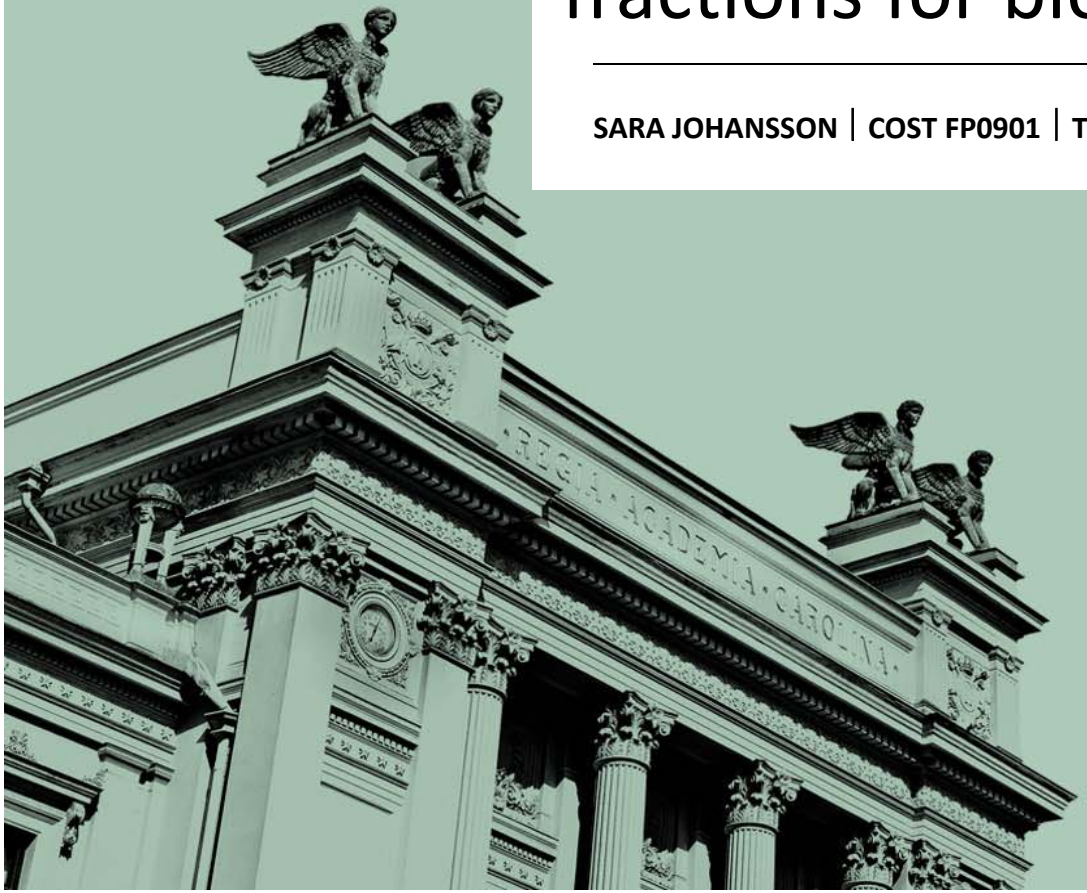
# Characterization of tree and wood fractions for biorefinery applications

**SARA JOHANSSON | COST FP0901 | TURKU SEPTEMBER 18, 2013**



# To characterize differences in *raw material composition* and *processability* of well-defined tree and wood fractions


SLU
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences
Institutionen för skogliga biomaterial och teknologi

**Department of Forest Biomaterials and Technology**

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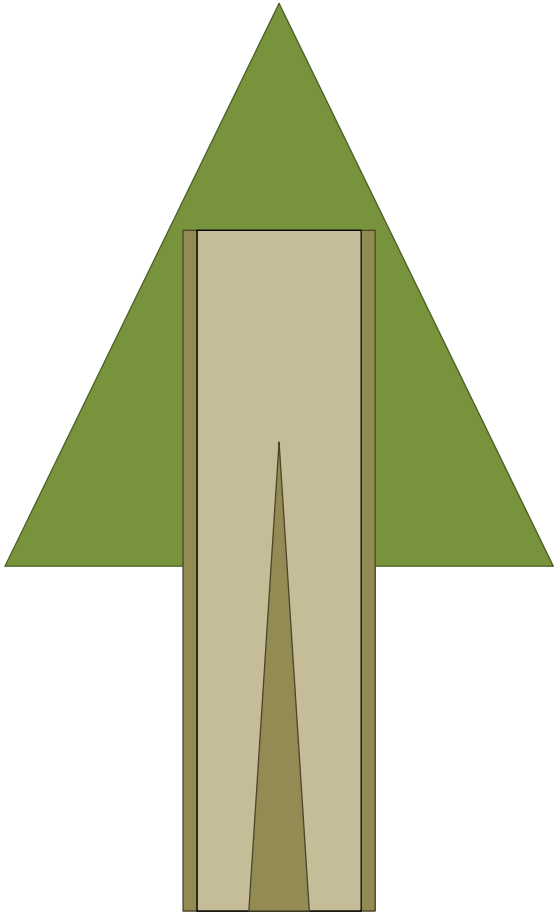
Lunds Tekniska Högskola

**Department of Chemical Engineering**

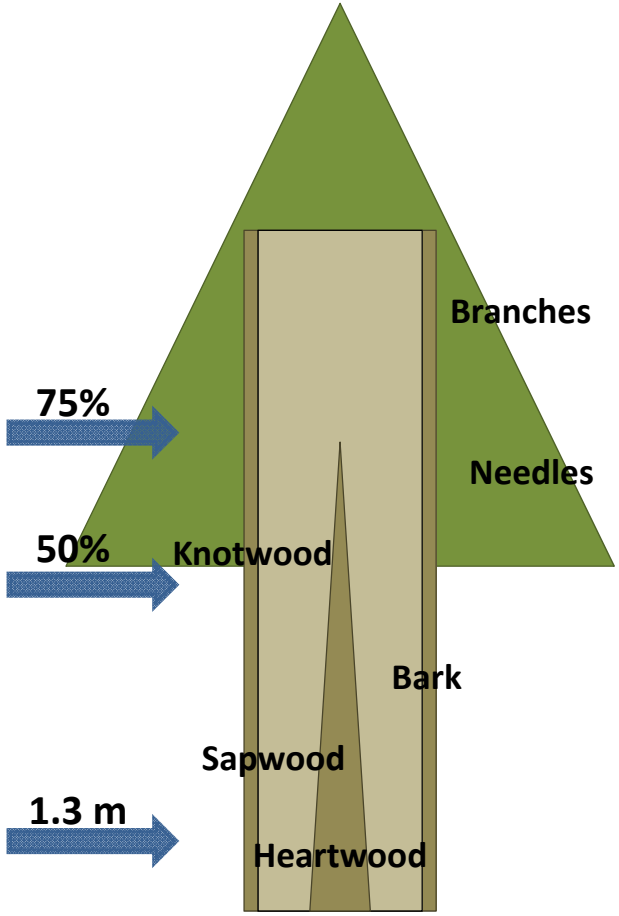
# 2 trees from SLU field trials



Scots pine
(*Pinus sylvestris*)

- Tree 1
  - From clearcut stand
  - Dense population in youth
  - Slow growth
- Tree 5
  - From thinned stand
  - Extremely sparse population in youth
  - Fast growth

# Each tree divided into 9 fractions




- Needles
- Branches
- Sapwood
  - 1.3 m, 50%, 75%
- Heartwood
  - 1.3 m, 50%
- Knotwood
- Bark

# Objectives of the work in Lund

- **Raw material analysis**
  - Moisture and ash content
  - Total extractives content
  - Structural carbohydrates and lignin

- **Pretreatment**
  - Solid fraction
    - Carbohydrates and lignin
  - Liquid fraction
    - Mono and oligosacharides
    - Furans and acetic acid
  - Yields and recoveries

- **Enzymatic hydrolysis**
  - Carbohydrates and lignin
  - Overall glucose yield

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# Raw material

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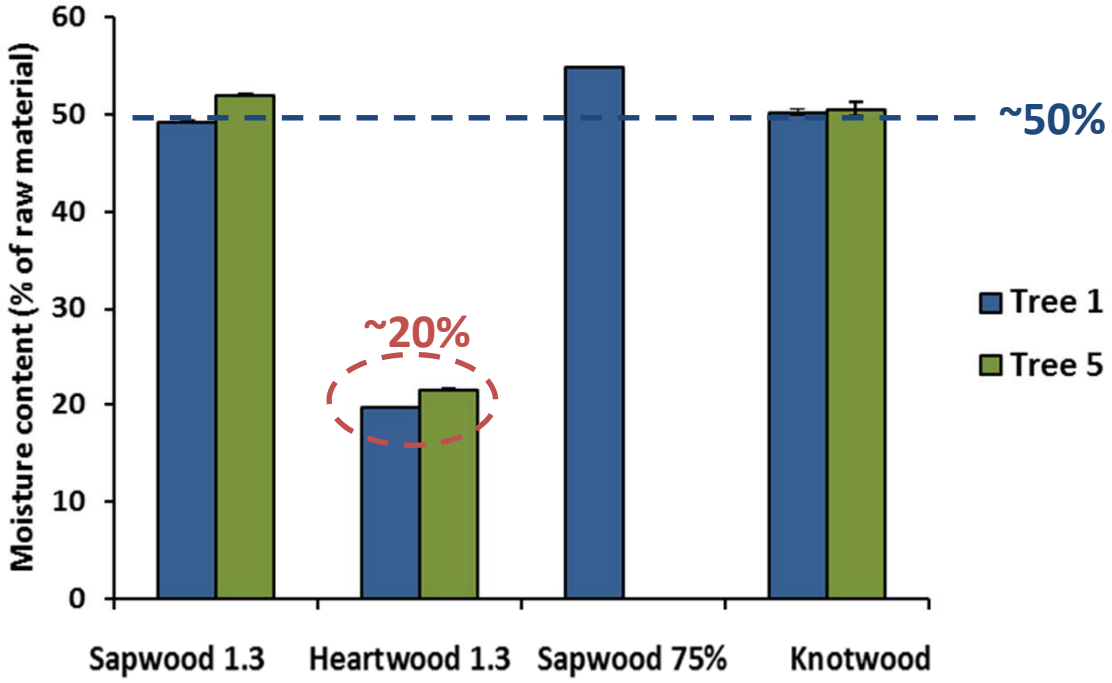
# Moisture content



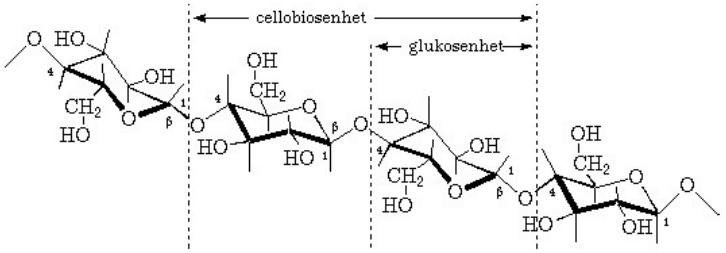

**Heartwood is considerably drier than other fractions**

# The composition of pine

**Percent dry weight composition**

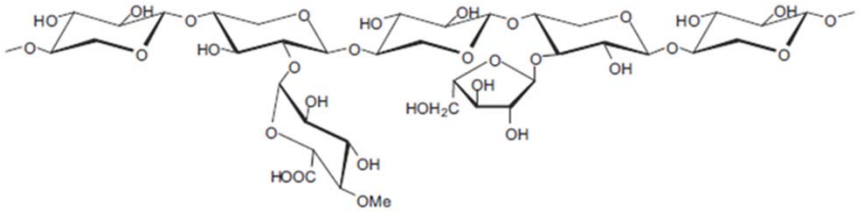
| Glucan | Mannan | Xylan | Lignin |
|---|---|---|---|
| 46 | 12 | 9 | 30 |

*Handbook on Bioethanol*, ed. Wyman C.E.

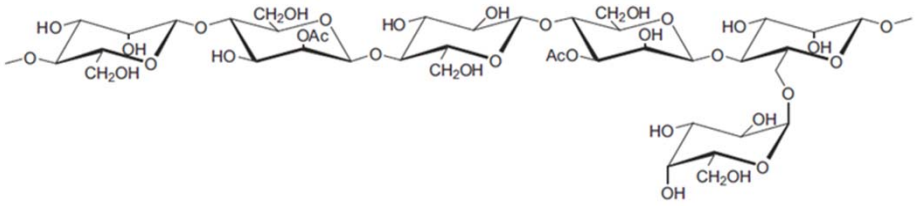


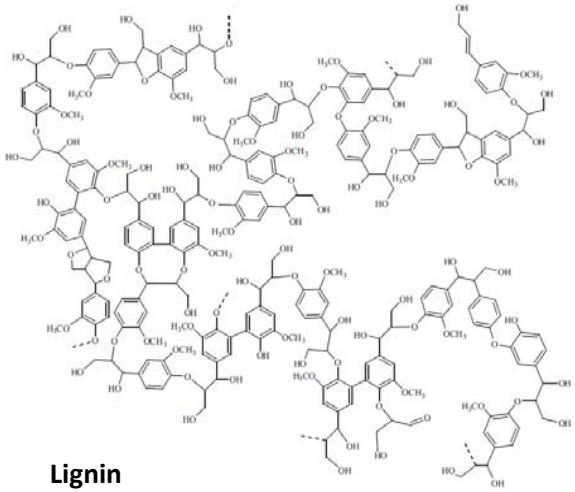

**Cellulose**

**Arabinoglucuronoxylan**



**Galactoglucomannan**



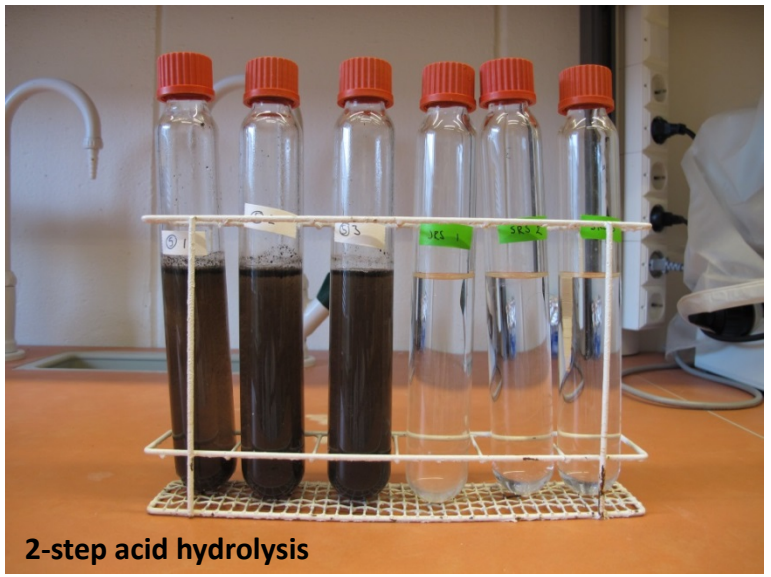


**Lignin**

*Pulp and Paper Chemistry and Technology*, ed. Ek, Gellerstedt, Henriksson

# Raw material analysis

- 2-step acid hydrolysis
  - strong acid
    - 30°C, 60 min
  - dilute acid
    - 120°C, 60 min
- Klason and acid soluble lignin
- HPLC used for sugar analysis

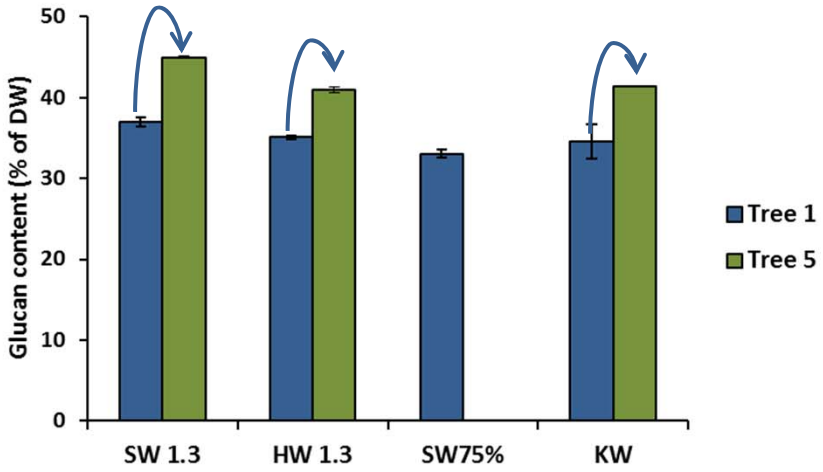


2-step acid hydrolysis

Milled and dried raw material

# Carbohydrates

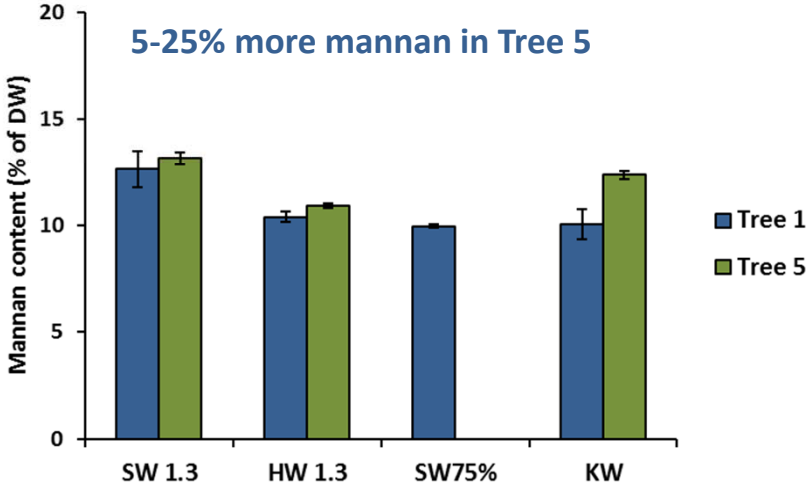
~20% more glucan in Tree 5



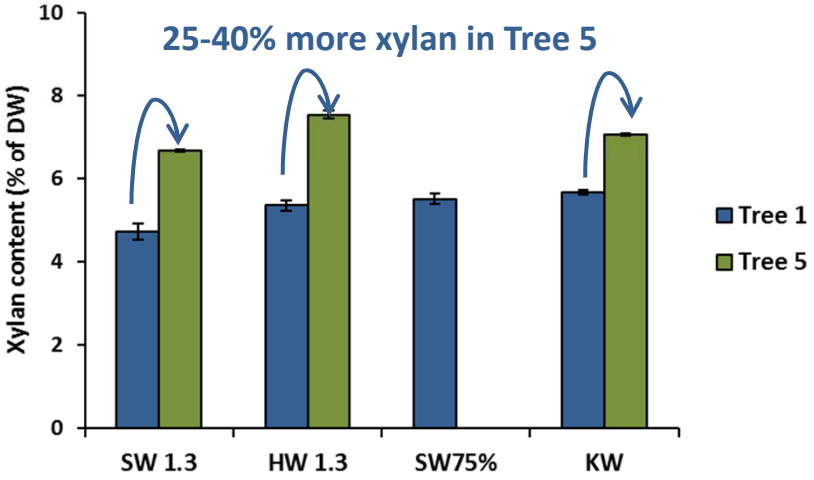

**Bigger difference between the trees than within the trees (glu and xyl)**

10-25% difference within the trees

5-25% more mannan in Tree 5




25-40% more xylan in Tree 5



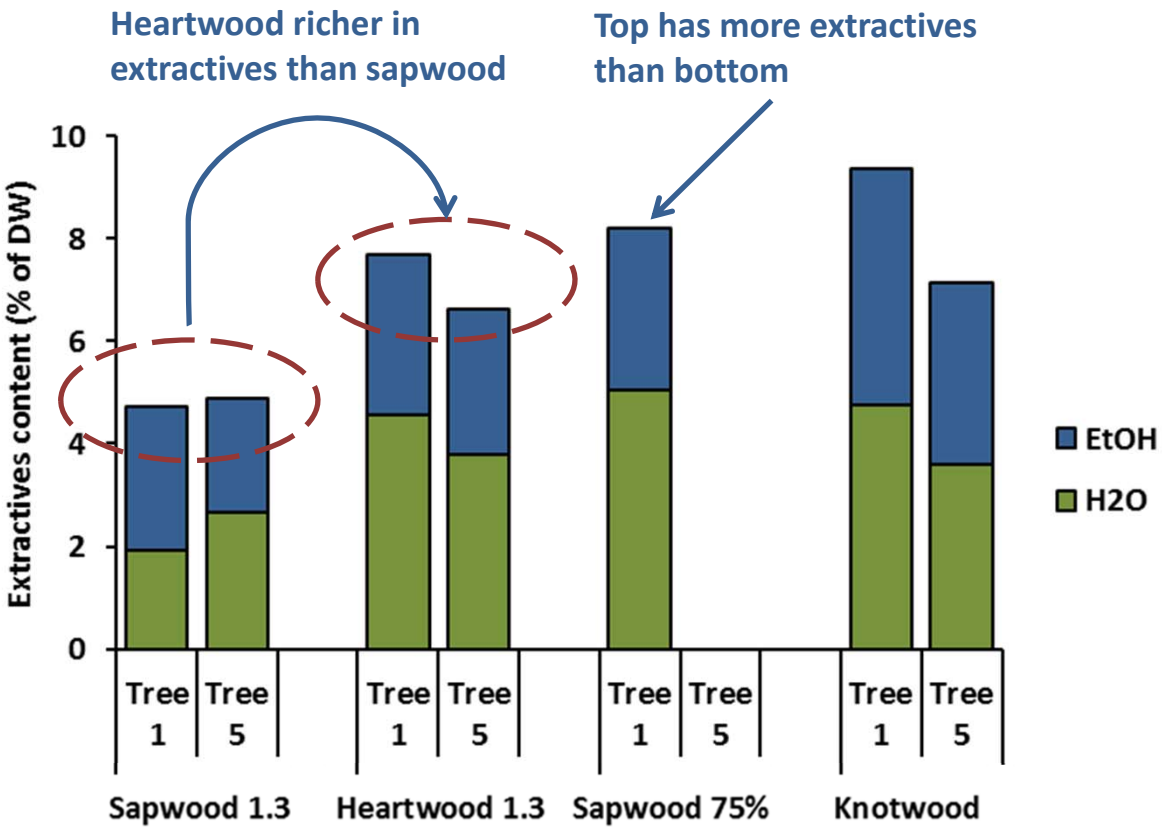
# Lignin content

**The faster grown tree (5) has a sligthly higher lignin content than the slower grown tree**

# Extraction

- Soxhlet extraction
  - Water
  - Ethanol
- Extraction before raw material analysis
  - To assess extractives content
  - Extractives may disturb results

# Extractives




**Hydrophilic**

- Salts
- Sugars
- Lignans
- Fenols
  - fungicides

**Hydrophobic**

- Fats and fatty acids
- Waxes
- Terpenes
  - ”pine smell”

# Summary
# Raw material

- The faster grown tree richer in carbohydrates than the slower grown tree
- Heartwood richer in extractives than sapwood
- Top has more extractives than bottom (of the trunk)

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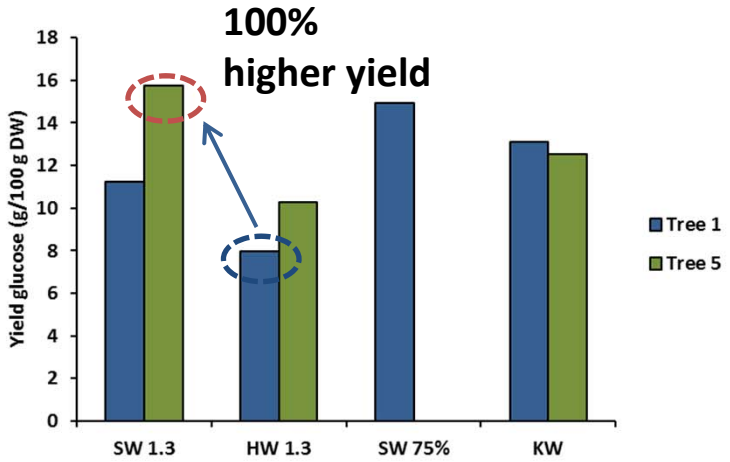
# Pretreatment


**Steam pretreatment**

- 2.5% $SO_2$ (based on moisture content)
- 210°C
- 5 minutes

# Yields of mono and oligosacharides after pretreatment

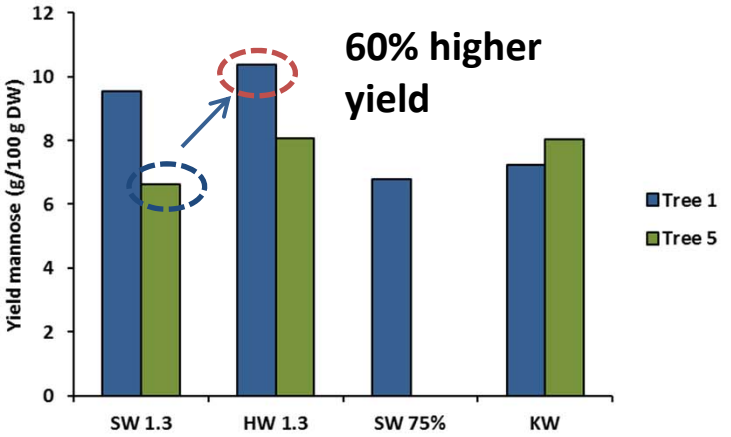


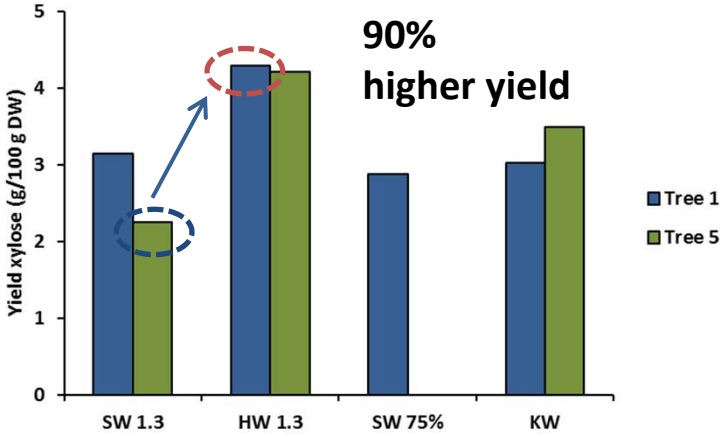

**Sapwood 1.3 m Tree 5 (fast growth)**

- Highest glucose yield
- Lowest mannose and xylose yields

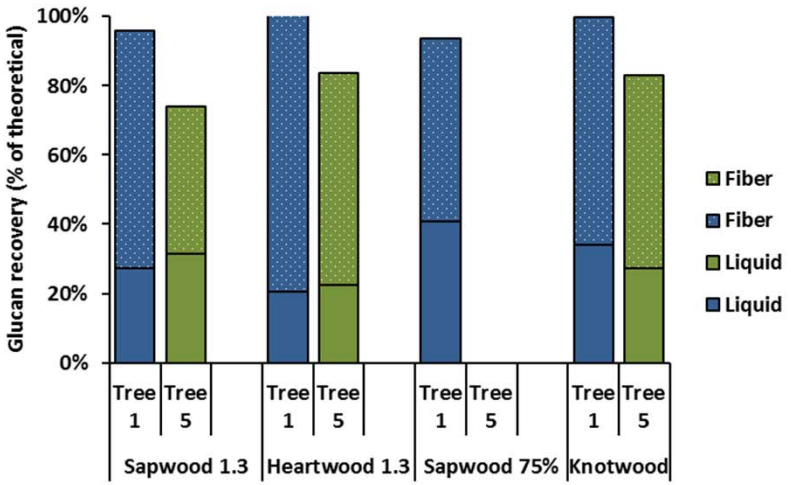
**Heartwood 1.3 m Tree 1 (slow growth)**

- Lowest glucose yield
- Highest mannose and xylose yields



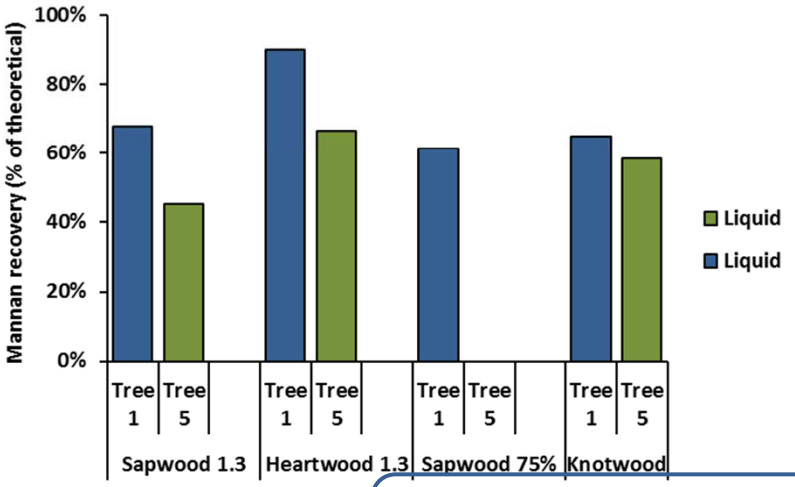



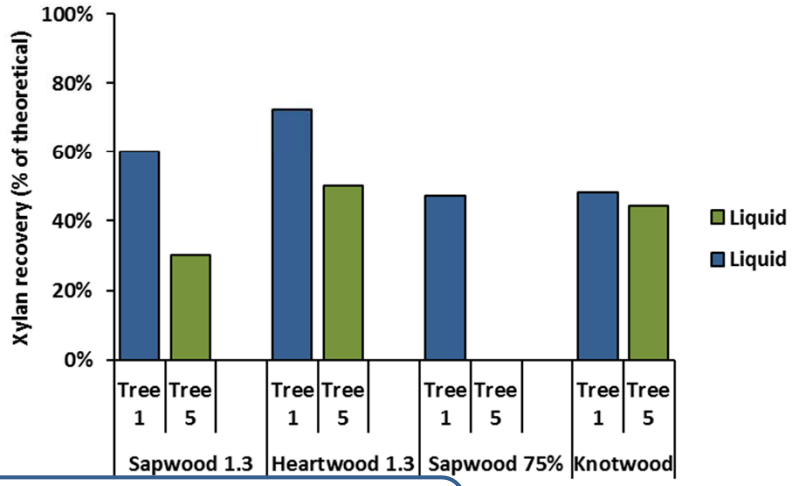
# Recovery of carbohydrates after pretreatment




Less sugars recovered from the faster grown tree
-> pretreatment acted more severely

Hemicellulose more easily hydrolyzed than cellulose
-> lower recoveries of mannan and xylan compared to glucan




Heartwood has somewhat higher recoveries of hemicellulose than other fractions

# Hydrolysis of lignocellulose

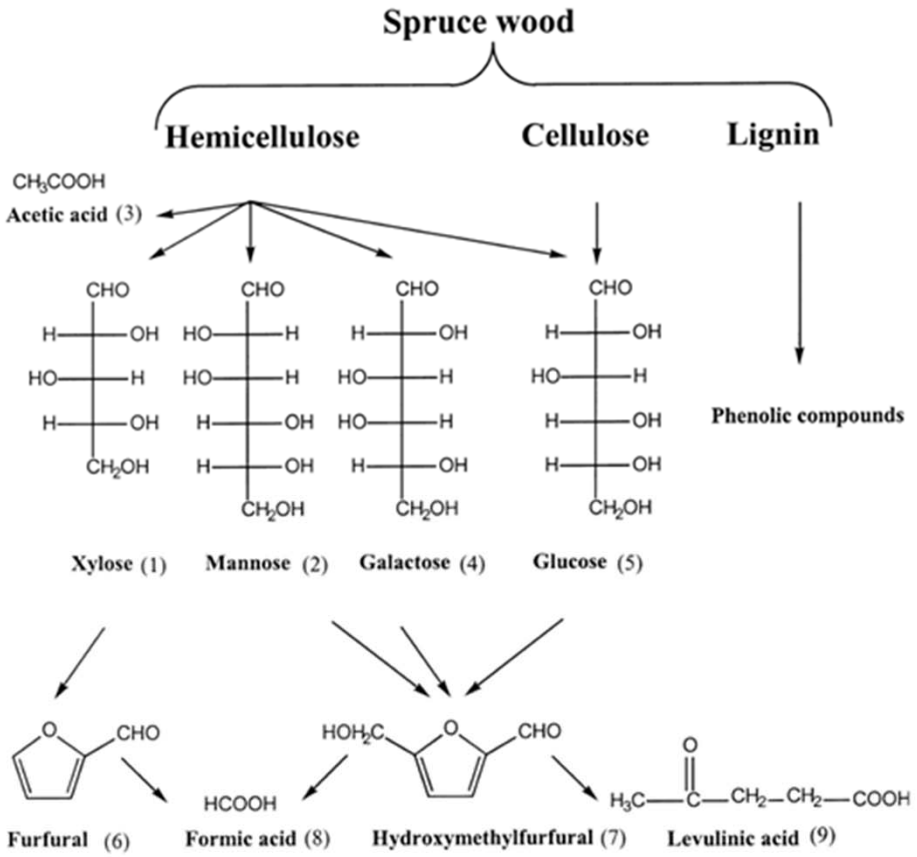
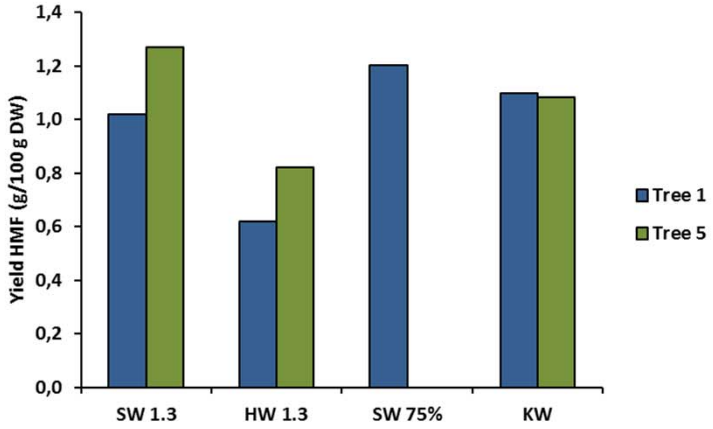
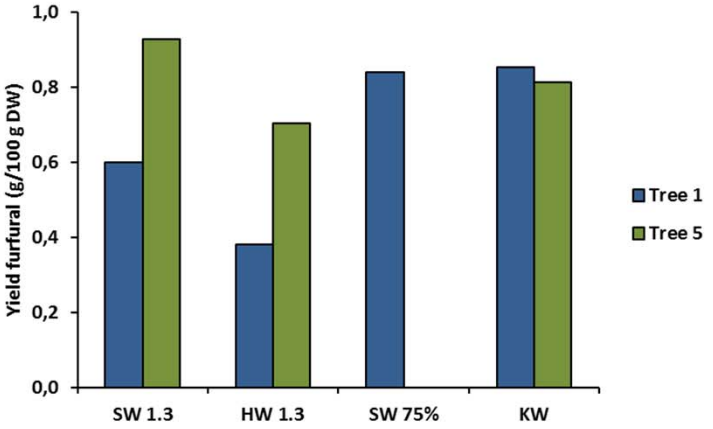


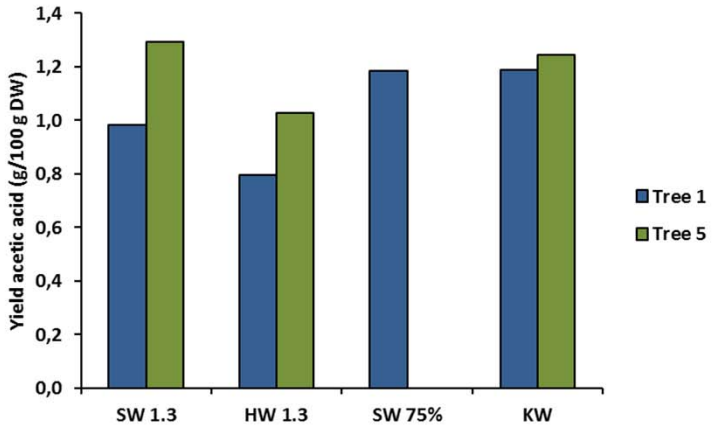

Fig. 1. Reactions occuring during hydrolysis of lignocellulosic materials. The furan derivatives and phenolic compounds will react further to form some polymeric material.

Palmqvist, E.; Hahn-Hägerdal, B., 1999

# Yields of furans and acetic acid after pretreatment




**The faster grown tree yielded more furans and acetic acid from sapwood and heartwood fractions**

**Knotwood had similar yields for both trees**

**Heartwood had lower yields than other fractions**

# Summary Pretreatment

- **All hemicellulose solubilized at the conditions used**
  - Glucan was recovered in fiber as well as in liquid fraction of the pretreated slurry
  - Mannan and xylan only recovered in the liquid fraction
- **The pretreatment acted harsher on the faster grown tree**
  - Lower carbohydrate recoveries than the slow grown tree
  - Higher yields of furans from sapwood and heartwood
    - knotwood had similar yields from the two trees
  - Lower WIS content than the slower grown tree
- **Heartwood withstood the pretreatment better than other fractions**
  - Higher recoveries of carbohydates
  - Lower yields of furans

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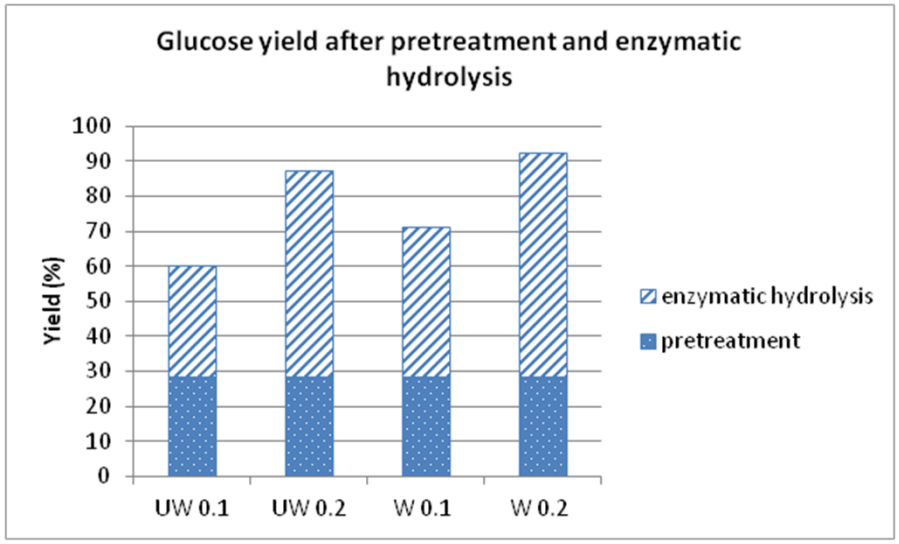
# Enzymatic hydrolysis




| | Conv. E.H (%)[1] | Overall yield (%)[2] |
|---|---|---|
| **UW 0.1** | 40 | 60 |
| **UW 0.2** | 76 | 87 |
| **W 0.1** | 56 | 71 |
| **W 0.2** | 86 | 92 |

[1] Final conversion, based on glucan content in pretreated material

[2] Overall glucose yield after pretreatment and enzymatic hydrolysis, based on glucan content in the raw material

- Sapwood (1.3 m) from slowgrown tree
- Washed and unwashed material
- 2 different enzyme dosages
  - 10 FPU/g WIS
  - 20 FPU/g WIS

# Outlook

- Pretreatments at different conditions
  - optimization
- Enzymatic hydrolysis of more pretreated material

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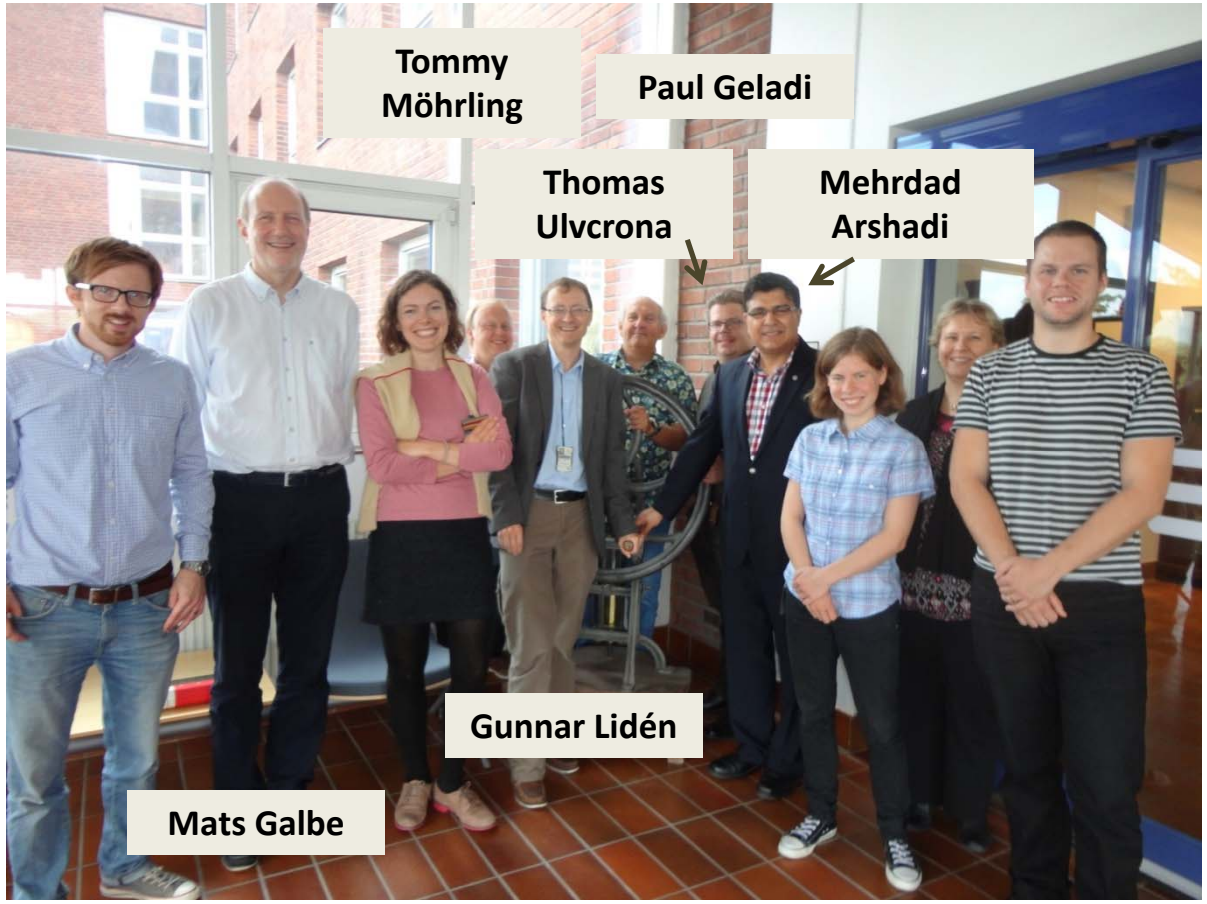


***Thank you for your attention!***

**This work was financed by a grant from the Bo Rydin foundation**

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