Fluid Dynamic Properties
of Bacterial Cellulose
and Application

By Andrew Keefe
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Cellulose Sources and Function

- **Cellulose**
  - β-glucose monomers (β-1,4-Glucan)
  - Strength, absorptive properties

- **Plant Cellulose**
  - Cotton, wood

- **Microbial (bacterial) cellulose**
  - Pure cellulose
  - Acetobacter Xylinum
Acetobacter Xylinum

- Aerobic, gram negative
- Most productive cellulose producing bacterium
- Cellulose pellicle
Cellulose Growth

- Glucose, oxygen, nutrients and minerals
- Optimal Growth
- Bioreactor
• *Acetobacter xylinum*’s carbon pathway during digestion of glucose into cellulose and cellular energy.
Growth: Glucose

<table>
<thead>
<tr>
<th>Glucose Concentration</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 g/L</td>
<td>17.82 g</td>
</tr>
<tr>
<td>20 g/L</td>
<td>17.71 g</td>
</tr>
<tr>
<td>30 g/L</td>
<td>15.90 g</td>
</tr>
<tr>
<td>40 g/L</td>
<td>16.18 g</td>
</tr>
<tr>
<td>50 g/L</td>
<td>17.30 g</td>
</tr>
</tbody>
</table>

Mass of Cellulose vs Glucose Concentration
Growth: Glucose Free Media (GFM)

<table>
<thead>
<tr>
<th>Glucose Free Media Concentration</th>
<th>x0.5</th>
<th>x1.0</th>
<th>x1.5</th>
<th>x2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>11.63</td>
<td>14.93</td>
<td>19.58</td>
<td>25.54</td>
</tr>
</tbody>
</table>

Cellulose Mass vs GFM concentration
Glucose and GFM effect on Cellulose produced

![Graph showing the relationship between Cellulose mass and GFM concentration and Glucose concentration. The graph indicates a positive correlation between the GFM concentration and Cellulose mass, with a slight decrease in Cellulose mass as the Glucose concentration increases.](image-url)
Oxygen: Airflow

<table>
<thead>
<tr>
<th>Glucose Concentration</th>
<th>10 g/L</th>
<th>20 g/L</th>
<th>30 g/L</th>
<th>40 g/L</th>
<th>50 g/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>16.25 g</td>
<td>27.17 g</td>
<td>15.87 g</td>
<td>31.03 g</td>
<td>33.21 g</td>
</tr>
<tr>
<td>Degree of Cotton Packing</td>
<td>Heavy</td>
<td>Medium</td>
<td>Heavy</td>
<td>Light</td>
<td>Light</td>
</tr>
</tbody>
</table>

Cellulose Mass vs Glucose Concentration and Degree of Cotton Packing
Drying
Absorption Testing

- Cellulose Thickness
- Treatment in Sodium Hydroxide
Treatment

- Boiling in 1M Sodium Hydroxide (NaOH)
- Removal of cells
- Effect on absorption
<table>
<thead>
<tr>
<th>Relative Pellicle Thickness</th>
<th>Sodium Hydroxide (NaOH)</th>
<th>Water (H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>3.8 mm</td>
<td>1.75 mm</td>
</tr>
<tr>
<td></td>
<td>4.0 mm</td>
<td>1.8 mm</td>
</tr>
<tr>
<td>Regular</td>
<td>3.9 mm</td>
<td>1.8 mm</td>
</tr>
<tr>
<td></td>
<td>3.9 mm</td>
<td>1.7 mm</td>
</tr>
<tr>
<td>Thick</td>
<td>4.1 mm</td>
<td>1.9 mm</td>
</tr>
<tr>
<td></td>
<td>4.1 mm</td>
<td>1.9 mm</td>
</tr>
</tbody>
</table>

**Main Effects Plot for Height**

- **NaOH Treatment**
  - No
  - Yes

- **Pellicle Thickness**
  - Light
  - Regular
  - Thick
The P value <0.001 in both cases. The P-value being the probability of rejecting the null hypothesis when it is true (Type I error).
Convergence Experiment
“Bunny Ears”

- Distance and rate of flow
- Test mixing ability of converging flows
Nano-Scale Laminar Flow Reactors (Axial and Lateral)

- Axial Reactor
  - Minor ability for flow
- Lateral Reactor
Results and Conclusion

- GFM and Oxygen played integral roles in producing higher quantities of cellulose.
- Cellulose thickness had no effect on absorption.
- Removal of embedded cells positively affected absorption.
- Rapid mixing between converging flows in cellulose resulted in immediate mixing.
- Potential is created for a lateral nano-scale laminar flow reactor.
Future Studies

- Differential equations to describe fluid flow through cellulose
- Construction of an enzymatic cellulose membrane (nano-scale laminar flow reactor)
- Differential equations modeling the reactivity of the enzymatic membrane
- Automated fed batch growth (multiple media additions)
Literature Cited

- Brown, Malcolm R. “Microbial Cellulose: A New Resource for Wood, Paper, Textiles, Food and Specialty Products” Position Paper, University of Texas at Austin, Austin, Texas

