Binderless opportunities for renewable materials

10th Circular Biobased Products Symposium

22 June 2023, Gijs van Erven

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Binderless technology - background

- Conversion of lignocellulosic biomass into high-quality thermoset material
- Using intrinsic functionalities of biopolymers present
- No additives – only heat and pressure → binderless
- Valorization of available side-streams into biobased materials with superior properties compared to current fossil-based products

Binderless technology - process

coconut husk

<2.5 mm

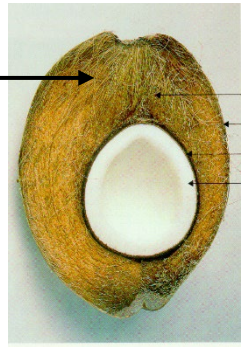
10-12% water

Pre-press
room temp.
100 bar
1 min

Press
180°C
150 bar
25 min

Binderless board

husk



CFC project
1998-2003

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Binderless research – recent findings

- Product characterization
- Process control and optimization
- Feedstock challenges and opportunities
- Unravelling biopolymer reaction mechanisms

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

NEXTEVO

staatsbosbeheer

ENKEV
Engineered for sustainability

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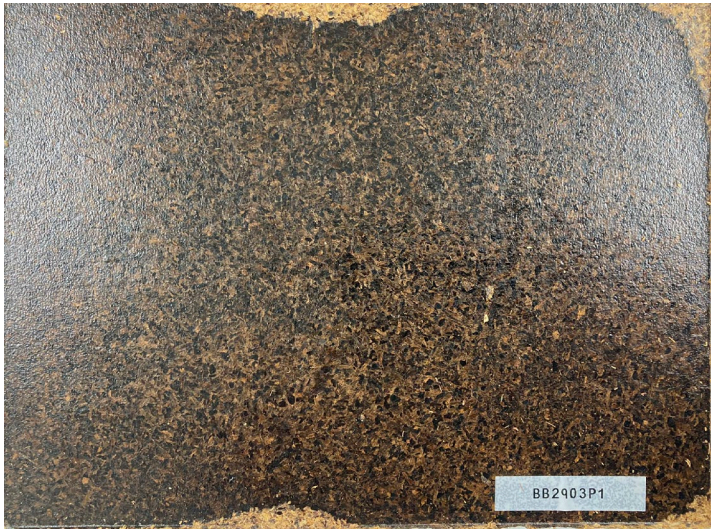
Natuurmonumenten

CBPM Sustainable Binderless Product Technology
TKI-LWV 19154
2019-2022

Binderless boards - visualization

Coconut husk

Binderless boards - visualization



Softwood prunings

Hardwood prunings

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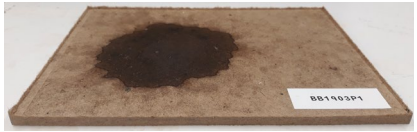
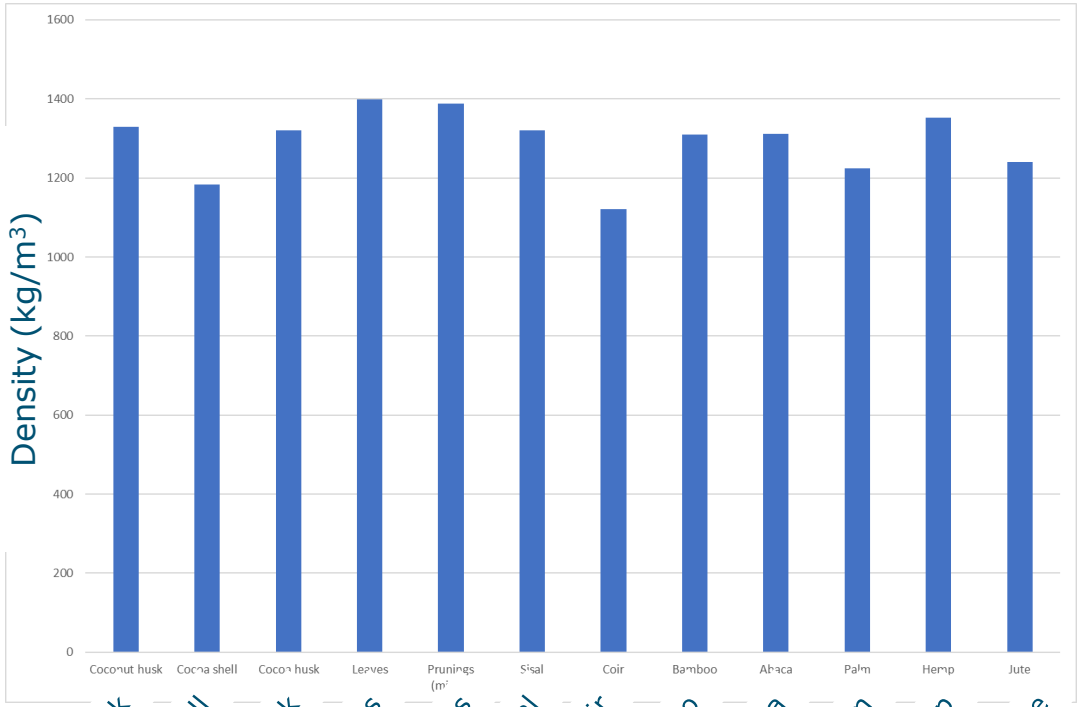
High density boards independent of feedstock used

Cocoa shell

Abaca



Jute



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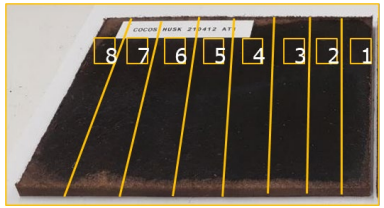
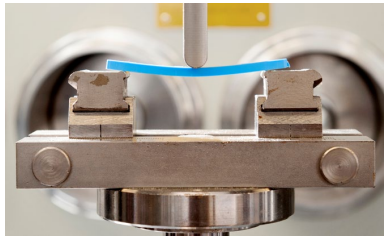
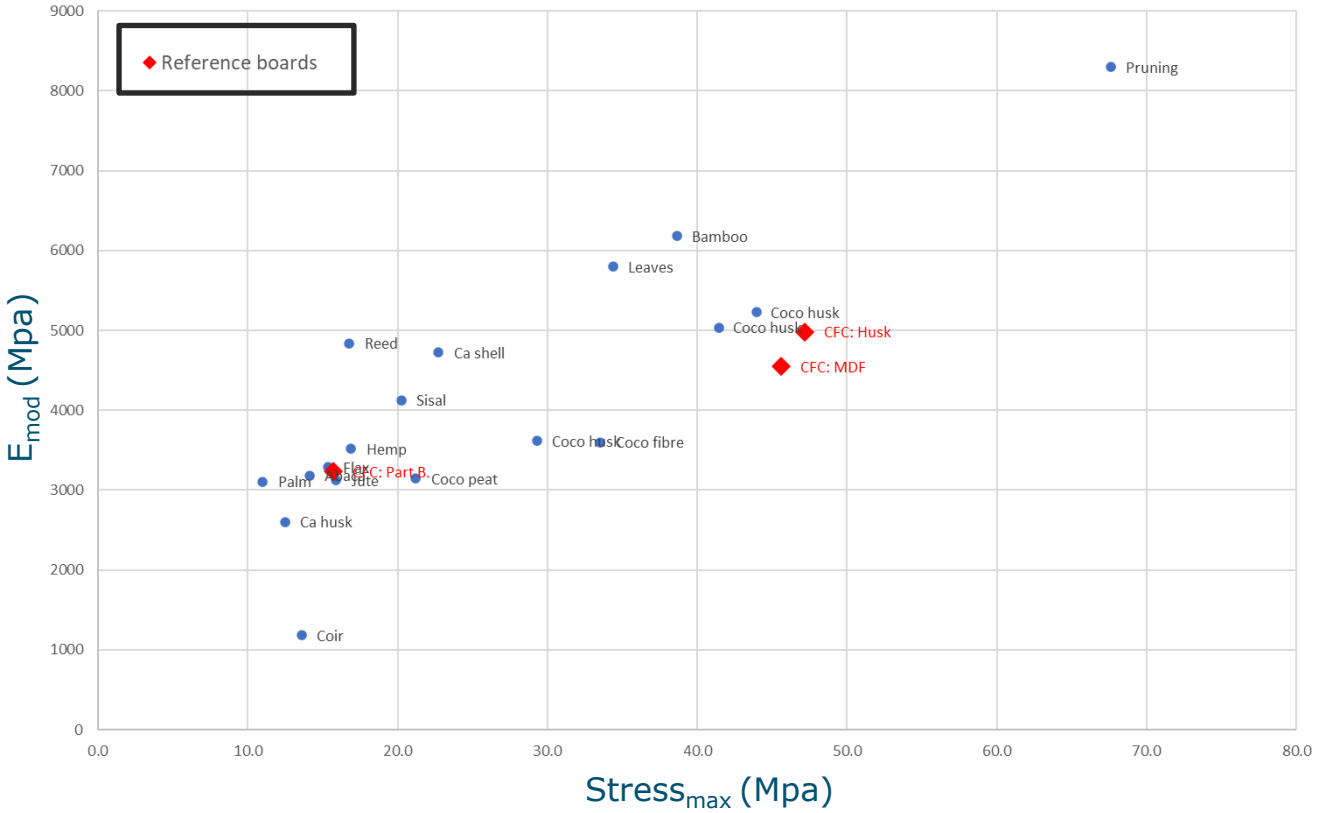
Evaluation of mechanical properties





3-point bending test

Feedstock dependent properties, not driven by density (*i.e.* reactivity)!



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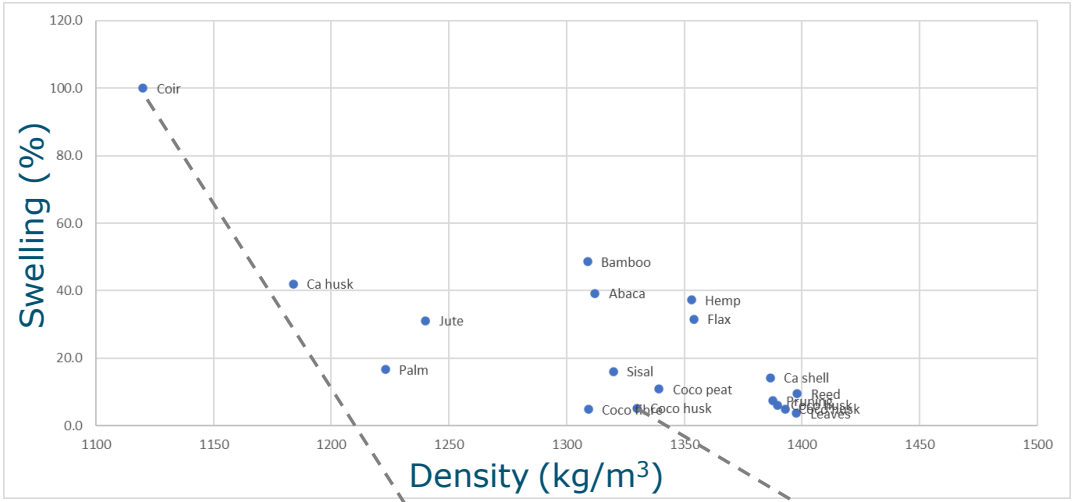
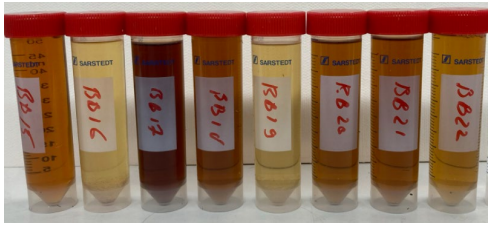
Evaluation of water resistance



Leaching extent

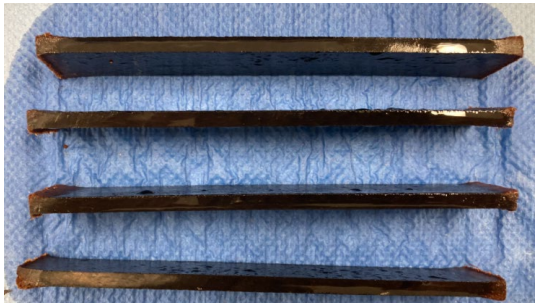


Sisal Bamboo Jute Abaca
Coir Hemp Flax Palm

Coconut husk Mixed prunings

Feedstock dependent properties, not driven by density (*i.e.* reactivity)!

Coconut coir fibre



Coconut husk

Understanding binderless boards at the molecular level

- Mechanistic insight into biomass conversion and underlying reactions
  - Process optimization
  - Predicting feedstock suitability
  - Structure-function relationships → steer final material properties

Accurate analysis of the molecules involved

- Content
- Structural features

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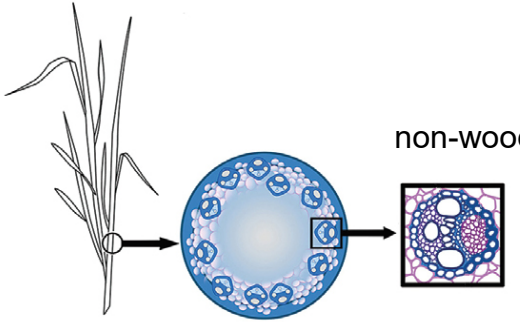
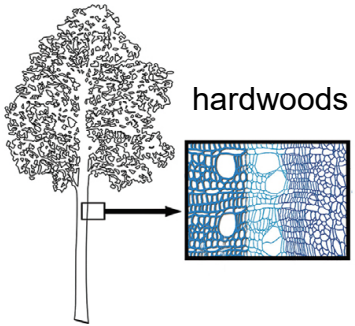
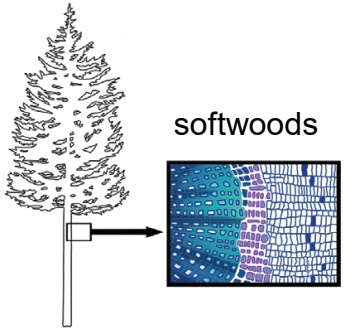
Plant biomass structure



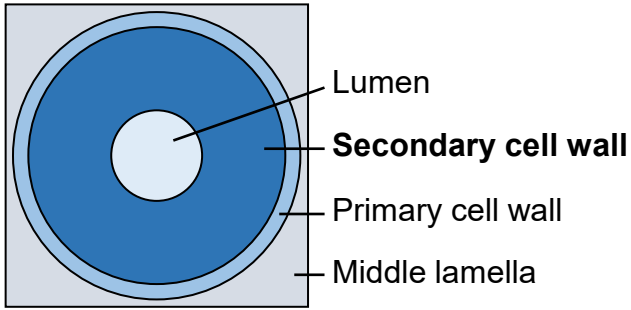
non-woods

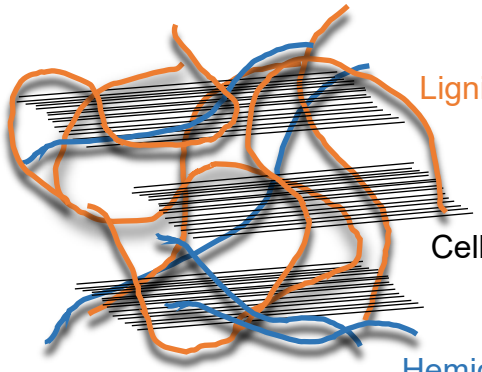


hardwoods

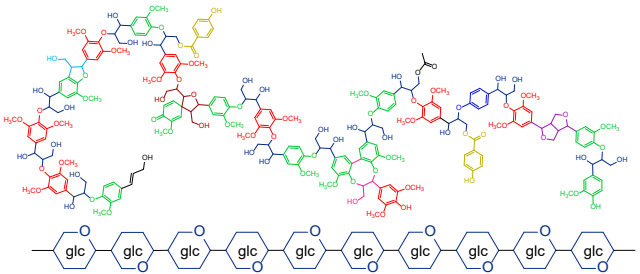


softwoods

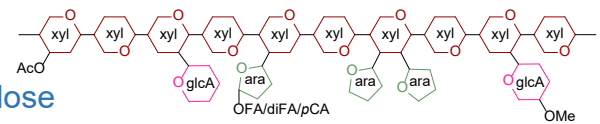




Lignin



Cellulose



Hemicellulose

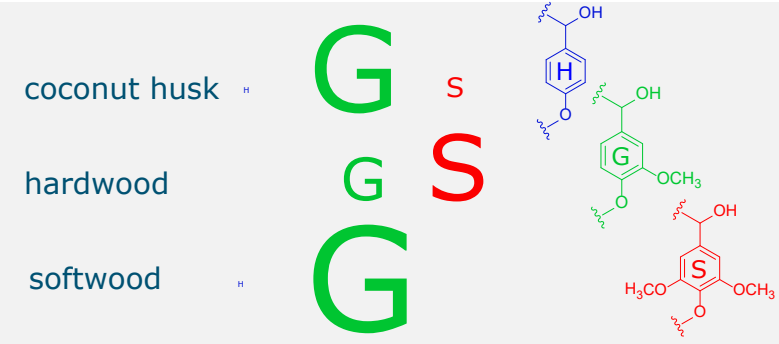
Chemical fine structure feedstock dependent → reactions during binderless board production?

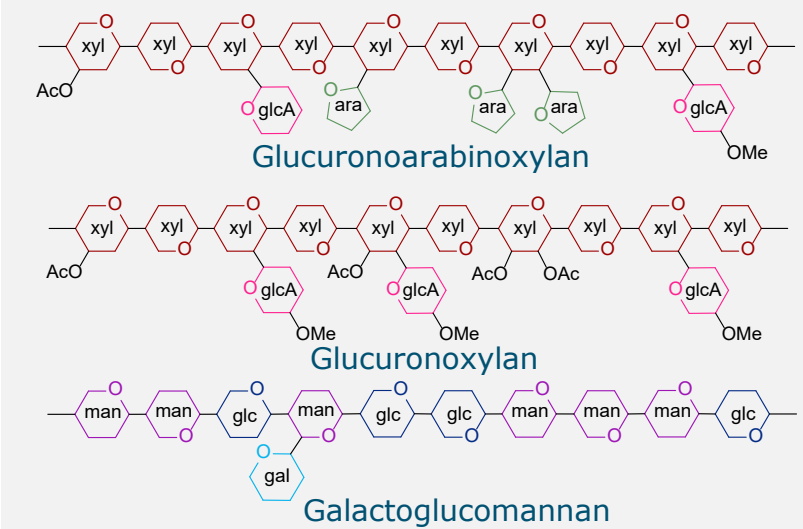
Chemical composition of feedstocks used

	Content (% w/w)		
Feedstock	**Cellulose**	**Hemicellulose**	**Lignin**
Coconut husk	24.0	16.4	32.2
Softwood prunings	23.6	12.0	32.8
Hardwood prunings	18.4	19.1	28.1

	Hemicellulose molar composition (mol %)				
Feedstock	**Arabinosyl**	**Xylosyl**	**Mannosyl**	**Galactosyl**	**Glucuronyl**
Coconut husk	16.4	57.2	2.1	7.0	17.3
Softwood prunings	6.9	25.5	32.0	12.0	23.6
Hardwood prunings	6.5	50.6	2.9	2.9	37.0

- Differences in chemical composition
- Differences in fine chemical structure



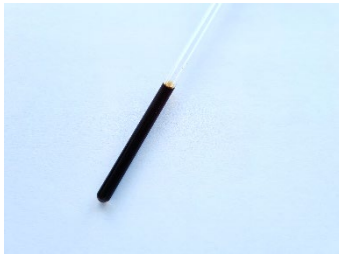


Different reactivity?

Mapping biopolymer reactions: proof-of-principle

- Planetary ball milling → ultra-fine sample → 2D NMR analysis in the gel-state
    - Feedstock input vs board output
        - Coconut husk
        - Softwood prunings
        - Hardwood prunings

Results to be published → slides will be shared at later stage



Conclusions

- Binderless technology can be extended to locally sourced, low-value side-streams, yielding 100% biobased products with high-quality attributes and added value
    - Softwood and hardwood prunings of particular interest
- Detailed characterization allows mechanistic insight into reactions of biopolymers during binderless board production
    - Hemicellulose and lignin are responsible for *in situ* binder formation
- New routes and avenues opened to innovate and expand the technology
    - Extrapolation of insights to steer process and final material properties

Inspiration

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Outlook

- Further development technology based on novel insights
  - Using a wide variety of (local) side streams and smart side stream mixtures
  - Converging different feedstocks into one product and diverging one feedstock into different products
  - Targeting relevant demonstration products
  - Focus on development of a techno-economically viable process demonstrated at pilot-scale

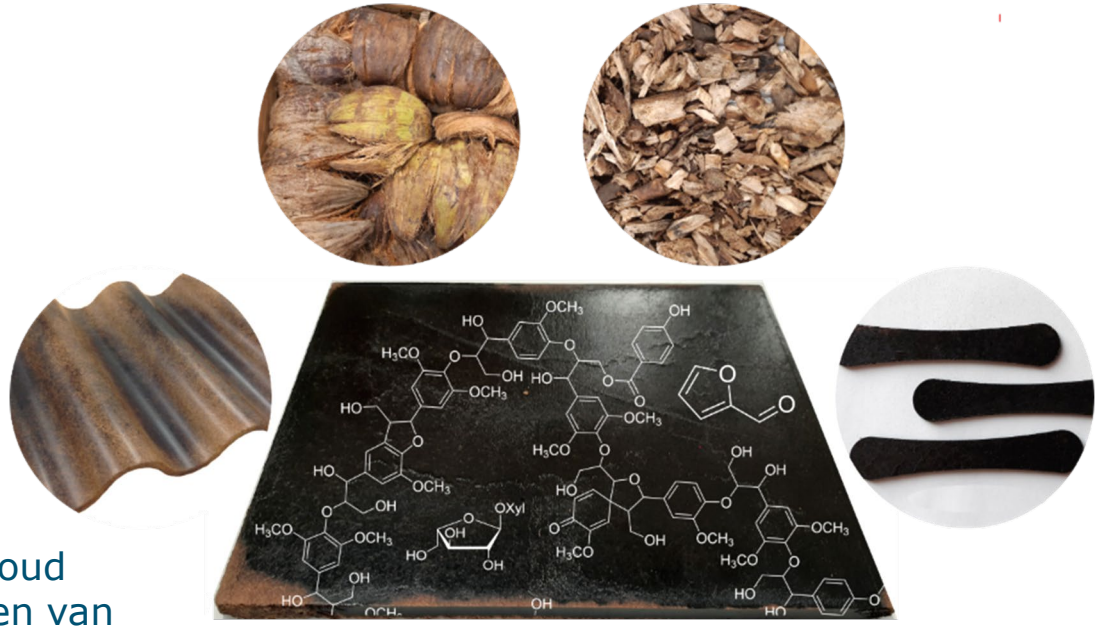
- New project: More with Binderless
  - Dutch “Topsector Kennis en Innovatie (TKI)” innovation agenda and subsidy tender
  - Consortium of knowledge institute WFBR and industrial partners

Call for partners – More with Binderless

- We are looking for industrial partners
  - To share their challenges, want and needs...
  - .... actively participate in this project and exploit the generated results.
- Value chain approach
  - Feedstock suppliers
    - Create added value using lignocellulose- and hemicellulose-containing side streams
    - Wood (processing) leftovers, nut shells, reed, miscanthus, roadside vegetation, coconut husk, molasses, ...
  - Technology providers
    - Create added value for their technological (processing) solutions
    - Compression molding equipment, extrusion molding equipment, ...
  - Product manufacturers and wholesalers
    - Create added value for their product portfolio
    - Interior materials, construction materials, furniture, packaging, horticultural products, complex 3D-shapes, ...

Thank you for your attention!

Any questions?



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