No-cook process at very high gravity of various cassava starches for ethanol production

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Comparison of bioethanol production from different energy crops.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield (ton ha⁻¹ year⁻¹)</th>
<th>Conversion rate to bioethanol (L ton⁻¹)</th>
<th>Bioethanol yield (L ha⁻¹ year⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>70</td>
<td>70</td>
<td>4900</td>
</tr>
<tr>
<td><strong>Cassava</strong></td>
<td><strong>23</strong></td>
<td><strong>150</strong></td>
<td><strong>3450</strong></td>
</tr>
<tr>
<td>Sweet sorghum</td>
<td>35</td>
<td>80</td>
<td>2800</td>
</tr>
<tr>
<td>Maize</td>
<td>5</td>
<td>410</td>
<td>2050</td>
</tr>
<tr>
<td>Wheat</td>
<td>4</td>
<td>390</td>
<td>1560</td>
</tr>
<tr>
<td>Rice</td>
<td>5</td>
<td>450</td>
<td>2250</td>
</tr>
</tbody>
</table>

Ethanol Production from cassava

Why Cassava

Cost structures of the ethanol production from fresh cassava roots

- Feedstock cost 65%
- Net Operating cost 19%
- Investment cost 16%

Sugary cassava root

Special starches

Flour

Cellulose

Fermentation

Hydrolysis

Pretreatment

Ethanol

By-products

Sorapipatana & Yoosin, 2011
Cassava special starches
CIAT developed unique genotypes in the world

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Amylose content (%)</th>
<th>Granule size (µm)</th>
<th>Crystallinity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waxy cassava</td>
<td>0.0</td>
<td>16.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Small Granule</td>
<td>26</td>
<td>5.8</td>
<td>-</td>
</tr>
<tr>
<td>Double mutant</td>
<td>0.0</td>
<td>6.5</td>
<td>-</td>
</tr>
<tr>
<td>Normal Cassava</td>
<td>16.8</td>
<td>15.1</td>
<td>35.0</td>
</tr>
</tbody>
</table>

![Waxy cassava](image1)

![Small granule](image2)
Very High Gravity (VHG): 30% dry matter

Increasing plant capacity and reduction in capital costs
Increasing plant efficiency
Reducing risk of contaminating bacteria

**Simultaneous Saccharification and Fermentation (SSF)**
Dry matter content during SSF process

- Waxy cassava (AM 206-5)
- Rice
- Double mutant (AM 1290-1)
- Normal Cassava (Cumbre-3)
- Small Granule (GM 4694-1)
- Double mutant (AM 1288-17)
Evolution of the concentration of Glucose during SSF process

- Rice
- Waxy cassava (AM 206-5)
- Double mutant (AM 1290-1)
- Small Granule (GM 4694-1)
- Double mutant (AM 1288-17)
- Normal Cassava (Cumbre-3)
Ethanol production during SSF process

- Small Granule (GM 4694-1)
- Normal Cassava (Cumbre-3)
- Double mutant (AM 1288-17)
- Double mutant (AM 1290-1)
- Rice
- Waxy cassava (AM 206-5)

Optimum
# Ethanol yield during SSF process

<table>
<thead>
<tr>
<th>Starch</th>
<th>Genotype</th>
<th>Characteristic</th>
<th>90 hours</th>
<th>160 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava</td>
<td>GM 4694-1</td>
<td>Small granule</td>
<td>80.1</td>
<td>84.9</td>
</tr>
<tr>
<td>Cassava</td>
<td>Cumbre-3</td>
<td>Normal</td>
<td>70.1</td>
<td>84.7</td>
</tr>
<tr>
<td>Cassava</td>
<td>AM 1288-17</td>
<td>Double mutant</td>
<td>68.2</td>
<td>80.1</td>
</tr>
<tr>
<td>Cassava</td>
<td>AM 1290-1</td>
<td>Double mutant</td>
<td>53.0</td>
<td>67.8</td>
</tr>
<tr>
<td>Cassava</td>
<td>AM 206-5</td>
<td>Waxy</td>
<td>33.4</td>
<td>42.4</td>
</tr>
<tr>
<td>Rice</td>
<td>Rice</td>
<td>Normal</td>
<td>39.0</td>
<td>57.9</td>
</tr>
</tbody>
</table>

* The conversion efficiency was calculated from the theoretical yields
Highest rate of hydrolysis with Small Granule Cassava (GM 4694-1) and Double Mutant (AM 1290-1)

Combination of:
1) Small granule variety
2) Very high gravity fermentation process
Enables high ethanol yield at lower costs and shorter time – nearly 3 days faster for same ethanol production as the control
Thank you!

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