VALORPLUS:
VALORISING BIOREFINERY BY-PRODUCTS

FP7 EC KBBE-CALL 7- Project No. 613802
VALORPLUS: VALORISING BIOREFINERY BY-PRODUCTS

Valorisation of biorefinery by-products leading to closed loop systems with improved economic and environmental performance

Objective:

• Develop new knowledge, technologies and products that will enable the valorisation of important biorefinery by-products.
• Sustainable and economically viable integrated closed loop biorefineries – with improved economic and environmental benefits.

With funding from the EU FP7 programme, the Valor Plus project consists of a strong consortium of 14 partners, including SMEs, research centres, universities and one large enterprise. The Valor Plus project is focused on the following key areas:

- **Pre-treatment and fractionation**: development of a novel methodology for the controlled breakdown, release and fractionation of the biomass by-products.

- **Hemicellulose, Lignin and Valorisation**: engineering of new enzymes and microorganisms, and combined chemo-enzymatic and chemo-microbial processes for the controlled hydrolysis and transformation of hemicellulose and lignin feedstocks to value product streams.

- **Glycerol Valorisation**: engineering of new microorganisms suitable for the fermentation of crude glycerol to higher value product streams.

- **Demonstration of the technological and economic potential**: demonstrating component technologies, roadmaps for technology and product stream integration, case studies and a full life cycle assessment.

http://www.valorplus.eu

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 613802.
Partners of ValorPlus

- Pan-European consortium spanning the complete biorefinery value chain; kick-off: 12/2013; end-date: 12/2017

- Involved countries:
  - UK
  - Germany
  - Spain
  - Austria
  - Italy
  - France

1 Large enterprise
ABENGOA RESEARCH

2 Research centres
CARTIF
Fraunhofer IFAM

8 Small and medium enterprises
A8A
asebio
Biobasic environment

3 Universities
Technische Universität München
Politecnico di Milano
Brunel University London
What is our goal?

Composition of lignocellulosic biomass

- Cellulose: 40-50%
- Hemicellulose: 20-30%
- Lignin: 10-25%

Valorisation already possible → Biofuels

Valorisation not sufficient

Valorplus
Preventing and valorising bio-waste in biorefineries
What is our goal?

Composition of lignocellulosic biomass

- Cellulose: 40-50%
- Hemicellulose: 20-30%
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• Pre-treatment and fractionation
• Hemicellulose and lignin valorisation
• Glycerol valorisation
• Demonstration of the technological and economic potential

Closed loop biorefinery
### The project idea: Road map for future products

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<thead>
<tr>
<th>Source</th>
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<td>• Fuels</td>
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<tr>
<td></td>
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Utilisation paths of hemicellulose hydrolysates from lignocellulosic biomass

**Products:**
1. Process for the enzymatic hydrolysis of hemicellulose
2. Process for the cloning and production of enzyme toolboxes
3. Enzyme toolboxes
4. High value monosaccharides and oligosaccharides
Paths for utilisation of high value hemicellulose oligomers

**Products:**
1. Process for the separation, purification and characterisation of oligosaccharides
2. Test method for the determination of pre-biotic properties of oligosaccharides
3. Functional food formulations

**Oligomers**
e.g., glucomanno- and arabinoxylo-oligosaccharides

**HPLC-ELSD**
Separation & purification

**ANEROBIC MICRO-REACTORS**

- Bacterial Population Analysis
- Microbial growth
- Beneficial metabolites

**Oligosaccharides**

**Bifidobactrium**
Pre-biotic assays

**Functional applications of oligosaccharides (oligomers)**

**Functional formulations**
Utilisation paths of C5 sugars and C5 sugars rich substrates by engineered Clostridium acetobutylicum

Genetic engineering & growth of microbial strains (Clostridium acetobutylicum)

Microbial growth → Strain selection → Strain engineering & growth

Microbial strains

Fermentation of C5 sugars rich substrates

Separation & purification

C5 sugars rich substrates

Products:
1. Process for the screening & engineering of microbial strains
2. Engineered microbial strains (Clostridium acetobutylicum) for the optimised fermentation of C5 sugars to acetone and butanol
3. Processes for the optimised fermentation of C5 sugars rich substrates to acetone and butanol
4. Acetone and butanol
Utilisation paths of C5 sugars and C5 sugars rich substrates by yeast strains

**SCREENING & GROWTH OF MICROBIA STRAINS (YEAST)**

- Microbial growth
- Strain selection
- Optimised microbial growth

C5 sugars rich substrates → Microbial strains → Aerobic fermentation of C5 sugars rich substrates → Single cell proteins (SCP)

- Microbial strains → Anaerobic fermentation of C5 sugars rich substrates → Separation & purification → Ethanol (Biofuel)

- Microbial strains → Anaerobic fermentation of C5 sugars rich substrates → Separation & purification → Xylitol

Products:
1. Process for the screening and growth of microbial strains (yeast)
2. Selected microbial strains (yeast) for the production of SCP, ethanol, xylitol, acetic acid & sugar alcohols
3. Processes for the optimised fermentation of C5 sugars rich substrates
4. SCP, ethanol, xylitol, acetic acid, sugar alcohols (e.g., arabitol, mannitol or butanediol)
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|            | Oligomers        | • Pharmaceutical and medicinal applications                             |
| Lignin     | Lignin monomers  | • Bioresins                                                             |
|            | Lignin macromolecules | • Functional additives                                                   |
| Plant oils | Biodiesel        | • Aromatic Platform Chemicals (benzene, toluene, xylene, phenol, vanillin) |
|            | Crude glycerol   | • Biodiesel                                                             |
|            |                  | • Lipids and alcohols                                                  |
|            |                  | • Valuable organic acids                                               |
**Lignin valorization**

**ENZYME SCREENING & ENGINEERING**

- Model lignin polymers
- Enzyme libraries
- Enzyme toolbox

**Lignin fractions**

- Enzyme toolbox
  - Selective chemo-enzymatic depolymerisation
  - Separation & purification

- Enzymatic transformation & functionalisation

**Products:**

1. Process for the screening & engineering of enzymes
2. Process for chemo-enzymatic depolymerisation and transformation of lignin
3. Engineered enzyme toolboxes for lignin depolymerisation and transformation
4. High value lignin by-products (monomers, macromolecules and functionalised lignin derivatives)

**Separation & purification**

- Monomers and macromolecules

**Characterisation of lignin derivatives**

- High value monomers and macromolecules

**High value lignin derivatives**
Paths for utilisation of lignin and its derivatives

Products:
1. Process for the formulation of coatings (paints)
2. Process for formulation of adhesives
3. Paints and adhesives
4. Process for formulation and production of packaging biopolymer films
5. Packaging biopolymer films
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- Hemicellulose
- Lignin
- Plant oils

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- C5 & C6 sugars
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Products:
1. Process for the screening & engineering of microbial strains
2. Engineered microbial strains for the fermentation of glycerol
3. High value glycerol by-products (lactic acid & 1,3-Propanediol)
Summary

- **Goal**: Valorisation of the underused parts of plant biomass: lignin, hemicellulose, glycerol
  - There should be no waste streams: closed-loop biorefinery!
  - Let's produce more than just biofuels!

- **Next Steps:**
  - **Demonstration**: Linking the achievements & optimizing of process flows
  - **Calculation for the rentability**: Upscaling, LCA …

  Do we have what it takes to change the art of biorefinery?
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