RT-Algae: an integrated cultivation, harvesting, dewatering and conditioning process of microalgal biomass for biofuel and high value compounds production

Achieving Advancements in Algae Development, Wednesday, July 22, 2015

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3 Rio Tinto Alcan, Centre de recherche et développement Arvida, Jonquière, QC, Canada.
4 Innofibre, Trois-Rivières, QC, Canada.
Context of the RTA Project

- Rio Tinto Alcan (aluminium producer) interested in processing biomass for biofuels in colocation with their smelter plant in Alma, QC, Canada

- Use of Algal biomass
  - Reuse of heating losses
  - Use of smelter wastewaters
  - Local C, N, P sources

- For 4 years: researches and proposal of the RT-Algae Process
RT-Algae Process

Diagram: Flowchart showing the process of RT-Algae, including steps such as wastewater and carbon byproduct recycling, local dairy by-product, urea, P, Mg, Fe, biogas, anaerobic digestion, digestate, wet way I, switchable solvents extraction, residual biomass, green solvent, oil separation - solvents recovery, wet way II, harvesting and dewatering in a fourdriner of a paper machine, HTL, biocrude, oil extraction by distillation, transesterification, biodiesel, RTA vehicles fleet, green diesel, effluents gas (CO₂, heat), recycling water, drying, combustion, and heat.
RT-Algae Process
Cultivation

- Native strain: algae-bacteria consortium dominated by *Chlorella sp.*, isolated from smelter plant wastewaters / well adapted

- Strain can tolerate various C, N sources
  - cellulosic sugars: hydrolyzates from corn residues, alfalfa residues
  - hay or corn silage juices
  - dairy by-products
  - struvite

CHRTB Consortium

Up to 100L cultivation with alfalfa hydrolyzates
Large scale cultivation

- AlgaFuel™ 10 m³ tank
- Mixotrophic conditions: Productivity between 0.73 and 0.82 g.L⁻¹.d⁻¹; Alternative C,N sources to be tested
Pulp and paper technologies for harvesting and dewatering

- Pulp and paper industry: expert in «biomass» dewatering (decades of experience)
- Already scaled up
- Works on energy saving in progress
- Low energy vs conventional methods
- Equipment availability
Fourdrinier: wet section of a paper machine

- Dryer section
- Wet press section
- Wet end
Fourdrinier : wet section of a paper machine

Microalgae biomass adding

Vacuum box (6 vacuum pumps)

Top former

Canvas

Pulp adding
Headbox

Microalgae biomass

Conversion step

Fibers
Goal of this present work

Test laboratory devices to assess the feasibility of harvesting and dewatering microalgal culture on the Fourdrinier of a paper machine (Innofibre pilot plant)

**Studied parameters**

- Flocculants (type and %)
- Fibers added (type)
- Methods (type of sheet former)
# Flocculation methods

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Electrocoagulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cationic polyacrylamide</td>
<td>Sacrificial anode</td>
</tr>
<tr>
<td>0%, 1%, 3%</td>
<td>10 A DC</td>
</tr>
<tr>
<td></td>
<td>15 minutes</td>
</tr>
</tbody>
</table>
Fibers

**Paper pulp**

- **Kraft** (890$ US / T)
- **CTMP** (755$ US / T)
- **Recycled cardboard** (150$ US / T)
  (unbleached kraft)

**Ground wood**

- (280$ US / T)
Methods: Pulp and paper laboratory devices

**Dynamic sheet former**
- Dewatering by centrifugation force
  - Algae: 660 g/m² (95%)
  - Fibers: 2 layers of 21,35 g/m² (5%)
  - 4 types of fibers
  - Flocculant 0%, 1%, 3%

**Static sheet former**
- Dewatering by slight vacuum
  - Algae: 330 g/m² (95%)
  - Fibers: 1 layer of 21,35 g/m² (5%)
  - Flocculant 1% vs electrocoagulation
Results - Dynamic sheet former

**Flocculant proportions with kraft fiber**

<table>
<thead>
<tr>
<th>% dryness</th>
<th>% of harvested microalgae</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>69</td>
</tr>
<tr>
<td>13</td>
<td>73</td>
</tr>
<tr>
<td>14</td>
<td>62</td>
</tr>
</tbody>
</table>

% dryness: 3% 1% 0%

**Fiber types with 1% flocculant**

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<tr>
<td>13</td>
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</tr>
<tr>
<td>14</td>
<td>66</td>
</tr>
<tr>
<td>21</td>
<td>73</td>
</tr>
</tbody>
</table>

% dryness: Kraft CTMP Wood ground Recycled cardboard (kraft)
Results - Dynamic sheet former

- 1% flocculant
- Kraft fiber or cardboard recycled kraft fiber: retained more than 99% of microalgae
- % of harvested microalgae limited by the device
Results - Static sheet former

Flocculant types with kraft fiber

% dryness

% retention

Control
+ 10 minutes vacuum
Electrocoagulation

1% flocculant

11
16
11
98
99
97
Results - Static sheet former

» 1% flocculant and electrocoagulation equivalent

» Longer vacuum time increases the dryness

Sheets

Filtrate
Conclusion

- The use of flocculant is required
- Electrocoagulation can replace the flocculant
- Kraft fibers are more appropriate to make a coat on the canvas to retain microalgae and reduce clogging
- Recycled cardboard fibers may be an alternative

- Test laboratory devices demonstrated the feasibility of harvesting and dewatering microalgae biomass on the fourdrinier of a paper machine
Conclusion

» Estimation of energy input for harvesting and dewatering microalgae biomass:

<table>
<thead>
<tr>
<th>Harvesting Technologies</th>
<th>Energy Input (kWh/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifugation</td>
<td>3.300&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Fourdrinier paper machine</strong></td>
<td>0.054 – 0.387</td>
</tr>
</tbody>
</table>

<sup>a</sup> NAABB final report, 2014
Work in progress

» Tests on the fourdrinier of the paper machine at Innofibre pilot plant

» VERTECH and EBI co-location projects
  • high value products for locales industries

» HTL on biomass harvested with pulp and paper technologies (presence of fibers, effect of electrocoagulation, effect of wastewater...)

Results will be presented by Guillaume Pilon
Acknowledgements

» Innofibre team (Daniel Thiboutot, Simon Fréchette, Josée Doucet)

» CRIEB team (Sabrina Rondeau, Michèle Deshaies, Alexandre Moreau)