16 bar, 160°C, 120min	76.63	13.32	61.07	678	67.67 ± 2.32
H_2O/ACO (50/50%), O_2 8 bar, 175°C, 120min	82.3	13.9	50.5	561	52.36 ± 1.01
H_2O/ACO (50/50%), O_2 16 bar, 175°C, 30min	79.74	15.69	64.56	717	67.43 ± 2.87
H_2O/EtOH (50/50%), O_2 16 bar, 160°C, 120min	72.96	16.03	52.5	583	58.72 ± 4.98
H_2O/EtOH (50/50%), O_2 16 bar, 175°C, 60min	81.28	13.99	67.1	745	70.21 ± 0.91
H_2O/THF (50/50%), O_2 16 bar, 150°C, 120min	73.09	13.3	78.93	837	86.97 ± 6.7
H_2O/ THF (50/50%), O_2 16 bar, 160°C, 120min	79.13	12.1	85.7	912	89.78 ± 10.1
H_2O/THF (50/50%), O_2 16 bar, 160°C, 60min	68.99	15.55	72.96	785	83.29 ± 1.14
H_2O/ THF (50/50%), O_2 16 bar, 175°C, 60min	85.28	10.82	53.23	591	55.25 ± 0.42

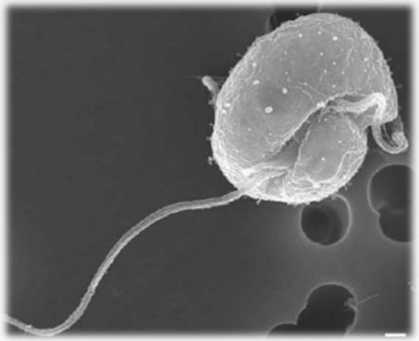
the most efficient in producing lactic acid with high yields that reach up to **0.91 g lactic acid /g biomass** after 168 h of fermentation, at 9% initial DM.

Production of omega-3 fatty acids

Separate hydrolysis and fermentation (SHF) of ***cellulose-rich biomass fractions*** (>65% w/w cellulose) by *Crypthecodenium cohnii*, following pretreatment and enzymatic saccharification

Fatty acid composition
C14
C16
C18:0
C18:1
C22:0 (DHA)





The microalgae is capable of utilizing biomass sugars to grow and accumulate fatty acids.

Biomass pretreatment	Biomass (g/L)	Fatty acids (g/L)	Total fatty acids (% dry cell weight)	DHA (g/L)	DHA (% of total fatty acids)
THF/H_2O (50/50), 160°C, 16 bar, 60 min	8.39 ± 0.09	1.05 ± 0.15	17.6 ± 2.1	0.47 ± 0.12	45.1 ± 2.8
EtOH/H_2O (50/50), 160°C, 16 bar, 120 min	7.31 ± 0.29	0.65 ± 0.02	17.4 ± 3.2	0.36 ± 0.02	56.17 ± 1.9
ACO/H_2O (50/50), 160°C, 8 bar, 120 min	9.03 ± 0.03	1.41 ± 0.08	14.4 ± 0.9	0.66 ± 0.04	46.74 ± 1.5

Conclusions

Oxidative organosolv delignification

- Use of O_2 instead of acids poses some advantages such as minimization of acidic wastes that require treatment, no need for corrosion resistant equipment.
- Oxidative delignification was very efficient at removing lignin (>95% DD).
- Cellulose recovery in solid form at 100%.
- Parameters effect is intertwined. Overall increase in temperature, O_2 pressure, time results in higher DD.
- Different solvents (acetone, ethanol, THF) efficient under different conditions.
- THF was very efficient at low T (150 ^oC), acetone was more efficient as T increased while ethanol needed higher T to perform well.
- Produced pulps successfully fed to microalgae and LA bacteria producing FA and LA.
- 0.91 g lactic acid/g biomass, >80g/lt lactic acid concentration, efficient production.
- >50% DHA in fatty acids produced by microalgae.

Thank you for your attention!

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http://nowastebiotech.cperi.certh.gr/

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