Timber residue as a source for hemicellulose process chemicals

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UK timber production

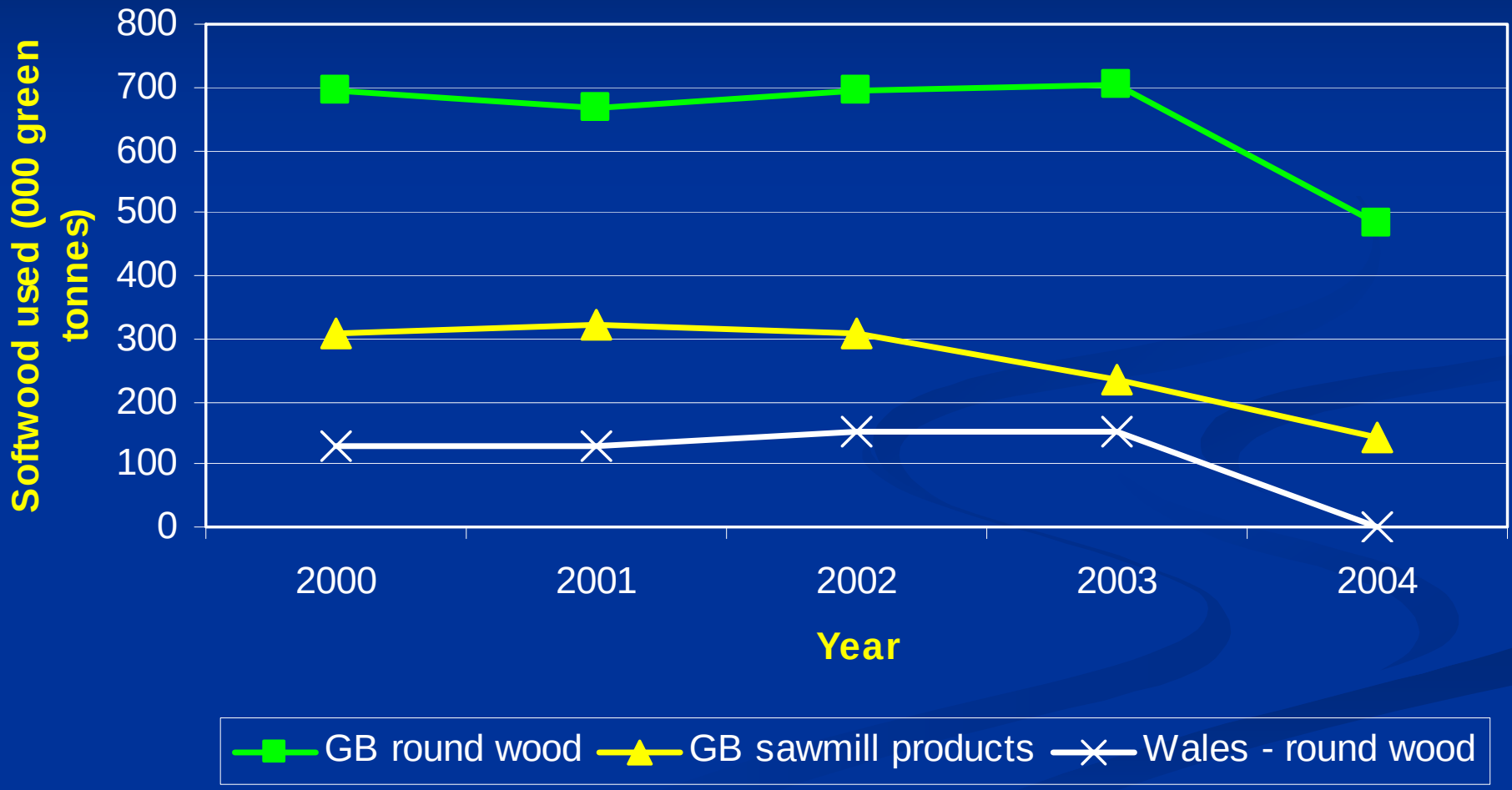
- 2,377,000 hectares in GB
- 1,406,000 hectares of softwood
  - A large proportion is Sitka spruce (*Picea sitchensis*)

Region	Sitka spruce as percentage of total softwood
Great Britain	49%
England	23%
Scotland	57%
Wales	56%

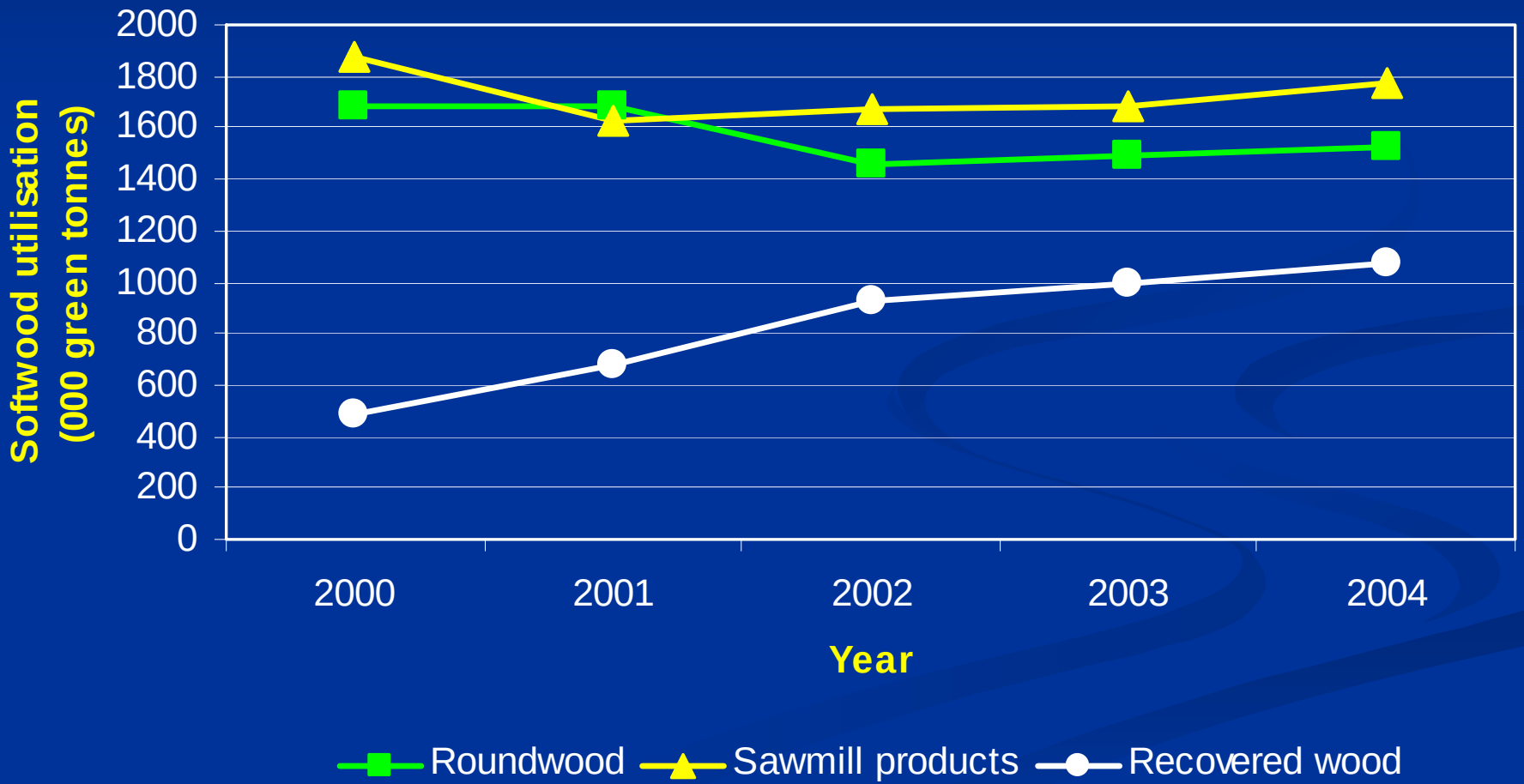
Sitka spruce

- Not heavily used in construction
  - Poor durability
  - Poor dimensional stability
  - Difficult preservative treatments
- Main use is paper and composite production
  - Declining use with conversion to use of recycled fibre/recovered wood.

Use of softwood by the UK pulp and paper industry



Wood utilisation in wood based panel production



Alternative markets?

- Biomass fuel
  - Currently only 2% of UK softwood is sold for energy production
- Silvichemicals
  - Chemicals derived from trees and timber

Silvichemicals

- Timber is a sustainable source for chemicals
  - Cellulose
  - Extractives
  - Degradation products
    - monosaccharides
    - pyrolysis products
    - technical lignin
  - Hemicellulose?

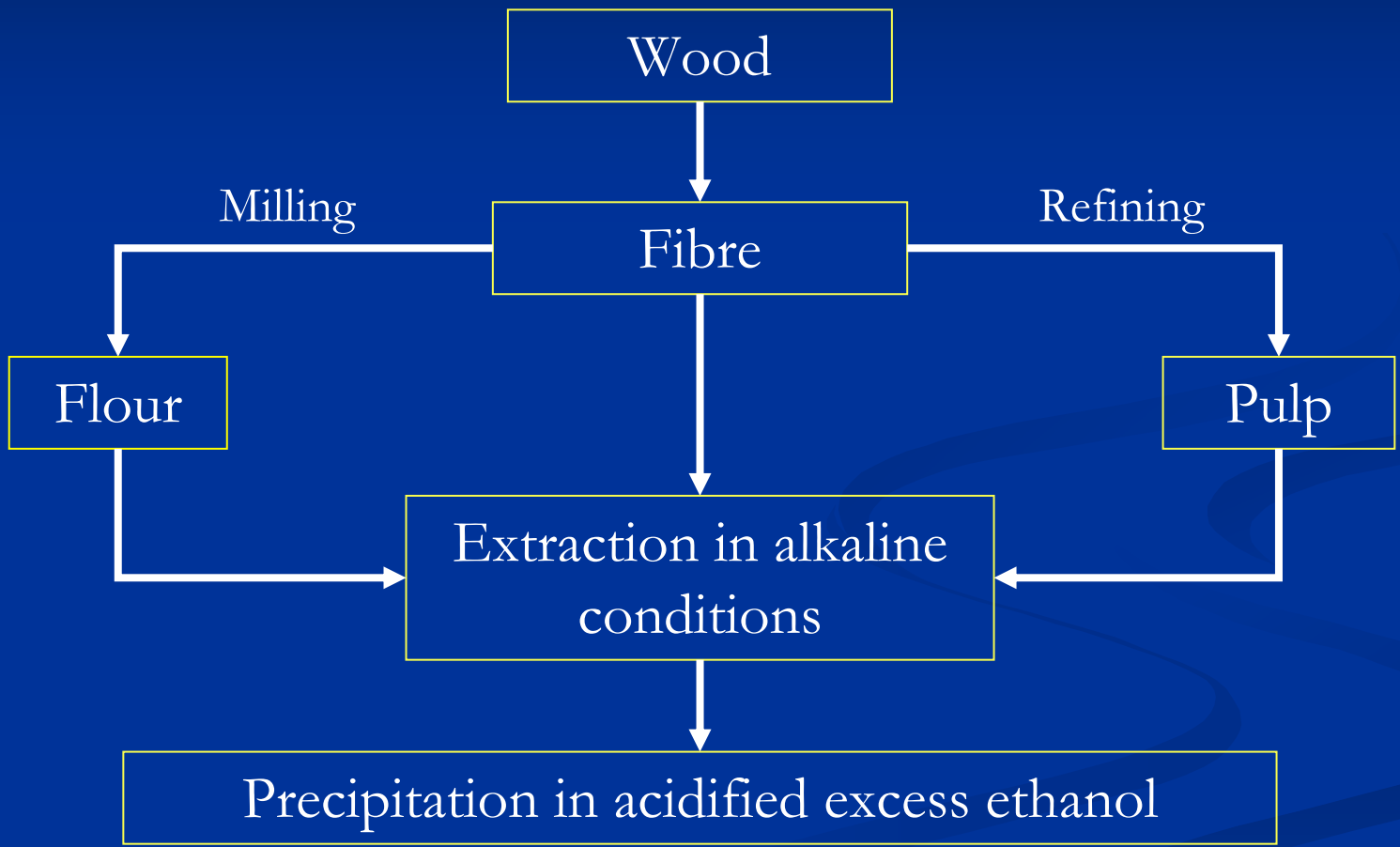
Hemicellulose

- Economic viability dependent on extraction of material with high intrinsic value
- Good environmental credentials will increase intrinsic value
- Utilisation
  - adhesives
  - food industry
  - pharmaceutical industries

Hemicellulose extraction

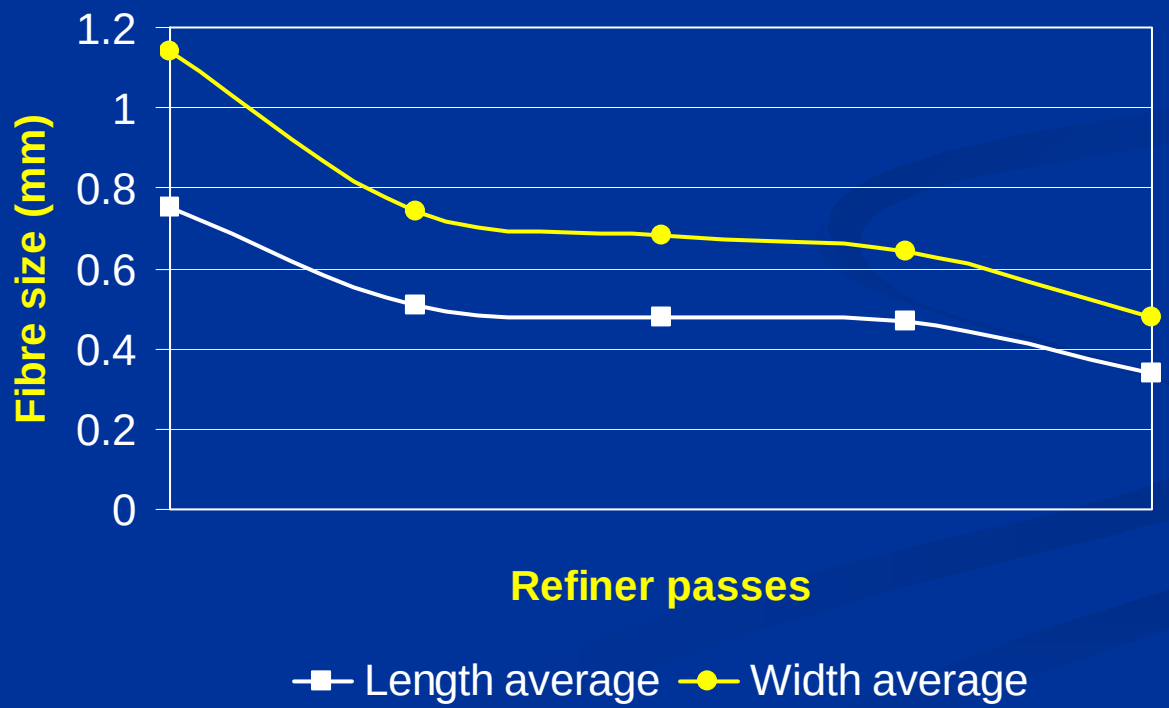
- For efficient hemicellulose extraction removal of lignin is required
  - Chemical
    - High environmental impact
  - Mechanical
    - Refining
    - Microwave
    - Ultrasound

General extraction procedure



Refining

- Atmospheric refiner used to produce pulp
  - Water throughput reduces thermal damage
  - Fibre size reduced by at least 50%



Microwave extraction

- Found to be ineffective
  - Very low yields in comparison to refining
- High energy consumption
  - unlikely to be economically viable

Extraction

- Mild alkaline conditions to reduce environmental impact
- Variables
  - Alkali concentration
  - Delignification with hydrogen peroxide
  - Addition of Borate
  - Temperature
  - Form of substrate (Fibre, flour or pulp)

Analysis of hemicellulose

- Hemicelluloses were analysed on basis of monosaccharide composition
  - Acid hydrolysis of gel form
  - High performance anion exchange chromatography with pulsed amperometric detection (HPAEC – PAD)

Results

- **Alkali concentration**
  - Increased concentration increases yield
  - Slight improvement in yield using potassium hydroxide rather than sodium hydroxide

- Delignification with hydrogen peroxide
- Temperature
- Addition of Borate
- Form of substrate (Fibre, flour or pulp)

Results

- Alkali concentration

- **Delignification with hydrogen peroxide**
  - Increases “purity” of yield

- Temperature
- Addition of Borate
- Form of substrate (Fibre, flour or pulp)

Results

- Alkali concentration
- Delignification with hydrogen peroxide

- **Temperature**
  - Increases yield

- Addition of Borate
- Form of substrate (Fibre, flour or pulp)

Hemicellulose yield dependent on preparation method

	Standard analytical method	24% NaOH +borate	24% KOH + borate	24% KOH + borate 60°C	24% KOH + borate +H_2O_2 60°C
Ppt yield (mg/g drywt)	466	460	435	410	200
Hemi-cellulose content of ppt	27%	15%	18%	20%	58%
Actual yield of hemicellulose (mg/g drywt)	125	70	78	82	116

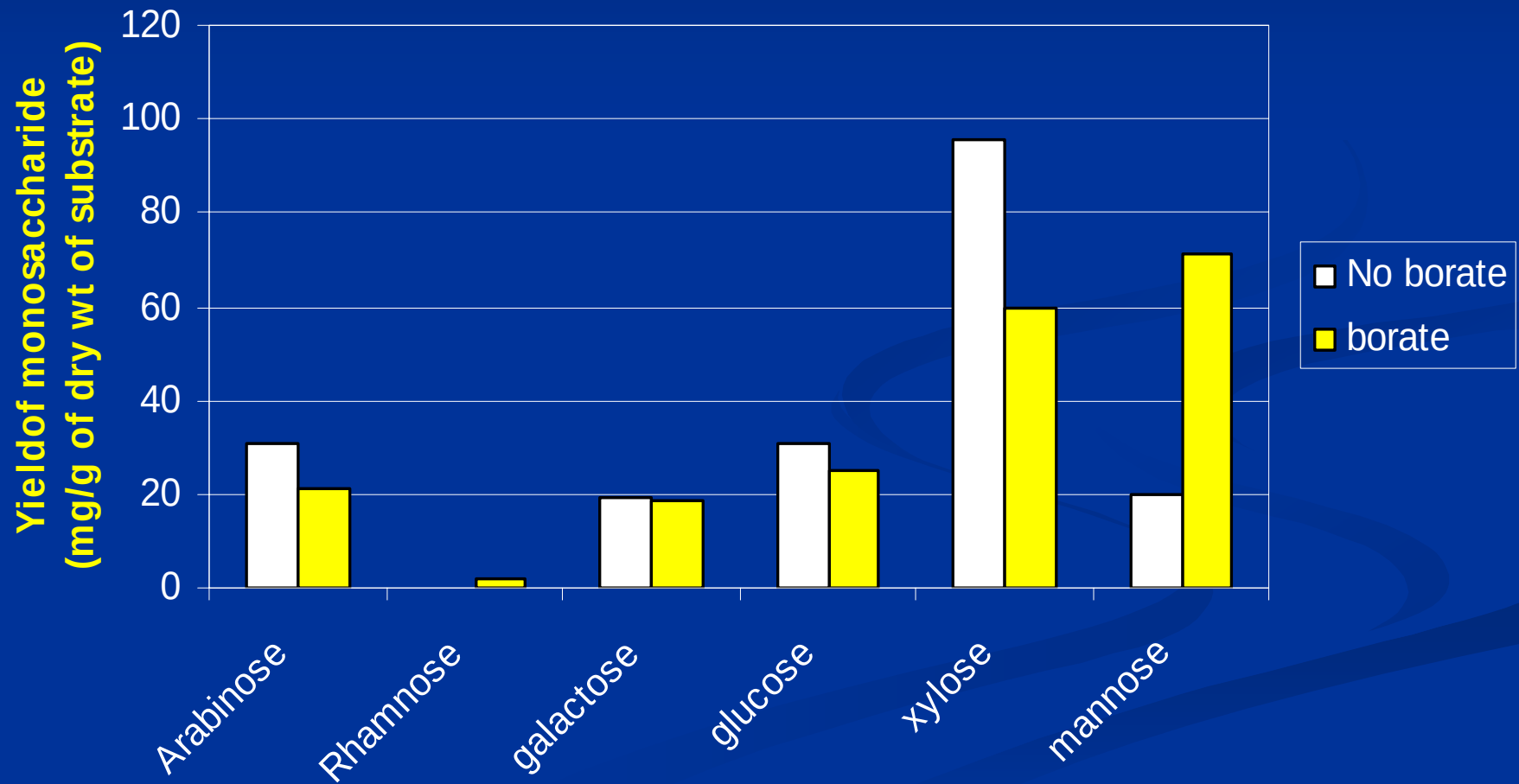
Results

- Alkali concentration
- Delignification with hydrogen peroxide
- Temperature

- **Addition of Borate**
  - Increases extraction of mannans

- Form of substrate (Fibre, flour or pulp)

Effect of borate on hemicellulose monosaccharide composition



Results

- Alkali concentration
- Delignification with hydrogen peroxide
- Temperature
- Addition of Borate

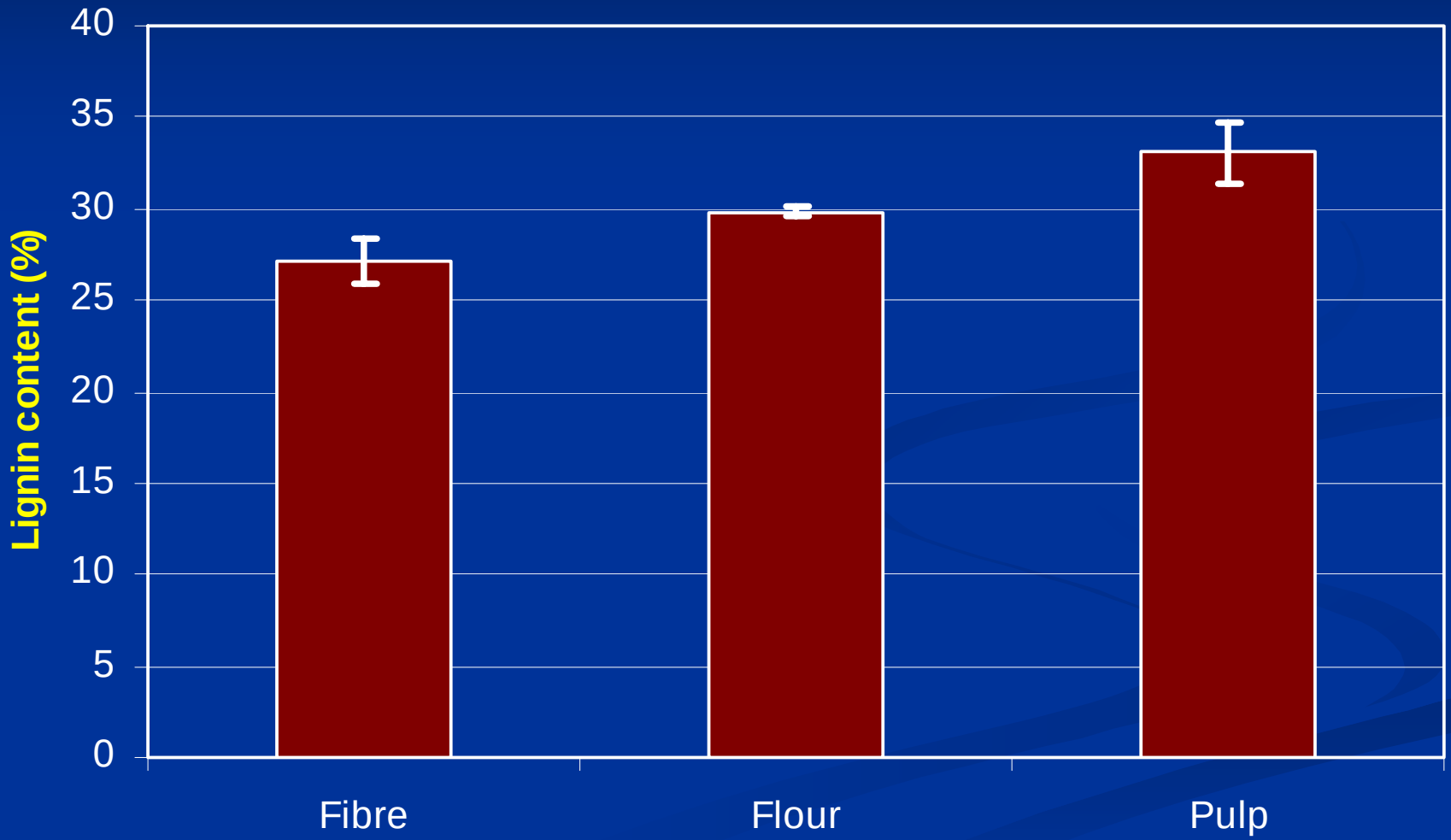
- **Form of substrate** (Fibre, flour or pulp)
  - Affects yield
  - Differences in monosaccharide composition

Hemicellulose yield dependent on substrate form

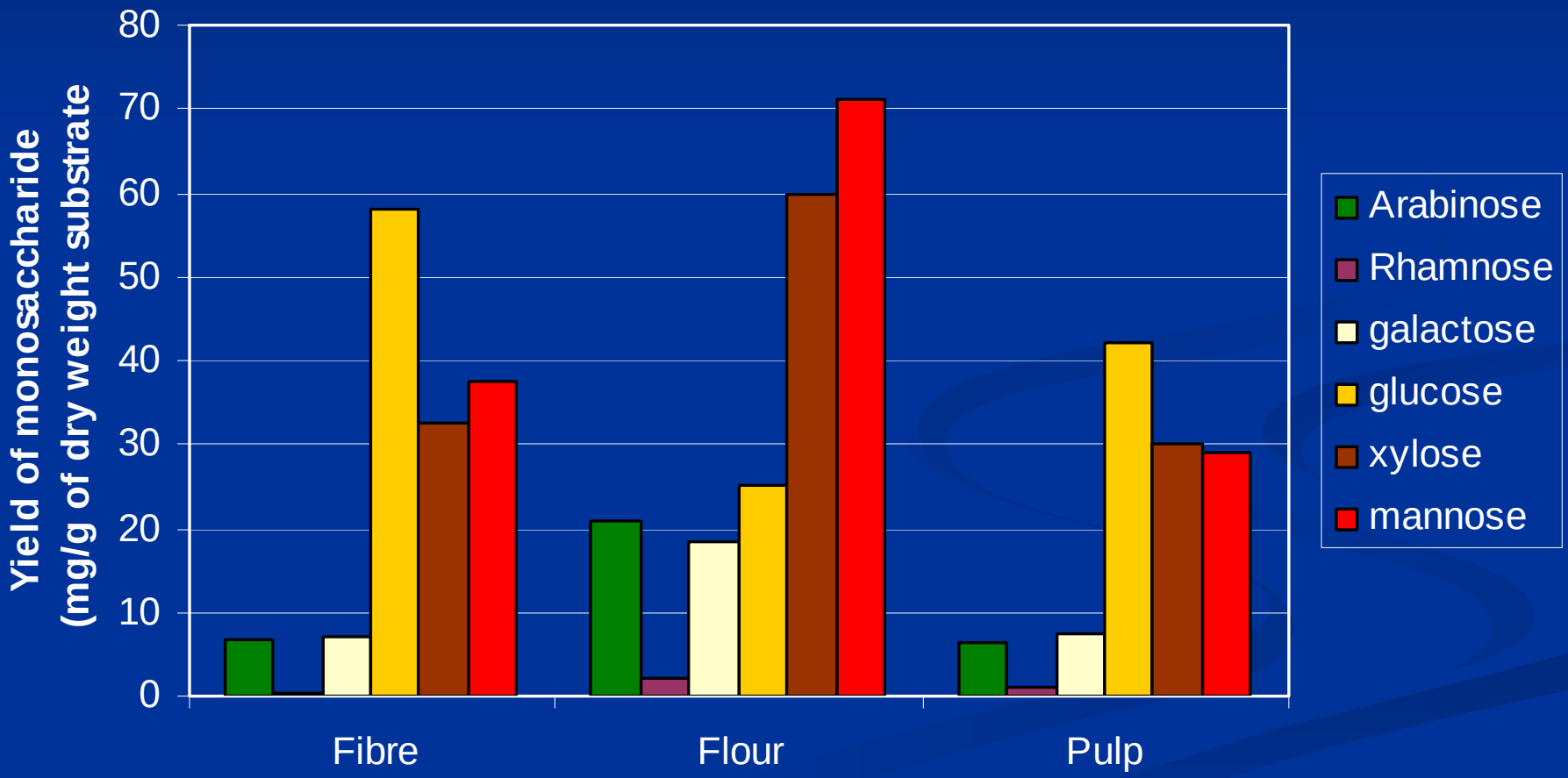
	Fibre	Flour	Pulp
Ppt Yield (mg/g dry wt)	240	510	200
Hemicellulose content of ppt	59%	40%	58%
Actual yield of hemicellulose (mg/g dry wt)	142	206	116

Conditions: 24% KOH + 15% borate + 2% hydrogen peroxide at 60°C

Lignin content of substrates



Monosaccharide yield from different substrates

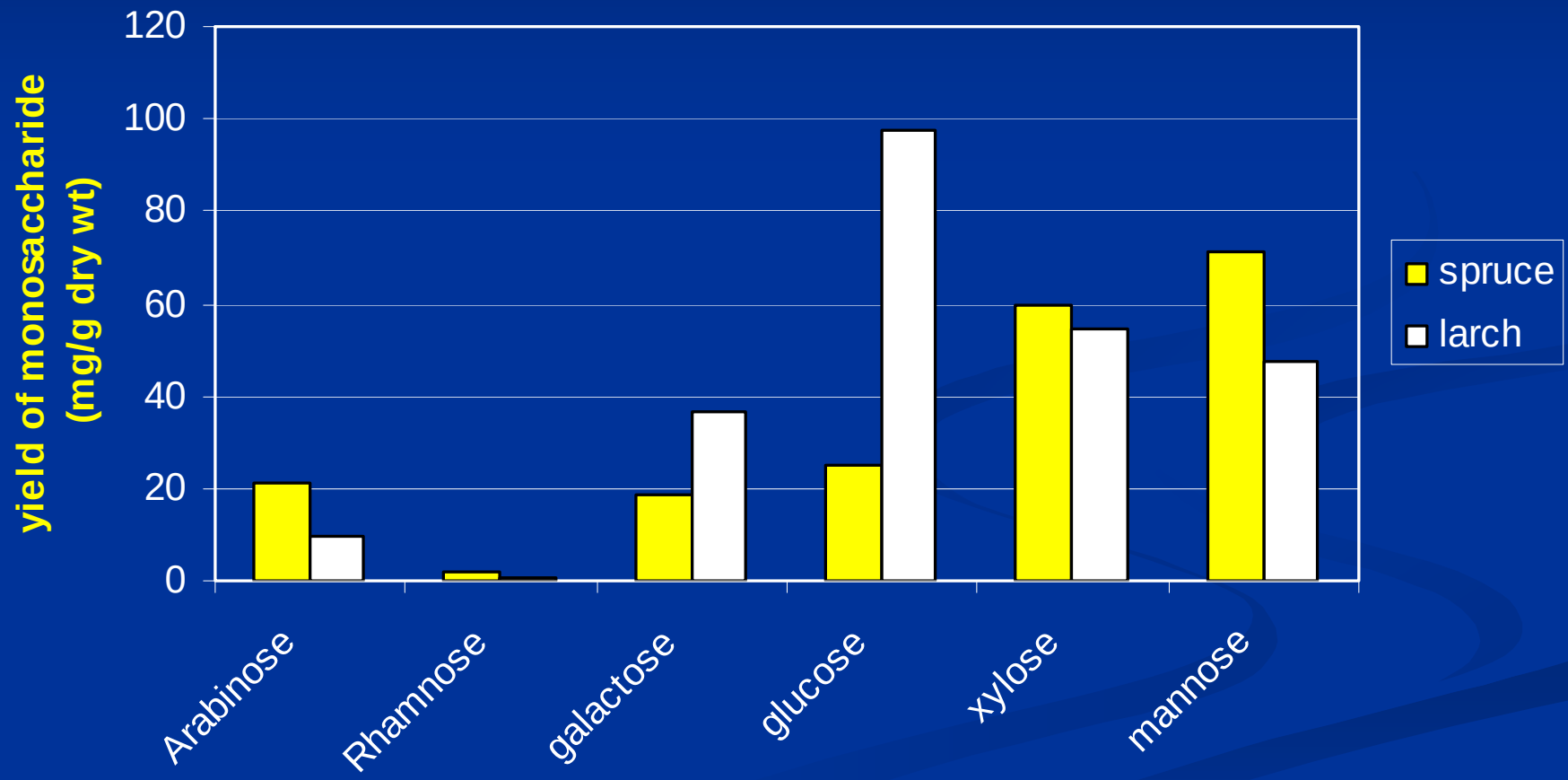


Suitability to other species

- The extraction procedure was tested for suitability on Japanese Larch (*Larix kaempferi*)

	Japanese larch
Ppt yield (mg/g drywt)	631
Hemi-cellulose content of ppt	36%
Actual yield of hemicellulose (mg/g drywt)	247

Spruce/larch comparison



Species comparison

	Norway* spruce	White spruce*	Black spruce*	Sitka spruce
Hemicellulose yield (mg/g dry wt)	218	207	222	206

	European Larch*	Japanese Larch
Hemicellulose yield (mg/g dry wt)	359	247

* - Willfor et al 2005

Conclusions

- The basic method is feasible with an encouraging yield obtained
- A number of challenges remain

Challenges

- **Optimising extraction procedure**
- Sequential extraction of hemicellulose fragments
- Characterisation of hemicellulose gels
- Identifying potential markets and uses
- Sequential extraction of cell wall components (cellulose, lignin and hemicellulose)
- Scale up

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Thank you