Zero Waste Ligno-Cellulosic Biorefineries by Integrated Lignin and Humins Valorisation

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ZELCOR

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Lignocellulosic biorefineries challenges

- Pulp & Paper industry
  - Increase pulp capacity by debottlenecking recovery boiler
  - Economic feasible outlets for side streams
- Biofuel/biochemical industry
  - Cellulosic bioethanol is more expensive
  - Focus on biochemicals or advanced biofuels
  - Economic feasible outlets for side streams
- Zelcor focusses on recalcitrant side streams by an integrated solution for conversion to value added products
  - Lignins
  - Humins

A consortium of 17 partners …

Academic Excellence in:

- **Lignin** chemistry
- **Biotechnology**
- **Insect** sciences
- **Bio-Products** design

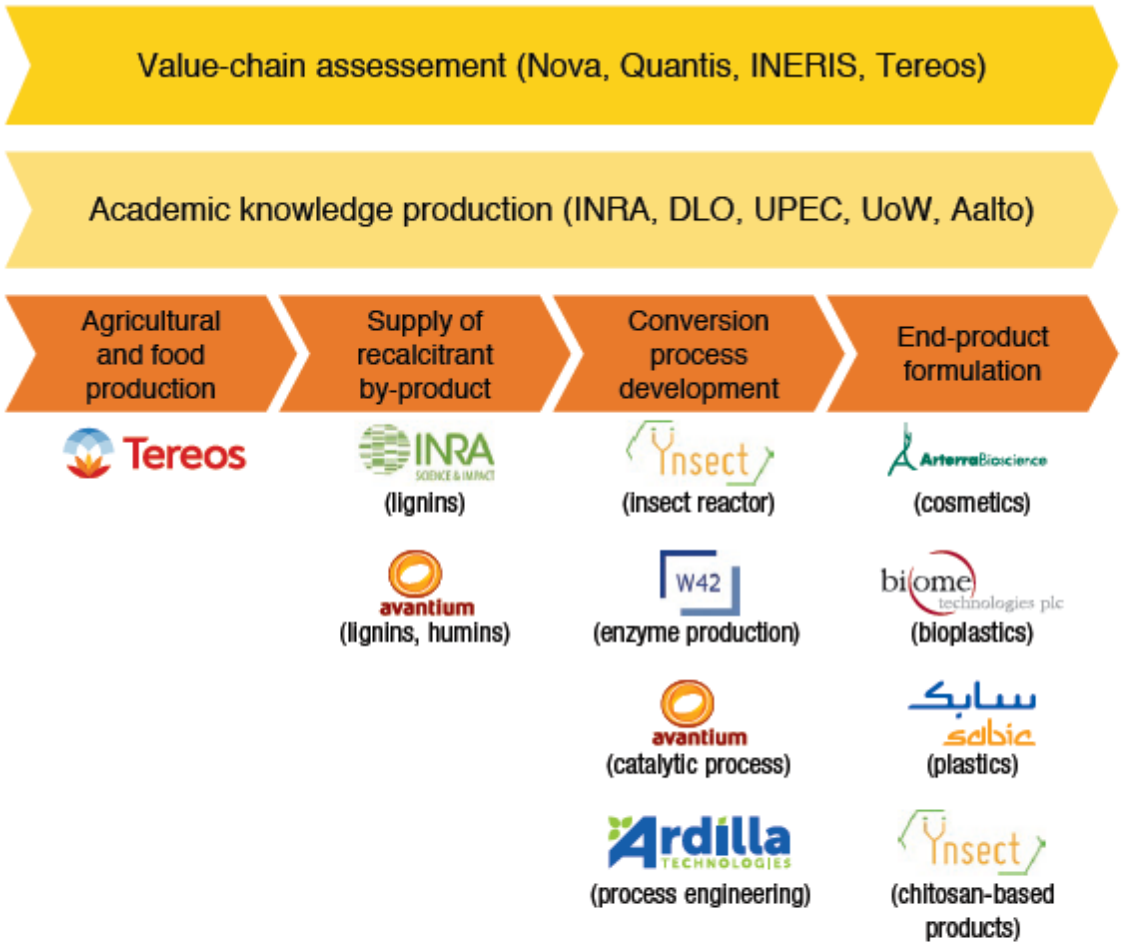
Key Industrial Actors for:

- **Lignocellulosic conversion**
- **Bioprocess engineering**
- **Enzyme production**
- **Biological activity screening**
- **Thermoplastics processing**
- **Bio-based polymers production**

Experts of Sustainability Assessment:

- **Environment (LCA)**
- **Safety**
- **Economy**

… to settle new value chains



End-Product Stakeholders

- Consumers
- Food Industry using plastic packaging and bottles
- Cosmetic Industry

… through a cascading approach

Lignocellulose recalcitrant by-products

FRACTIONATION

Functional Extracts

Antioxidants

Active Ingredients

Innovative technologies

Residue

CATALYTIC CONVERSION

Building Blocks

Bio-based Polymers

Residue

BIOCONVERSION

Chitin Feed, Biogas

New enzymes

Insect –based factory

Zelcor innovative features

- Several types of biorefinery residues representative of future industrial productions (humins, lignins, lignin-rich distillation residue)
- A common concept applied to all the substrates: zero waste and cascading processing strategy (extraction, self assemblying, depolymerisation, bioconversion)
- Implementation of innovative conversion routes fitting with green chemistry principles: combination of chemistry with biotech
- A wide range of new potential products (cosmetics, bioplastics, coatings, chemistry)

Selection of Raw materials

- Raw material selection
  - Variety in biomass source
  - Variety in extraction processes
  - Relevant process
- Production + distribution

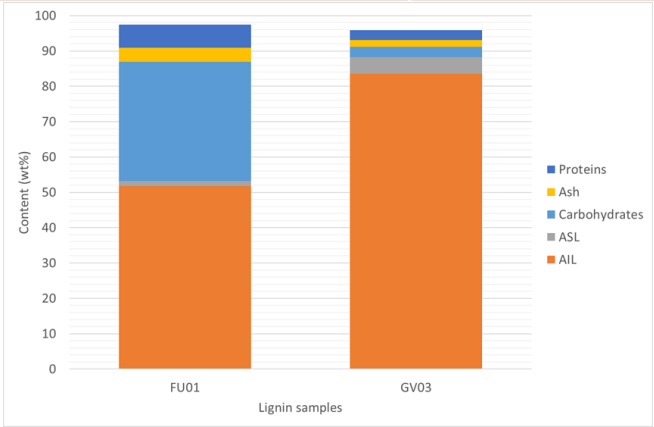
Lignins	Feedstock	Process	Supplier
P1000	Wheat straw / Sarkanda grass mix	Soda	Greenvalue LLC (US)
Distillation residue	Wheat straw	Futurol	PROCETHOL 2G (FR)
Zambezi	Spruce	HCl	Avantium (NL)

Humins	Feedstock	Process	Producer
Liquid humins	Sugars	YXY	Synvina (NL)

Raw material properties

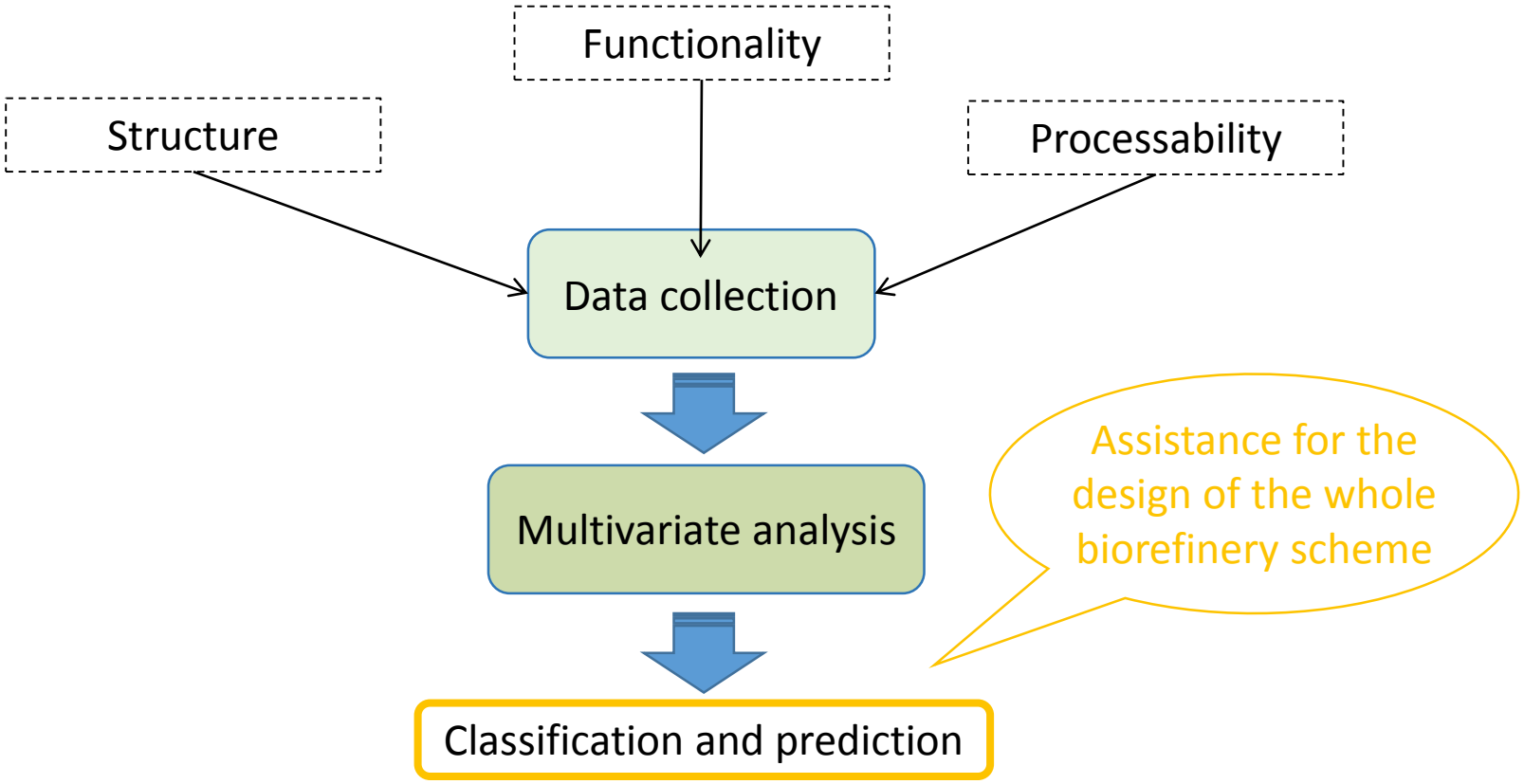
- *Lignins and humins were extensively characterised for composition, properties, functional groups etc.*

	HCl (Zambezi)	Soda (P1000)	Residue (Futurol)	Humins (YXY)
Dissolved during isolation	No	Yes	No	Yes
Soluble at RT	No	Yes, alkaline and some organic solvents	No	Yes, organic solvents
Non phenolic compounds	Sugars	Proteins, sugars	Sugars, proteins	Monomers, sugars
Mw	Unknown	Low	Unknown	Low
Ash content	Low	Low	High	Low



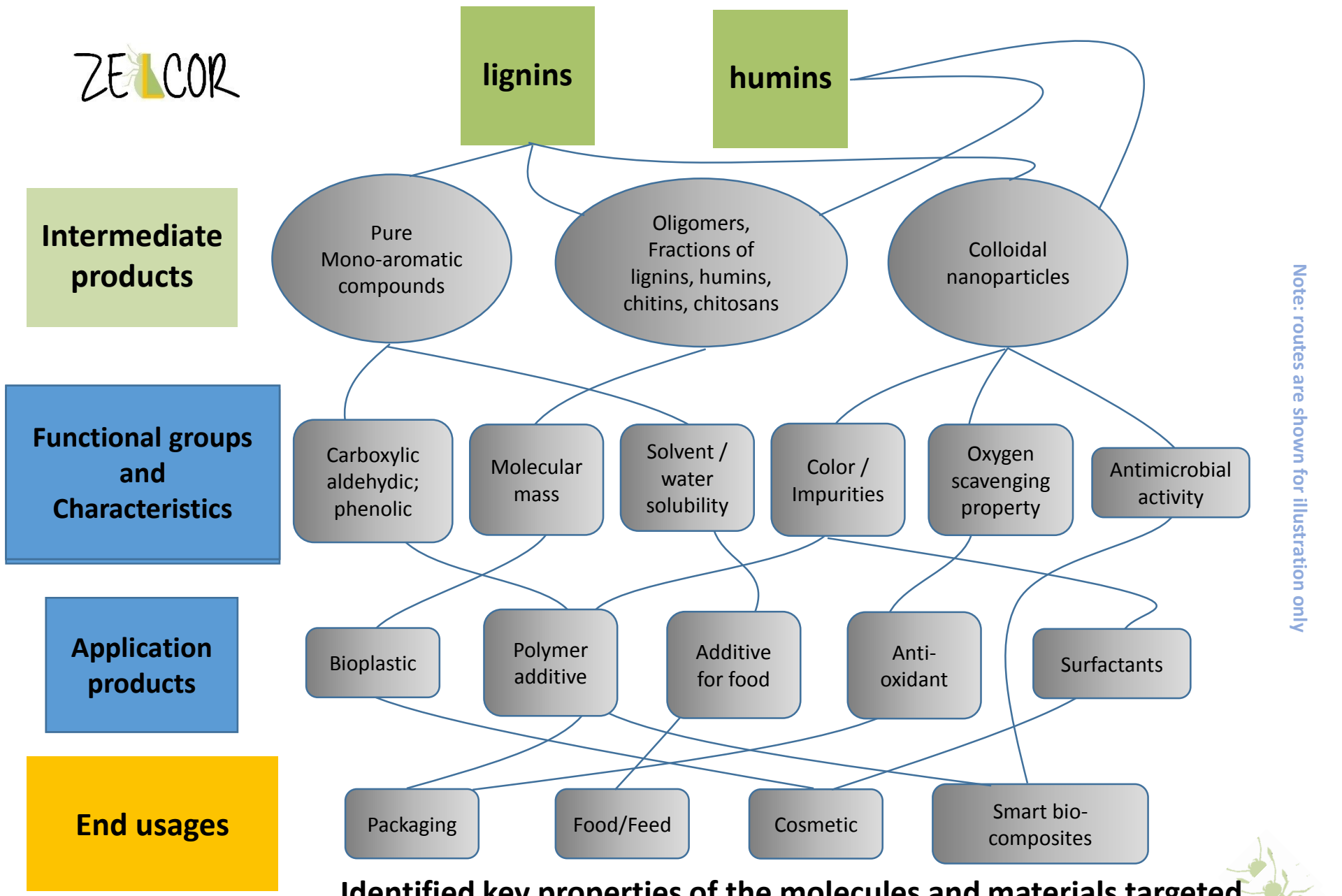
Variability assessment

- Variability of the raw materiel = botanical origin, production process, stability over time
- Impact of variability on the downstream conversion processes



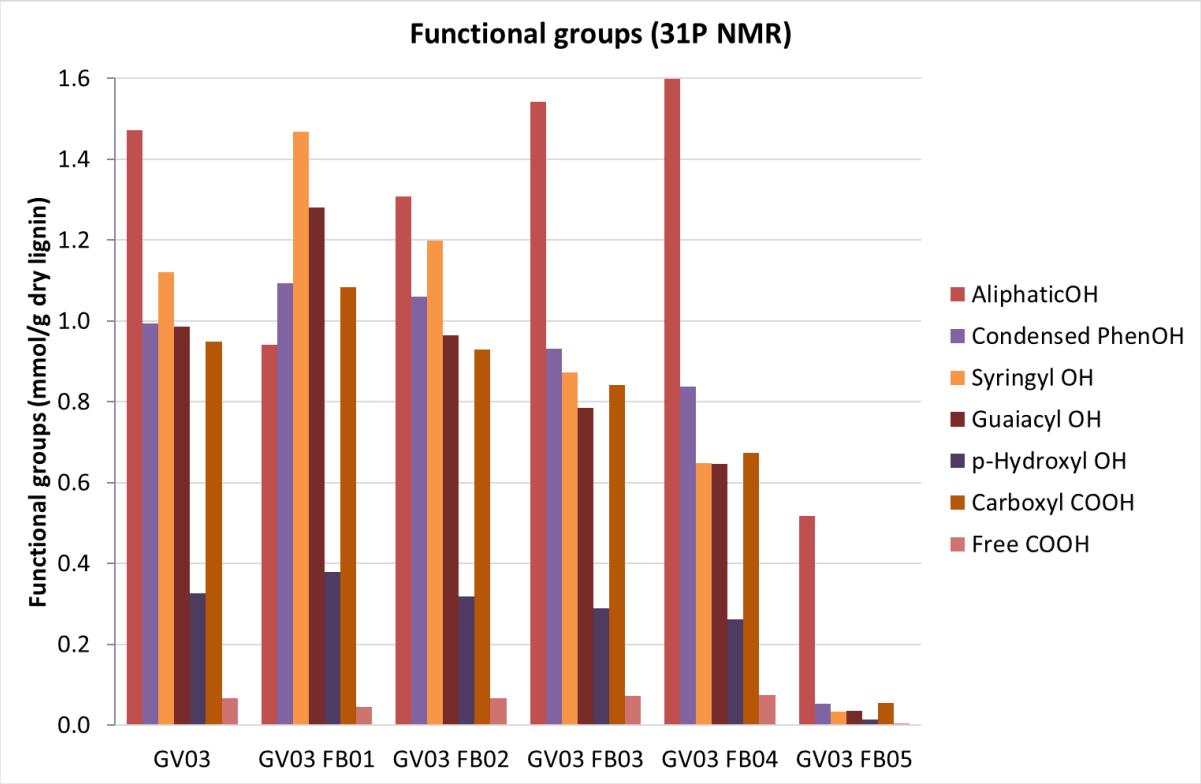
Functionality versus application

- To assess target functionalities for end-users and industrials
- To develop methods to screen new functionalities according to the products specifications
- To formulate the biomolecules, nanoparticles or preparations at laboratory scale to assess technical feasibility
- To identify the candidates for demonstration
- To build and implement the strategy to improve of the conversion process and provide biomolecules and nanoparticles of interest for further demonstration
- To provide data for the safety assessment of ZELCOR bio-based intermediates



Identified key properties of the molecules and materials targeted for the valorisation of lignins, humins and chitins / chitosans

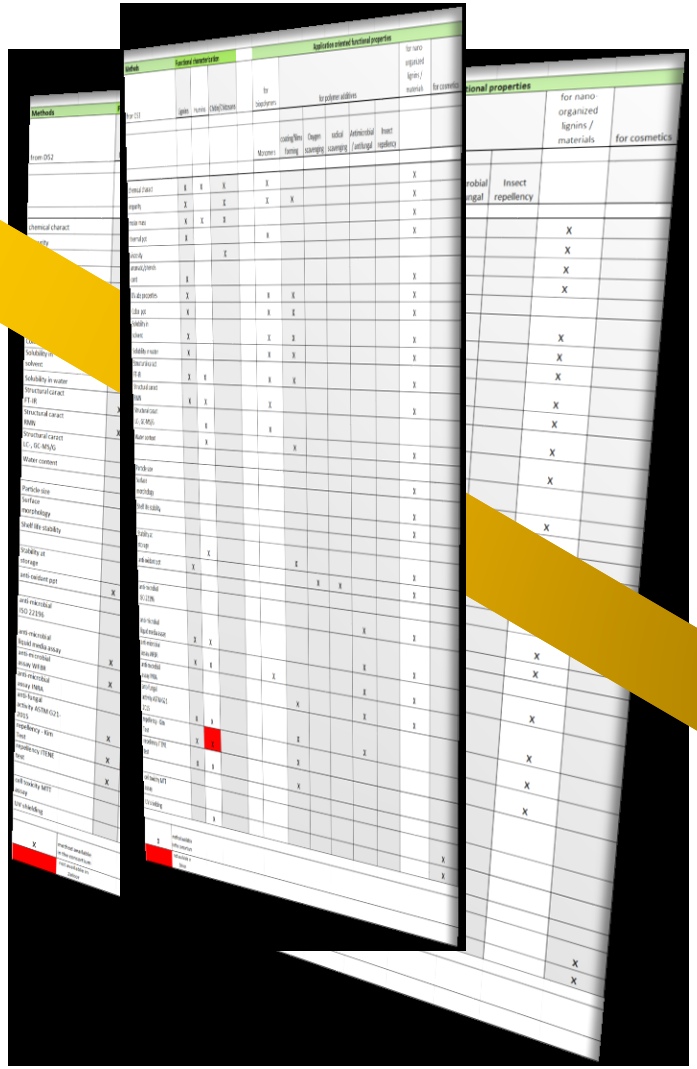
Lignin fractions functional group analysis



- In FB01 fraction higher aromatic OH and lower aliphatic OH
- Reversed tendency with the other fractions
- FB05 residue has a low solubility

Data base of 28 validated methods

What method to determine functionalities and screen new ones?



Products with adequate properties

Virtual platform of relevant and validated methods

Results at Month 18

- 4 raw material selected (industrial plant / pilots) all available at >50 kg scale: ready for process development
- 3 value chains identified for sustainability assessment
- 1 termite species (/16) selected : ready for bioreactor design
- 2 recombinant enzymes expressed in yeast: ready for immobilization and test on substrates in bioreactors
- 1 analytical platform settled gathering 30 methods: ready for the optimisation of intermediate products functionalities
- 4 main properties proved with quality criteria identified (biological activity, reactivity towards depolymerisation, antioxidant properties, self assemblying into particules)

Results at Month 18

- Demonstration of the interest of the cascading approach
  - Multi-functionality of the lignin fractions soluble in ethanol or ethyl acetate
  - Reactivity of the non-soluble fractions towards treatments by ionic liquid

CHEMISTRY & SUSTAINABILITY
CHEMSUSCHEM
ENERGY & MATERIALS

Imidazolium-Based Ionic Liquids as Efficient Reagents for the C–O Bond Cleavage of Lignin

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Future expectations

- Process development and design of purification and conversion of lignins and humins are ongoing
- Structure-property relationships will be established
- First application tests in packaging, cosmetics and particles in coatings are currently performed by industrial parties

- More information can be found:
  - www.bbi-europe.eu/projects/zelcor
  - www.zelcor.eu

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Summer School Announcement

- Zero waste biorefineries
- September 2-6 2018 in NL
- Focus on recalcitrant sidestreams
  - Lignin & Humins
- Specialised lecturers
- State-of-the-art
- Scientific knowledge
- Techno-economic evaluation
- LCA methodologies
- Case studies
- Biorefinery visit
- www.vlaggraduateschool.nl/en/courses/course/ZELCOR18.htm

Exploring Lignocellulosic Biomass 2018