Simultaneous Liquefaction, Saccharification and Fermentation for Ethanol Production from Cassava and Valorisation of By-products for Animal Feeding

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Presentation outline

• Cassava production in Vietnam
• Innovative and energy-saving processes for cassava-based ethanol production
• Adding values to ethanol by-products for animal feeding
## Cassava production in Vietnam

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (1,000 ha)</th>
<th>Yield (tons/ha)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>226.80</td>
<td>7.96</td>
<td>1,805,328</td>
</tr>
<tr>
<td>2000</td>
<td>237.60</td>
<td>8.36</td>
<td>1,986,300</td>
</tr>
<tr>
<td>2001</td>
<td>250.00</td>
<td>8.30</td>
<td>2,075,000</td>
</tr>
<tr>
<td>2002</td>
<td>329.90</td>
<td>12.60</td>
<td>4,156,740</td>
</tr>
<tr>
<td>2003</td>
<td>371.70</td>
<td>14.06</td>
<td>5,226,102</td>
</tr>
<tr>
<td>2004</td>
<td>370.00</td>
<td>14.49</td>
<td>5,361,300</td>
</tr>
<tr>
<td>2005</td>
<td>425.50</td>
<td>15.78</td>
<td>6,716,200</td>
</tr>
<tr>
<td>2006</td>
<td>474.80</td>
<td>16.25</td>
<td>7,771,400</td>
</tr>
<tr>
<td>2007</td>
<td>496.80</td>
<td>16.07</td>
<td>7,984,920</td>
</tr>
<tr>
<td>2008</td>
<td>560.00</td>
<td>16.05</td>
<td>8,988,000</td>
</tr>
<tr>
<td>2009</td>
<td>508.80</td>
<td>16.82</td>
<td>8,556,900</td>
</tr>
<tr>
<td>2010</td>
<td>496.20</td>
<td>16.50</td>
<td>8,521,600</td>
</tr>
<tr>
<td>2011</td>
<td>559.80</td>
<td>17.20</td>
<td>9,870,000</td>
</tr>
<tr>
<td>2012</td>
<td>500.00</td>
<td>17.80</td>
<td>9,000,600</td>
</tr>
<tr>
<td>2013</td>
<td>510.00</td>
<td>17.80</td>
<td>9,210,000</td>
</tr>
<tr>
<td>2014</td>
<td>560.00</td>
<td>18.30</td>
<td>10,200,000</td>
</tr>
</tbody>
</table>

(Ministry of Agriculture and Rural Development, 2015)
Benefits of using cassava as raw material for ethanol production

- Ease of plantation in various soil types and climate conditions;
- Low input and investment for planting;
- “All year round” availability of feedstock in form of fresh roots and dry chips;
- High starch-containing raw materials;
- Competitive production cost of ethanol from cassava as compared to other feedstock

(Sriroth et al., 2009)
Conventional ethanol process

1. **Grinding**
   - Cassava + Water
   - SLURRY

2. **Liquefaction**
   - JET COOKER
   - LIQUEFACTION

3. **Saccharification**
   - Alpha amylase
   - Glucoamylase

4. **Fermentation**
   - Yeast

5. **Distillation**
   - Ethanol

6. **DDGS**

Additional Information:
(Singh 2007; Gang, 2010)
Simultaneous Liquefaction, Saccharification, and Fermentation (SLSF)

**Diagram:**
- Cassava + Water → GRINDING → SLURRY → Liquefaction, Saccharification, Fermentation → DDGS → Distillation → Ethanol
- Yeast, Alpha amylase, Glucoamylase

*(Singh 2011; Gang, 2010)*
Advantages of SLSF process

• Lower investment cost (LESS EQUIPMENT)
• Cost-effective and energy-saving process (LESS STEAM);
• Reduced loss of sugar and amino acids caused by cooking
• Lower osmotic pressure on yeast

better fermentation efficacy
Added Value for Cassava-Based Coproducts: Distillers Dried Grains with Solubles (DDGS)-like products

(Singh 2011)
Objectives

- Developing energy-saving ethanol process based on:
  - Decreasing energy consumed by utilizing enzymes which are capable of hydrolyzing raw starch
  - Shortening production time by using Simultaneous Liquefaction Saccharification and Fermentation (SLSF) process

- Adding value to ethanol byproduct for animal feeding
Materials and methods

Cassava

<table>
<thead>
<tr>
<th>Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch (%)</td>
<td>76.0</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>11.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nature</th>
<th>Stargen 001 (Dupont)</th>
<th>Amigase Mega L (DSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature</td>
<td>Alpha-amylase and glucoamylase</td>
<td>Glucoamylase</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>20 – 40</td>
<td>60</td>
</tr>
<tr>
<td>pH</td>
<td>3.0 – 4.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

*Thermosacc* (Lallemand): > 2.10^{10} cells/g
Cassava + Water

Acidification

Simultaneous Liquefaction Saccharification and Fermentation (SLSF)

Process SLSF 1

Process SLSF 2

Active dry yeast

Urea

Stargen001

Stargen001 + Amigase Mega L

Distillation

Ethanol
Results and discussion
Cassava + Water (210 g/L)

Acidification pH 4.2

Simultaneous Liquefaction Saccharification and Fermentation (SLSF), 30°C

Active dry yeast (0.25 g/L)

Urea (0.4 g/L)

Stargen001 (2.5 mL/kg)

Distillation

Ethanol
Low reducing sugar content -> reduce yeast inhibition

↑EtOH -> SLSF2

EtOH (10.2% v/v) & yield (85.5%), > 120h
Cassava + Water (210 g/L)

Acidification pH 4.2

Simultaneous Liquefaction Saccharification and Fermentation (SLSF), 30°C

Active dry yeast (0.25 g/L)

Urea (0.4 g/L)

Distillation

Ethanol

Process SLSF 2

Stargen 002 2,5 mL/kg + Amigase Mega L) 0,5 mL/L)
- Reduce fermentation time (120h -> 96h)
- ↑ ethanol yield (= 91.3%)
SLSF process at pilot scale

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (L)</td>
<td>100</td>
</tr>
<tr>
<td>Starch (%)</td>
<td>79</td>
</tr>
<tr>
<td>Residual sugar at 96h (g/L)</td>
<td>7.4</td>
</tr>
<tr>
<td>Ethanol at 96h (% v/v)</td>
<td>10.3</td>
</tr>
<tr>
<td>Ethanol yield (%)</td>
<td>86.3</td>
</tr>
</tbody>
</table>
Process for cassava-based DDGS

SCHOOL OF BIOTECHNOLOGY AND FOOD TECHNOLOGY - HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
## Composition of cassava-based DDGS

<table>
<thead>
<tr>
<th>Composition (%)</th>
<th>Cassava DDGS</th>
<th>Corn DDGS *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>10.2</td>
<td>10.8</td>
</tr>
<tr>
<td>Protein</td>
<td>15.8</td>
<td>28.8</td>
</tr>
<tr>
<td>Starch</td>
<td>13.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Ash</td>
<td>2.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Fat</td>
<td>3.1</td>
<td>11.0</td>
</tr>
<tr>
<td>Fiber</td>
<td>15.8</td>
<td>7.1</td>
</tr>
</tbody>
</table>

(* Bhadra et al., 2007)
Conclusion

• Nocook SLSF process developed with cassava: ethanol yield of 91.3% and 86.3% at lab and pilot scale, respectively and SLSF duration of 96h
• Value added to SLSF by-product for animal feeding: DDGS ingredients with high content of fiber (15.8%)

Prospects

• Optimizing SLSF in term of ethanol yield, time and materials used
• Scaling cassava-based SLSF and DDGS processes at larger scale
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