"Chemical composition and biofuels potentials of various vegetal biomasses"

Godin, Bruno ; Agneessens, R. ; Schmit, T. ; Lamaudiere, Stéphane ; Goffart, Jean-Pierre ; Gerin, Patrick A. ; Stilmant, D. ; Delcarte, J.

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Chemical composition and biofuels potentials of various vegetal biomasses

B. Godin\textsuperscript{1,2}, R. Agneessens\textsuperscript{1}, T. Schmit\textsuperscript{1}, S. Lamaudière\textsuperscript{2}, J.-P. Goffart\textsuperscript{1}, D. Stilmant\textsuperscript{1}, P. Gerin\textsuperscript{2}, J. Delcarte\textsuperscript{1}

b.godin@cra.wallonie.be

\textsuperscript{1}Centre wallon de Recherches agronomiques (CRA-W)
Valorisation of Agricultural Products Department - Biomass, Bioproducts and Energy Unit

\textsuperscript{2}Université catholique de Louvain (UCL)
Earth & Life Institute - Bioengineering group
Context

Fossil fuels

- High greenhouse gas production → Climate change
- High fossil fuel dependence → Price volatility and Uncertain availability

Vanholme, 2012
Context

Biofuels

- Biomass → Renewable source of energy and products
- Development of a sustainable bio-based economy

Vanholme, 2012
Context

- Development of a sustainable bio-based economy
  - Requires a good knowledge of the contents and molecular composition of the chemical components of plant biomasses

Adapted of Ragauskas et al., 2006
**Context**

- **Fibrous crop biomasses**
  - Non-food crops
  - Low input requirements → Low greenhouse gas production
  - Grow in tough pedoclimatic conditions → Acceptable dry matter yield per hectare

- **Examples**

<table>
<thead>
<tr>
<th>Perennial crops</th>
<th>Annual crops</th>
<th>Residues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscanthus</td>
<td>Hemp</td>
<td>Spelt straw</td>
</tr>
<tr>
<td>Switchgrass</td>
<td></td>
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<tr>
<td>Tall fescue</td>
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</tbody>
</table>

Adapted of ENERBIOM, 2012
Chemical composition of biomasses

Structural components of cell walls

- **Lignin (5-15%)**
- **Hemicelluloses (10-30%)**
- **Cellulose (20-40%)**

- **Cellulose** → Linear polysaccharide homogeneously, glucose units
- **Hemicelluloses** → Ramified heterogeneous polysaccharides mainly, xylose units
- **Lignin** → Phenyl propanoid polymer, syringyl, guaiacyl and p-hydroxyphenyl units
- **Other components** → Pectins, soluble sugars, proteins, mineral compounds

Adapted of Gnansounou, 2006
Aim of this study

- **Relationship between chemical composition and biofuel potentials of plant biomasses**
  - On a wide diversity of plant biomasses

- **Fast biofuel potentials assessment**
  - Anaerobic digestion potential → Enzymatically digestible organic matter (DOM)
  - Bioethanol potential → Theoretical conversion of carbohydrates to ethanol
  - Combustion potential → Higher heating value (HHV) and Dry matter content

- **Chemical composition of plant biomasses**
  - Cellulose, Hemicelluloses, Lignin, Total soluble sugars, Starch, Proteins
  - Mineral compounds
Relationship between chemical composition and biofuel potentials of plant biomasses

- **Chemical composition of plant biomasses**
  - A wide diversity of biomasses
    → A wide diversity of chemical components contents
  - **8 distinctive biomass groups**
    - Phylogenetic origin
      → Commelinids: A subgroup of monocotyledons (e.g. miscanthus, tall fescue, spelt, corn) → Higher hemicelluloses content
      → Non-commelinid magnoliophyta: Dicotyledons (e.g. hemp, potato, sunflower, chicory) and a subgroup of monocotyledons (e.g. onion) → Lower hemicelluloses content (substituted by pectins)
      → Pinophyta: Coniferous species (e.g. aspen) → Very high lignin content
    - Fiber content → Degree of cell wall lignification
Chemical composition of plant biomasses

- 8 distinctive biomass groups:
  - **CO-FI**: Commelinid fibrous biomass (e.g. miscanthus, switchgrass, spelt straw)
  - **CO-LF**: Commelinid less fibrous biomass (e.g. fiber sorghum, fescue)
  - **CO-ST**: Commelinid high starch biomass (e.g. fiber corn)
  - **NC-WO**: Non-commelinid woody biomass (e.g. willow, aspen and oak wood)
  - **NC-FI**: Non-commelinid fibrous biomass (e.g. hemp, sunflower stalk, flax straw)
  - **NC-LF**: Non-commelinid less fibrous biomass (e.g. potato leaf, alfalfa, cabbage leaf)
  - **NC-SU**: Non-commelinid high sugars biomass (e.g. chicory tuber, onion bulb)
  - **PI-WO**: Pinophyta woody biomass (e.g. aspen, pine and larch wood)
Rapid biofuel potentials assessment

- Anaerobic digestion potential
  - Enzymatically digestible organic matter (DOM)
    - High suitability → Low degree lignification
    - Cellulose and Lignin

![Graph showing enzymatically digestible organic matter (DOM) for different plant species.]

- e.g. Switchgrass
- e.g. Tall fescue
- e.g. Fiber corn
- e.g. Willow wood
- e.g. Hemp
- e.g. Potato leaf
- e.g. Chicory tuber
- e.g. Aspen wood
Rapid biofuel potentials assessment

- Ethanol potential from structural carbohydrates
  - **Structural carbohydrates**
    - High suitability → Cellulose and/or Hemicelluloses
    - Pretreatment severity → Lignin

<table>
<thead>
<tr>
<th>Material</th>
<th>Cellulosic ethanol</th>
<th>Hemicellulotic ethanol</th>
<th>Total soluble sugar ethanol</th>
<th>Starch ethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO-FI (n=382)</td>
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<tr>
<td>e.g. Switchgrass</td>
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<tr>
<td>CO-LF (n=348)</td>
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<td>e.g. Tall fescue</td>
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<td>CO-ST (n=146)</td>
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<td>e.g. Fiber corn</td>
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<tr>
<td>NC-WO (n=8)</td>
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<tr>
<td>e.g. Willow wood</td>
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<tr>
<td>NC-FI (n=123)</td>
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<td>e.g. Hemp</td>
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<tr>
<td>NC-LF (n=21)</td>
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<td>e.g. Potato leaf</td>
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<tr>
<td>NC-SU (n=8)</td>
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<td>e.g. Chicory tuber</td>
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<tr>
<td>PI-WO (n=3)</td>
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<tr>
<td>e.g. Aspen wood</td>
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</table>
Rapid biofuel potentials assessment

- Ethanol potential from non-structural carbohydrates
  - Non-structural carbohydrates
    - High suitability → Total soluble sugars and/or Starch

![Bar chart showing ethanol potentials from different biomass sources](chart.png)
Rapid biofuel potentials assessment

- **Combustion potential**

  - **Higher heating value (HHV)**
    - High suitability → High degree lignification
    - Organic matter and Lignin
  
  - **Dry matter content**

![Graph showing HHV and dry matter content for different materials](image_url)
Relationship between chemical composition and biofuel potentials of plant biomasses

- **Essential variables**: Cellulose, Hemicelluloses and Mineral compounds

![Graph showing the relationship between chemical composition and biofuel potentials of plant biomasses]

- **NC-LF**: e.g. Potato leaf
- **NC-SU**: e.g. Chicory tuber
- **NC-FI**: e.g. Hemp
- **CO-LF**: e.g. Tall fescue
- **CO-ST**: e.g. Fiber corn
- **CO-FI**: e.g. Switchgrass
- **NC-L1**: e.g. Willow wood
- **PI-WO**: e.g. Aspen wood

Legend:
- Anaerobic digestion
- Bioethanol from structural carbohydrates
- Bioethanol from non-structural carbohydrates
- Combustion
Conclusions

- Each type of biomass generally suits to better to a given energy conversion processes
  - Intrinsic chemical properties of the biomass
  - Specificity of each type of energy conversion process

- Suitability assessment
  - Chemical composition → Fast assessment method of each process

- Most important chemical component to assess biofuel potential
  - Cellulose
  - Hemicelluloses
  - Mineral compounds
Thank you for your attention

Questions ?