Change of the properties of Vietnamese Bamboo species by thermal modification

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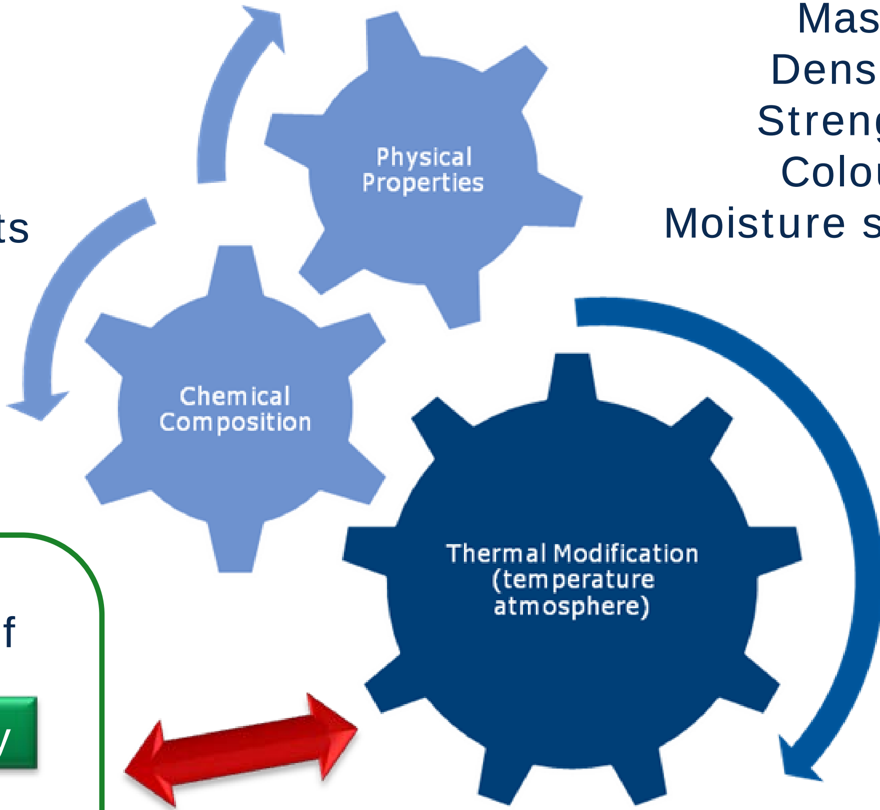
Outline

1. Motivation
2. Materials and methods
3. Results
   - Chemical composition
   - Physical properties
   - Correlations between chemical and physical Properties
4. Conclusions

Motivation

Content & Structure } Components



Mass
Density
Strength
Colour
Moisture sorption

Aim: Improvement of

- Dimensional stability
- Durability

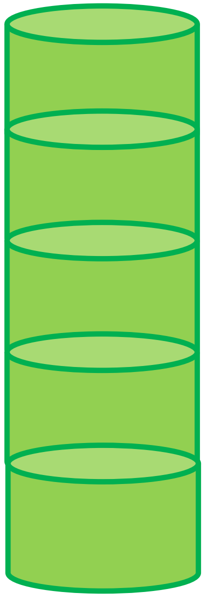
Materials and Methods

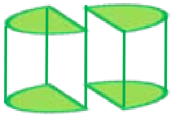
Bamboo species
- *Dendrocalamus barbatus* Hsueh et D. Z. Li (Vietnamese: Luong)
- *Dendrocalamus asper* Backer ex Heyne (Vietnamese: Buong)

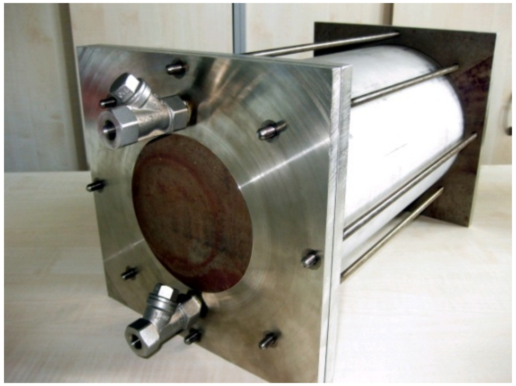
Harvesting
- April and October 2010
- Area of Tan Lac, Province Hoa Binh

Properties of culms
- 2 - 3 years
- 15 m high
- first 10 m from bottom were investigated

Preparation of samples for thermal modification
- Only internodes
- 5 slices from each internode
- Two parts of each slice

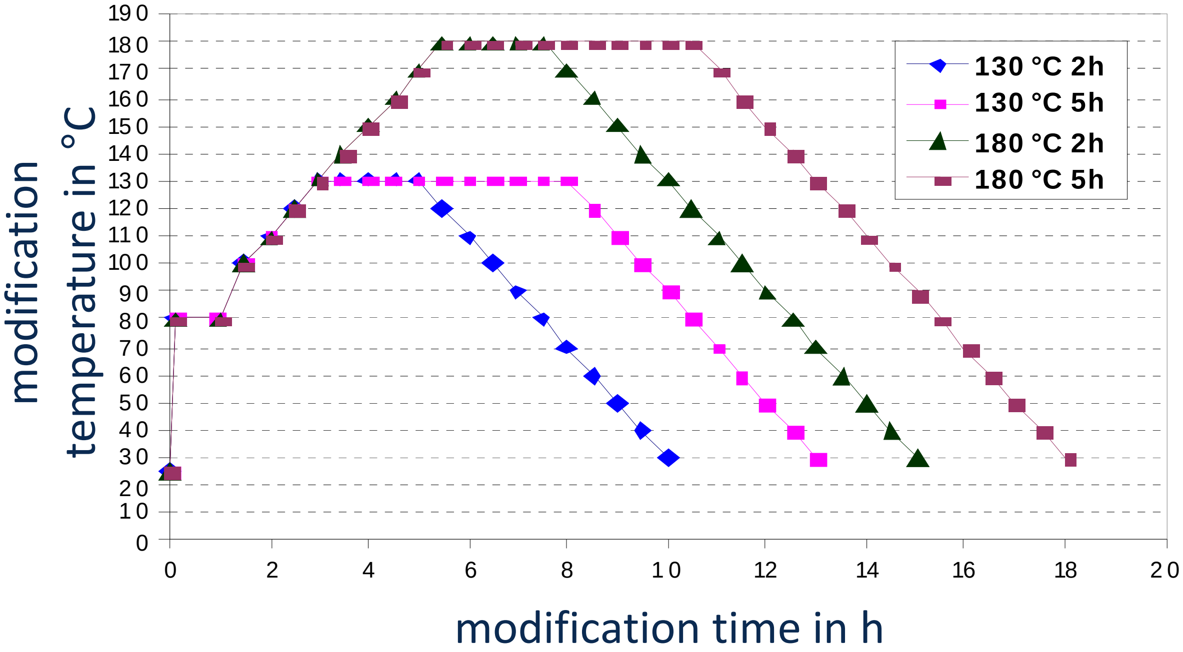






Treatment chamber for thermal modification of bamboo

Treatment charts for modification
at 130 °C and 180 °C



Materials and Methods

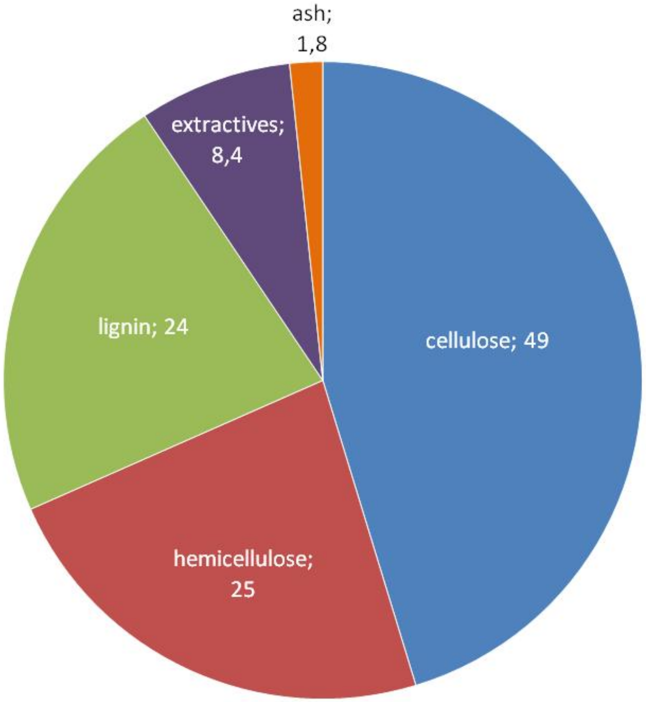
Chemical analyses

Component	Method
Cellulose	Method of Kürschner and Hoffer
Lignin	Klason-Lignin
Holo cellulose	Delignification by perchloric acid
Extractives	Extraction with ethanol/toluol
Sugars	Gentle hydrolysis / HPLC

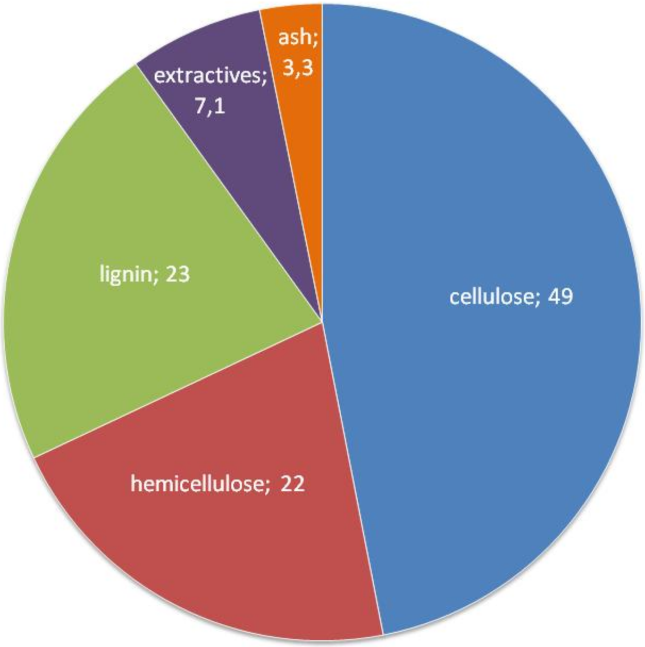
Physical Properties

Method	Sample dimension	Number of measurements per sample
Colour	Twin sample (not cut)	20 points per sample
Density, EMC	30 mm (height) * 15mm (width) * wall thickness	10
Shock resistance	15 mm (height) * 10 mm (width) * 1,2 mm (thickness)	2 - 12

Chemical composition of Bamboo species



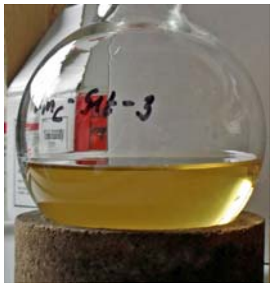
Dendrocalamus barbatus



Dendrocalamus asper

Colours of extractives

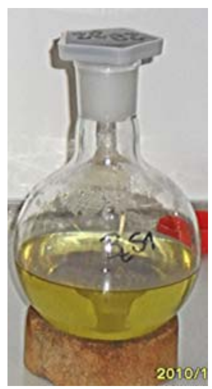
2 h 130 °C



Non treated samples

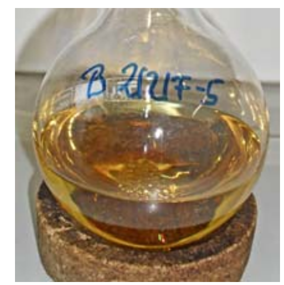
2 h 130 °C

5 h 130 °C



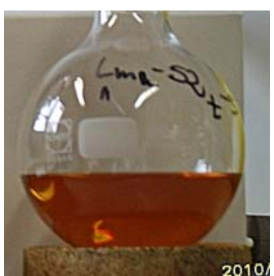
D. barbatus

D. asper



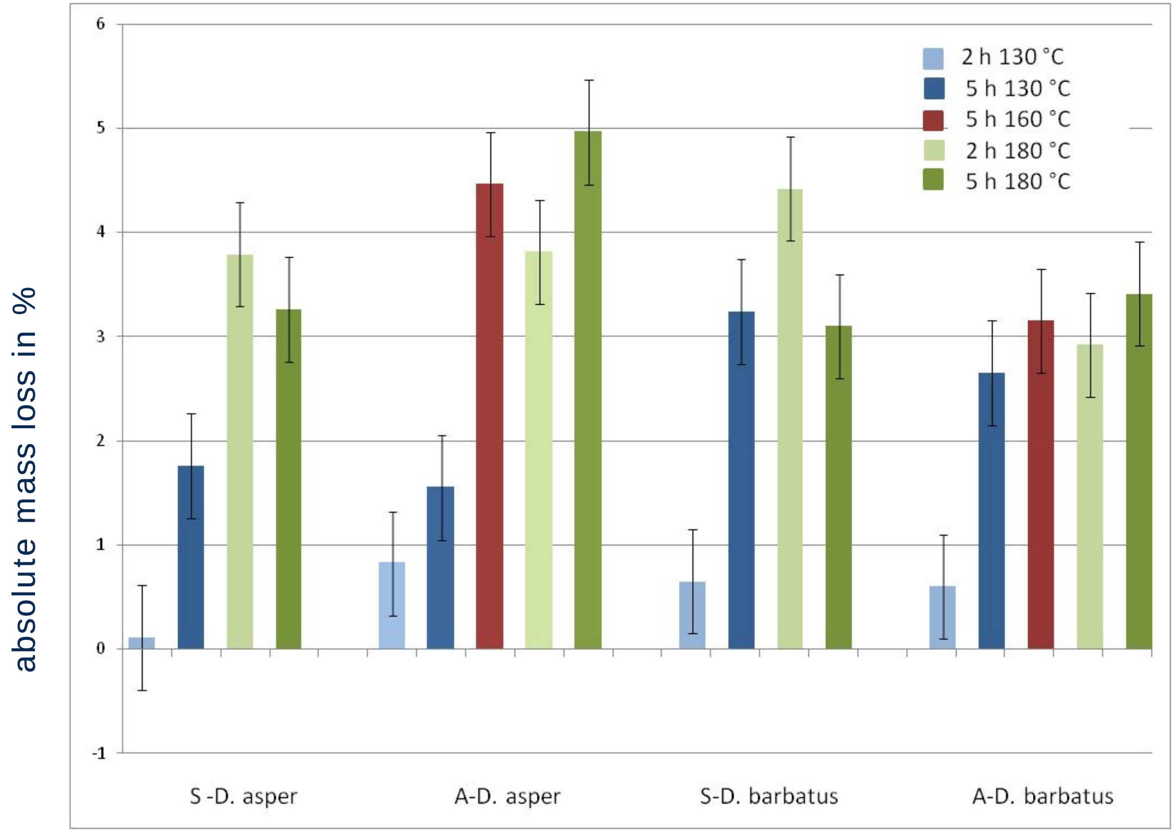
5 h 160 °C

5 h 180 °C



5 h 180 °C

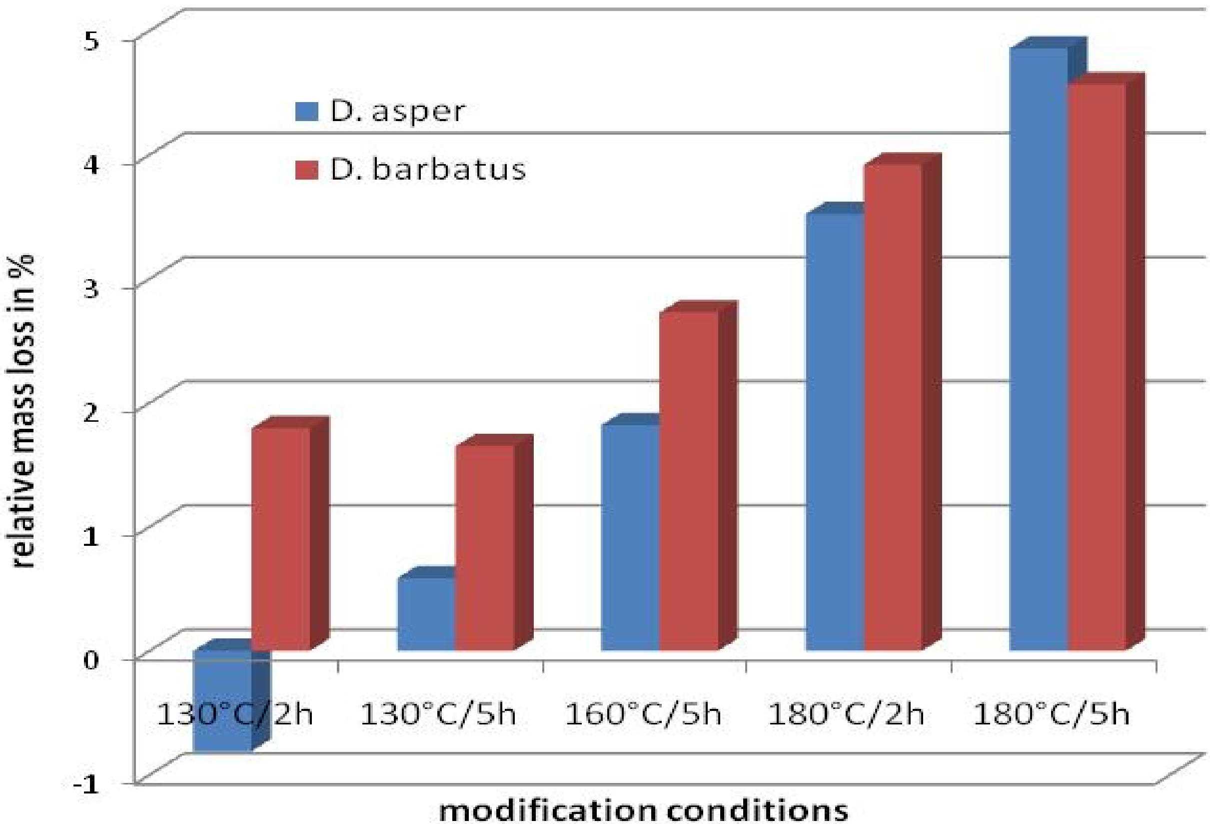
Mass loss of extractives



- Possible reactions:
  – disposal of volatile compounds
  – decomposition
  – condensation of aromatic compounds
- Lower contents of extractives at higher temperatures
- D. asper: big differences between 130°C and 160/180°C
- D. barbatus: small differences between 5 h 130°C and higher temperatures

Following investigations:
- extraction with different solvents
- GC/MS of extractives

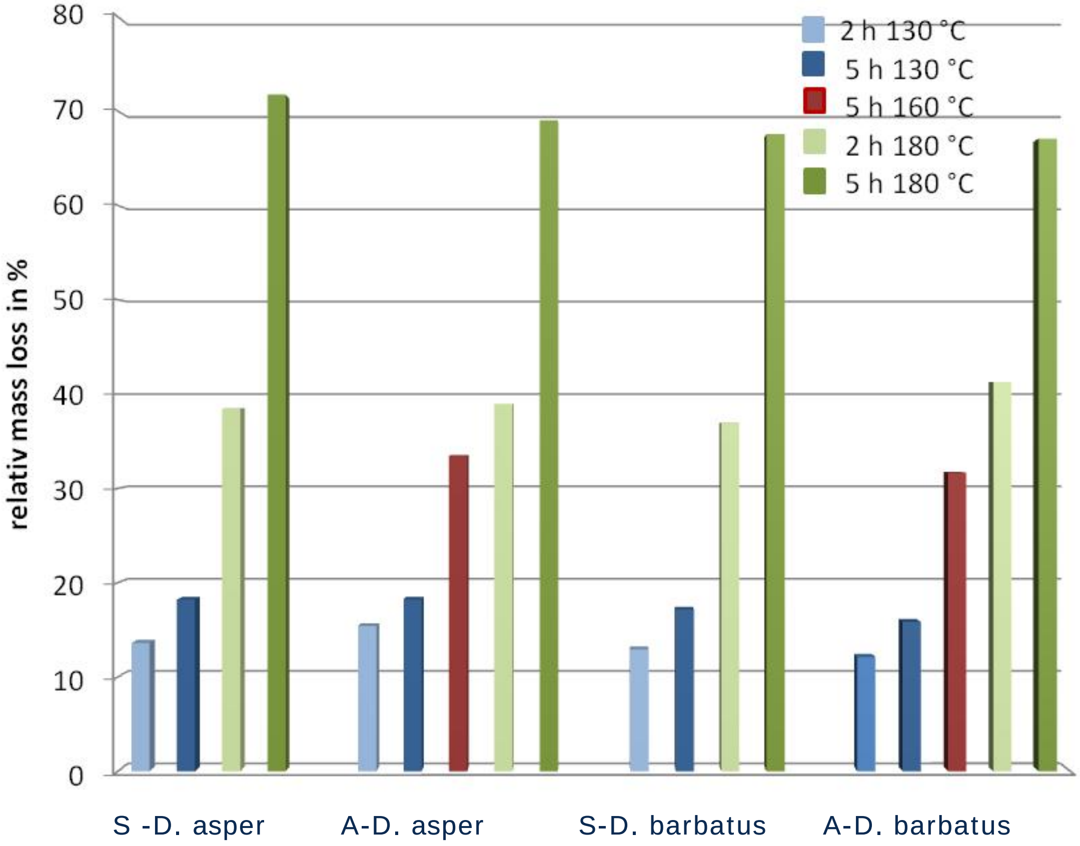
Mass loss of cellulose



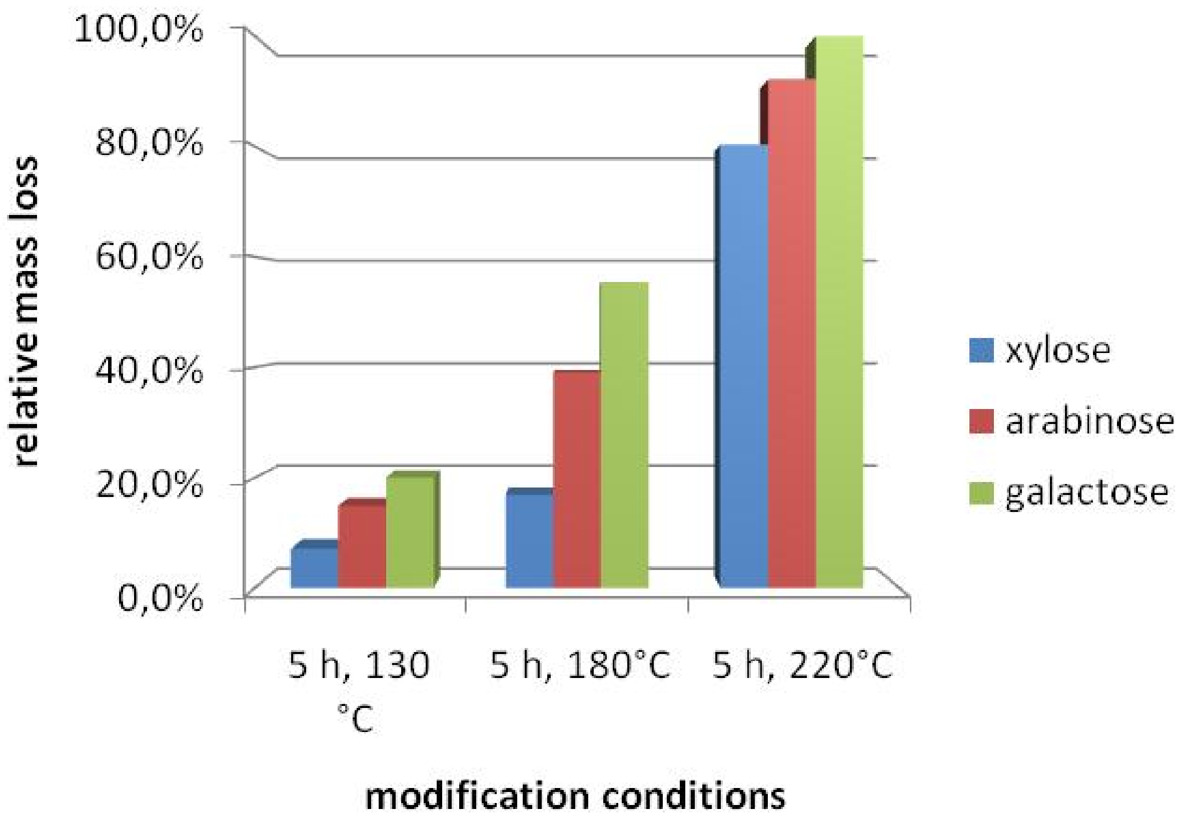
- Apparently mass loss
- Content of Cellulose slightly decreases by shorting of chains at higher temperatures
- Shorter chains are not detectable by this determination method
- Influence of modification temperature and time are similar
- D. barbatus shows stronger degradation at lower temperature

Mass loss of hemi cellulose

- Hemi celluloses show the highest degradation degree of the bamboo components
- Decomposition degree rises strongly with increasing temperature
- Only a small influence of time at 130°C
- An important influence of time at 180°C
- mass loss up to 70 %

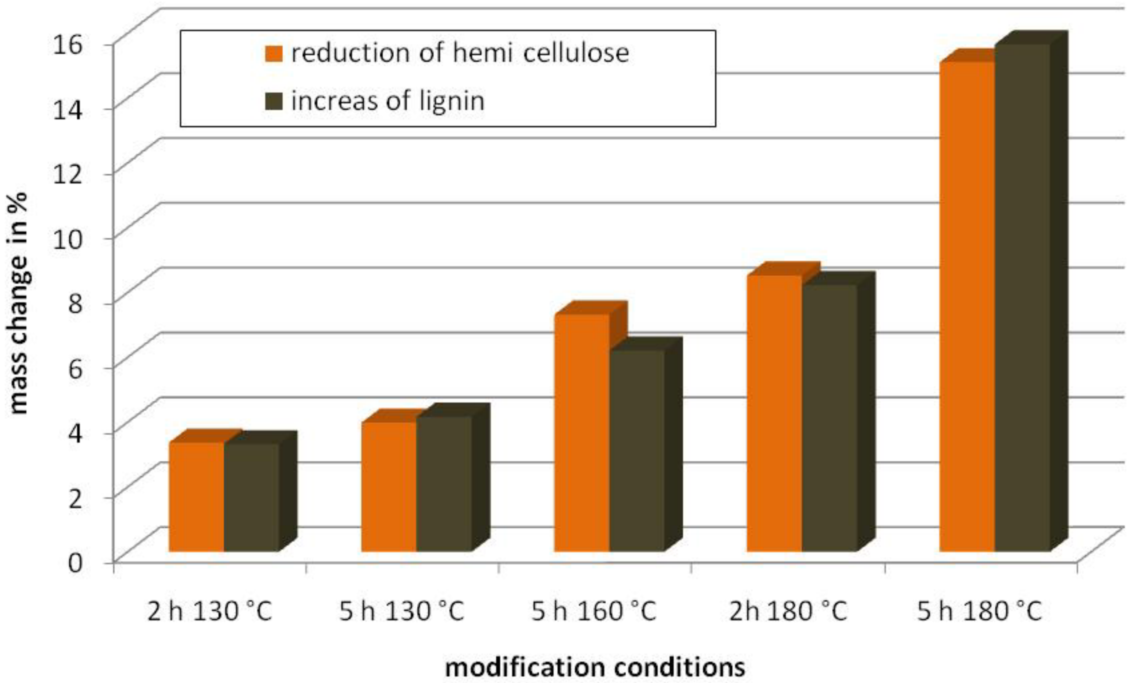


Mass loss of sugar components of hemi celluloses



- Relation between the sugars shifts to higher xylose content
- Up to 180 °C mainly arabinose and galactose degraded
- At 220 °C no galactose detectable
- Xylose degradation mainly at temperatures above 180 °C

Comparison between reduction of hemi cellulose and increase of lignin



- Absolute increase of mass of lignin nearly approximates the mass loss of hemi celluloses
- Possible reactions:
  - Formation of new polymers from degradation products of hemi celluloses
  - Cross linking of degradation products of hemi celluloses with lignin structure

Results

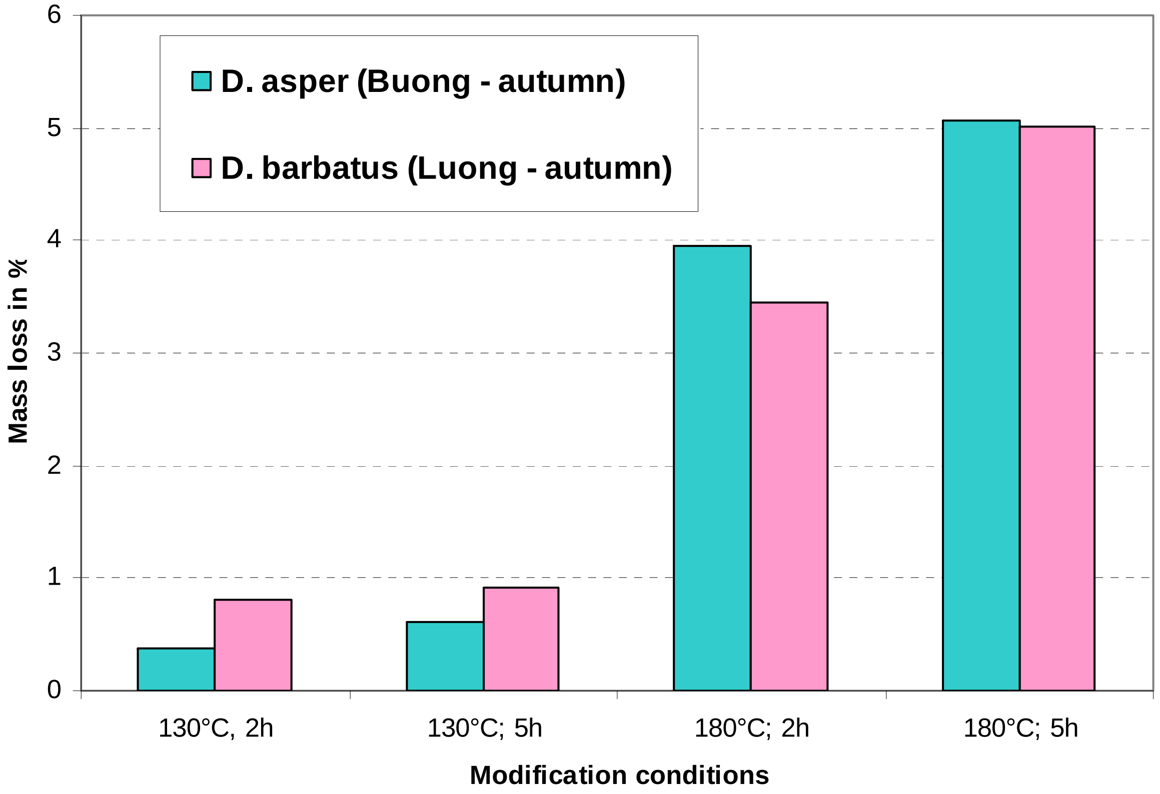
Colour

reference | 2 h 130°C | 5 h 130°C | 2 h180°C | 5 h 180°C | 5 h 220°C

D. barbatus

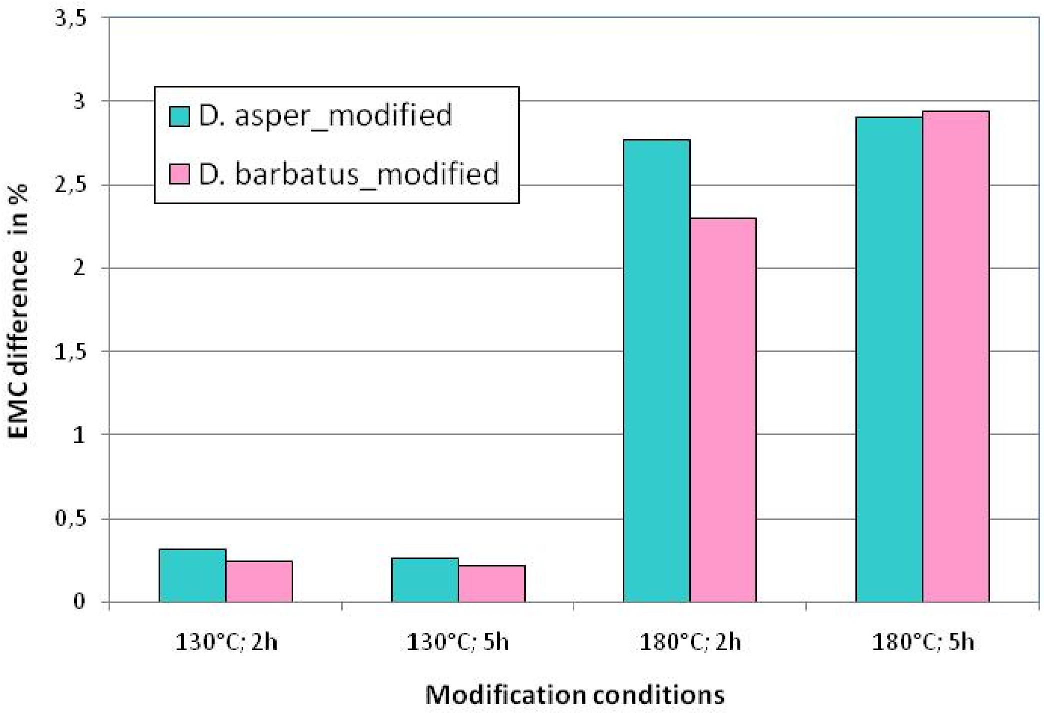
D. asper

Mass loss



- Samples were dried at 103 °C
- Mass loss is the difference between dried mass of the samples before and after thermal treatment.
- Absolute mass loss:
  - is generally low
  - depends on temperature
  - corresponds with absolute mass loss of extractives

Equilibrium moisture content



- Difference between non treated and treated twin samples
- EMC decreases with increasing temperature
- Decomposition of hemi celluloses results in a strong decrease of hydroxyl groups whereby the hydrophilic character decreases.

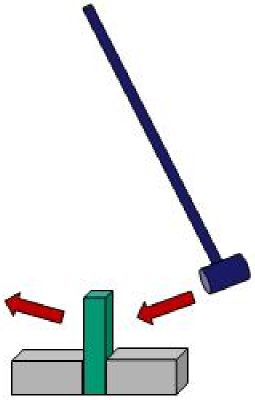
Shock resistance

Preparation of test pieces:

- test pieces were prepared from the outer and inner side of the bamboo column
- generally 12 pieces were made from each side

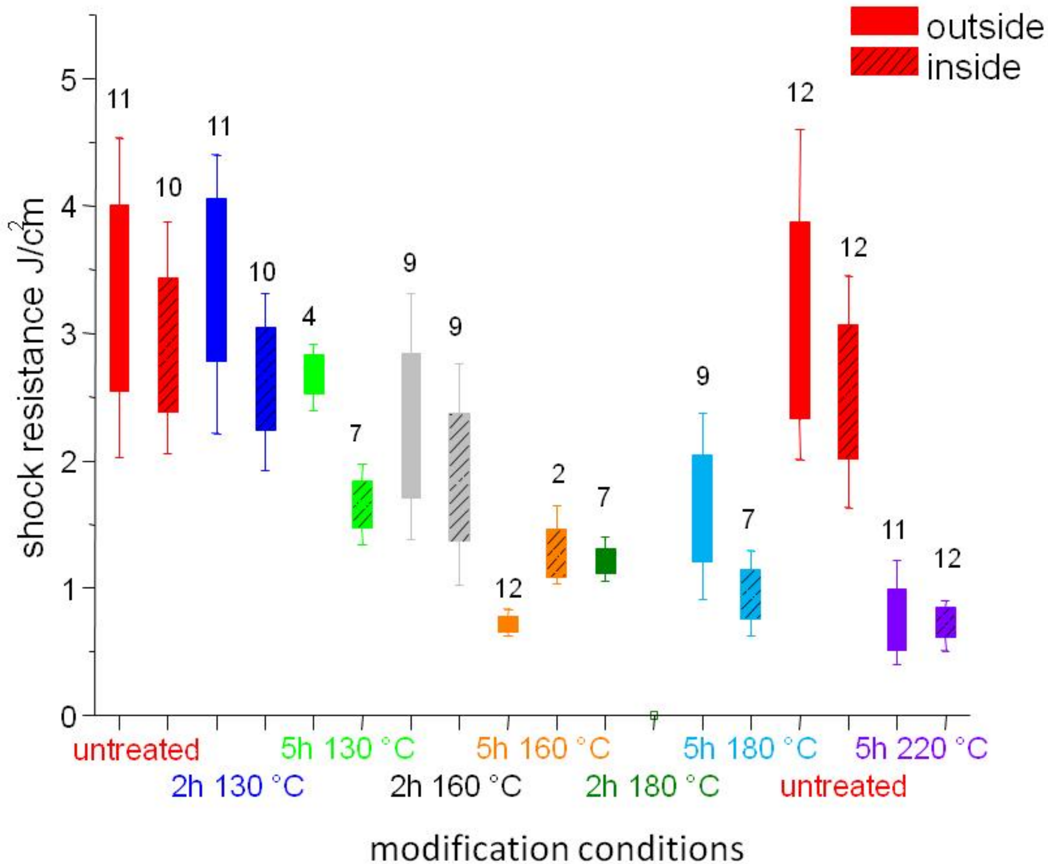
Measurement

- one piece is placed vertically to the hammer
- the hammer falls against the piece with defined force
- piece breaks
- shock resistance results from the further swinging of the hammer

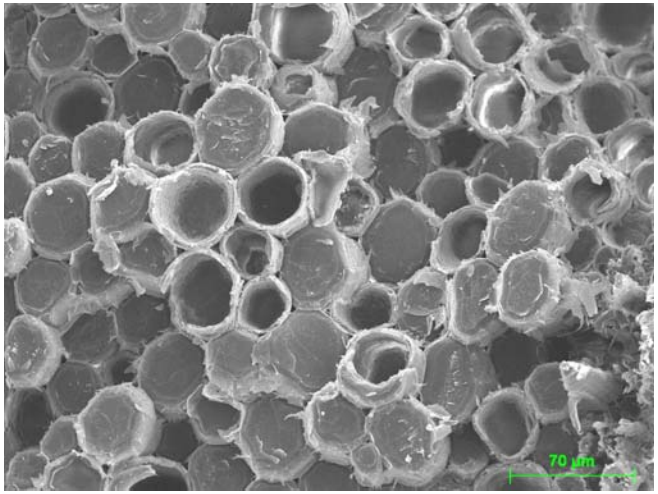


Shock resistance of thermal treated D. barbatus

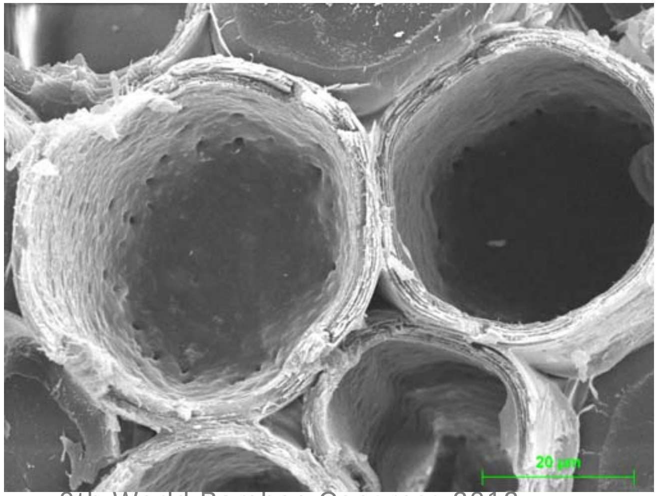
- Untreated samples have approximately the same values.
- Shock resistance is influenced by temperature as well as by treatment time.
- Wide value range because of the heterogeneity of natural samples
- Value range becomes smaller with increasing temperature.
- Inside pieces show smaller values.

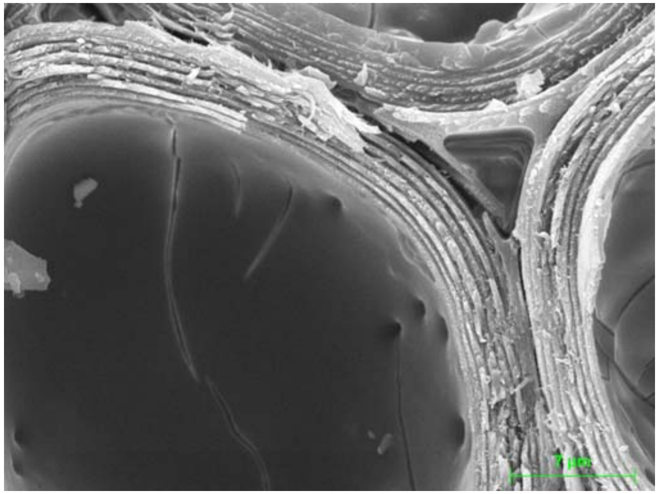


Morphology of fractures

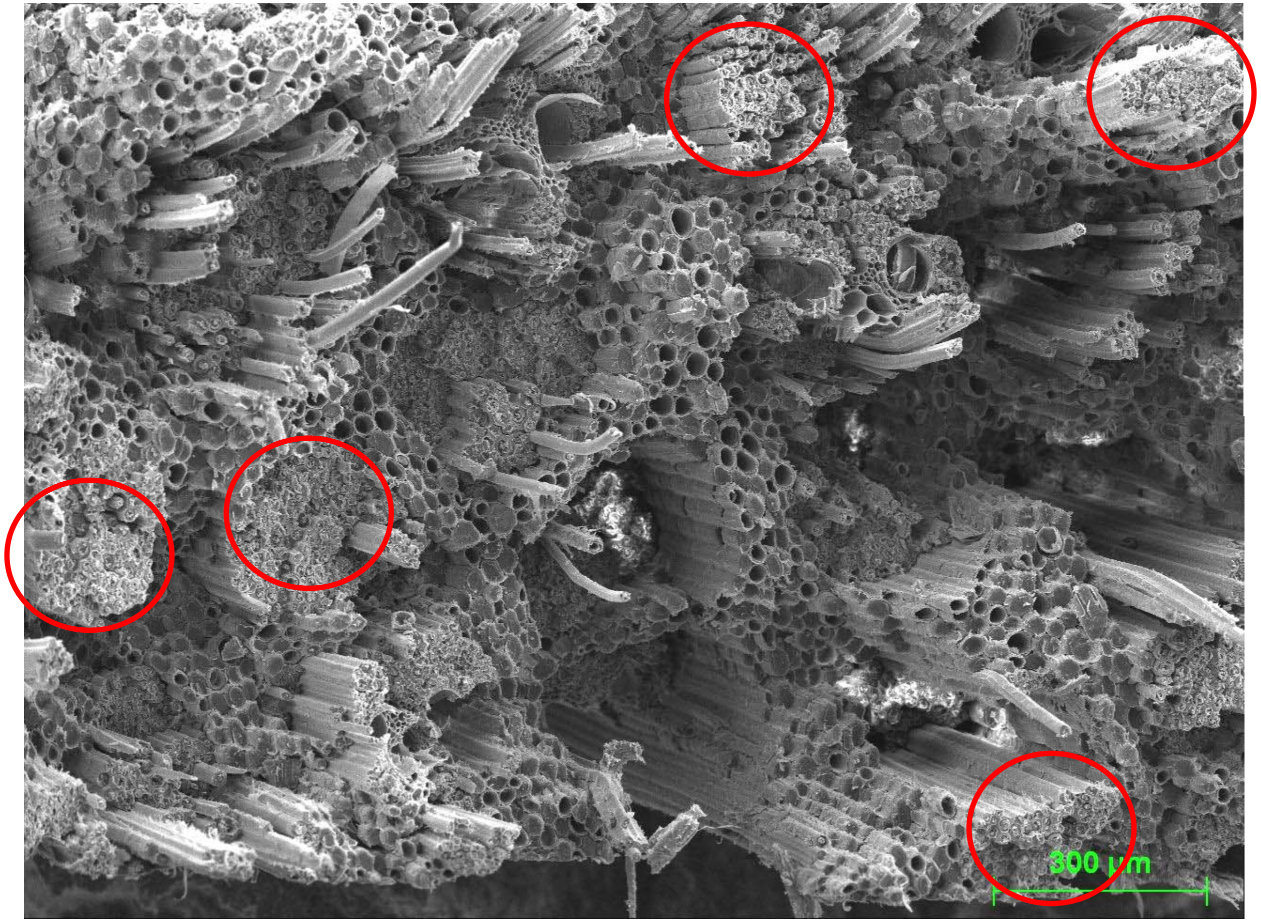


- Samples were investigated by SEM after shock resistance tests.
- Parenchyma cells show a similar fractures behaviour at all temperatures.
- There are brittle fractures through the lamellae of the cell walls.
- 80 – 90 % fractures occur within the intercellular region.
- Parenchyma cells and vessel cells show one fraction plain.





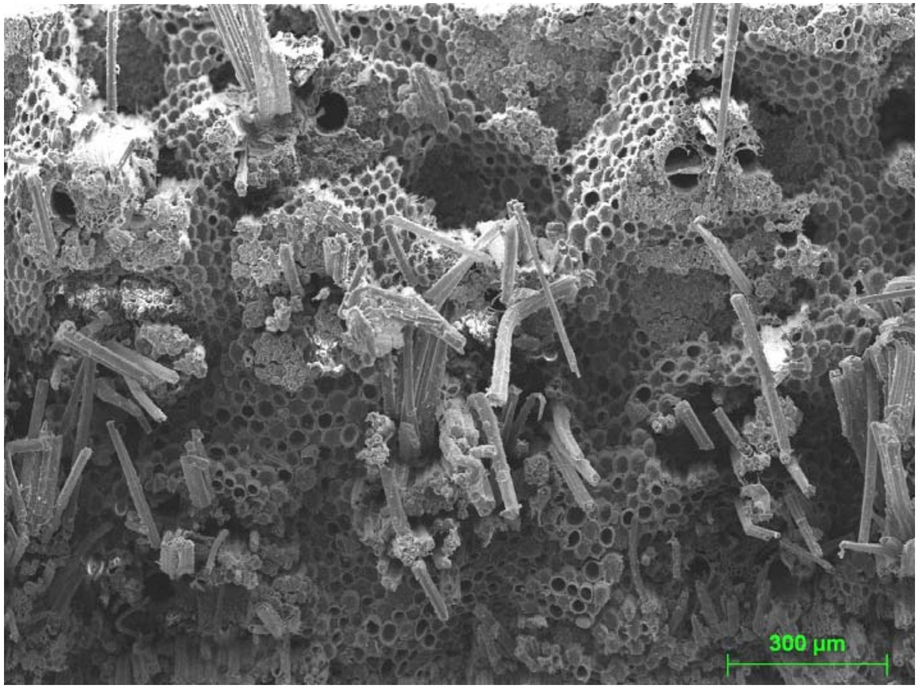
Morphology of fractures



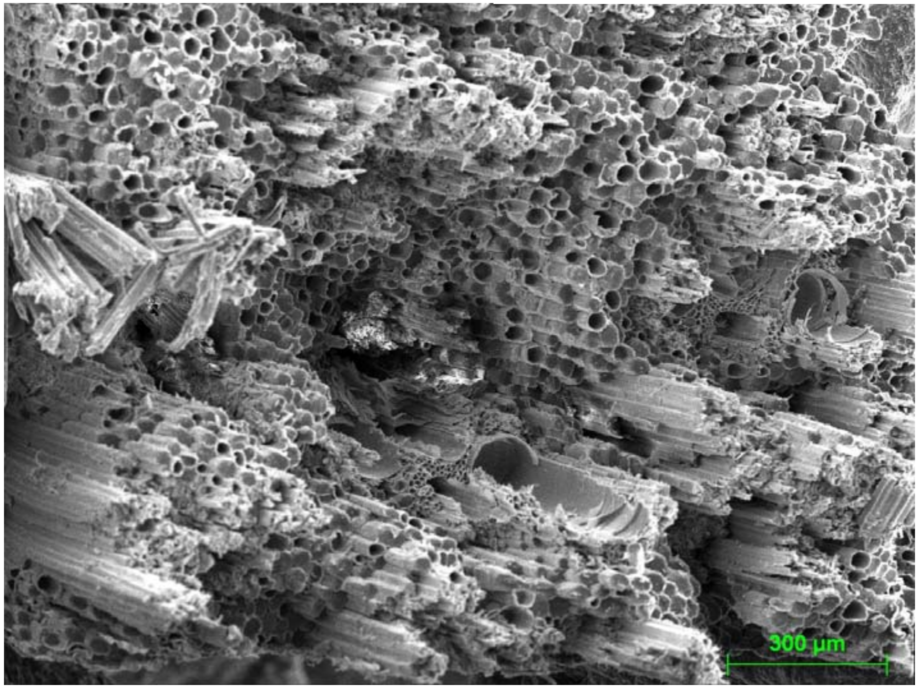
- Fibres of non treated samples show long fractures with a more or less strong structuring of the individual fibre.
- There are fibre bundles with the same fracture plane.
- The fracture plane of fibres and surrounding parenchyma cells are different.

Morphology of fractures

5h 160°C



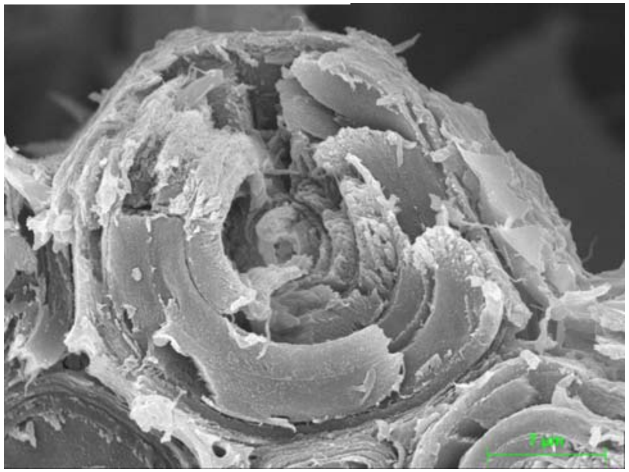
5h 220°C



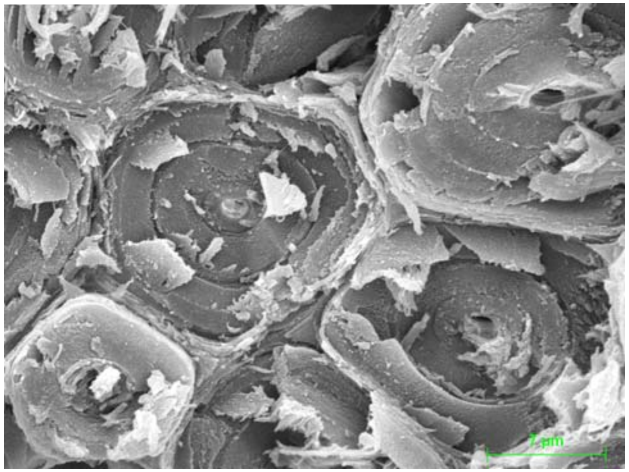
- The fibre fractures become shorter with increasing temperature.
- At 160°C there are some separate, long fibres but few bundles.
- At 220°C the fracture plane of fibres and parenchyma cells are similar.

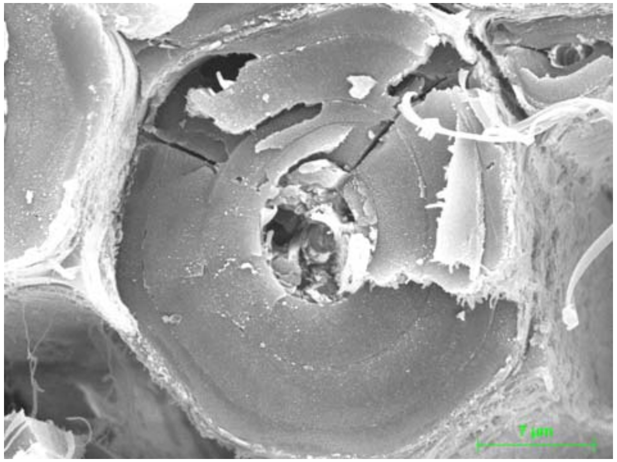
Results

non treated



5h 160°C

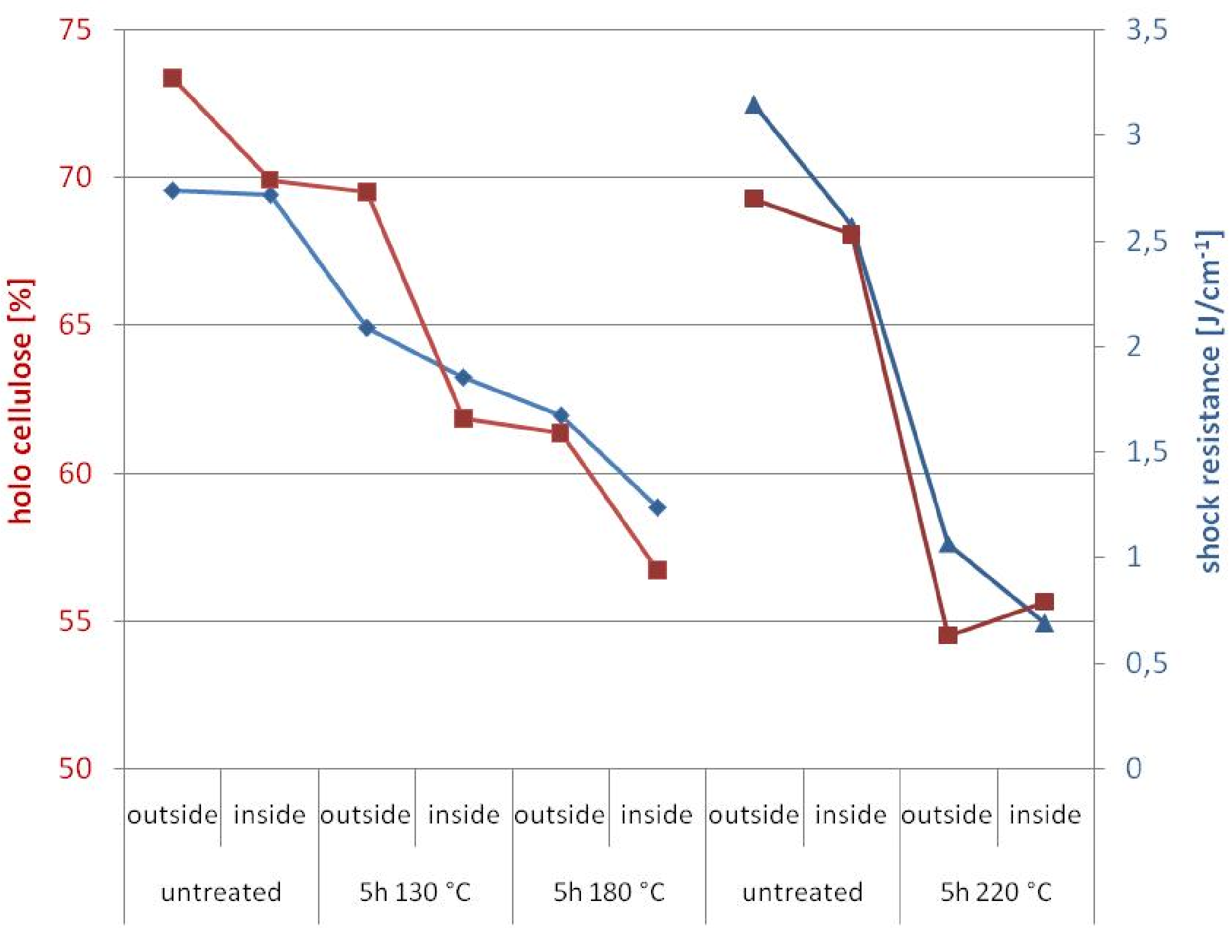




5h 220°C

- Individual fibres of non treated sample show structured partially fibrous fractures with different levels of the single lamellae.
- Fractures become more planar with increasing temperature.
- At 220°C some radial and tangential cavities are shown.

Correlation between shock resistance and content of holo cellulose



- Strong correlation between strengths and holo cellulose content
- Decomposition of hemi cellulose results in loss of their original function.
- Function of lignin is particularly reduced as well because of the chemical changes in its structure.

Conclusion

- Thermal modification of bamboo generates many changes in chemical composition.
- Quantity of these changes depends on the modification temperature and time.
- Treatments at 130°C cause only slight changes.
- Significant changes occur at modification above 180°C.
- Changes of physical properties are correlated with changes in chemical composition.
- Changes in strength are most important.
- Strong decreases in strength are caused by decomposition of hemi celluloses and the structural change of lignin.
- Fracture morphology shows a soaring brittleness of samples with increasing temperature.

Thank you
for your attention.

We would like to thank the DFG for financial support.