Meeting the Demands of Food, Feed, and Energy by Sweet Sorghum

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FAO, 14-15 July 2010

How to make integrated food-energy systems work for both small-scale farmers and rural communities in a climate change-friendly way.
Challenges

Food Crisis, Climate Change, and Energy Poverty

Political will needed to halt food price surge - FAO
Reuters, Saturday April 19, 2008
Biofuels are today the only direct substitute for oil in transport that is available on a significant scale. 73.6 billion liters of bioethanol were produced in 2009, and is projected to replace 12-14% of global gasoline consumption by 2015.
First generation bio-fuel feed stocks divert food crops to produce fuel, and can compete directly, or indirectly with food production resulting in:

- higher food prices
- food shortages
- De-forestation
- Expansion into environmentally sensitive ecosystems
Biofuel has to be non-competitive to feed, food & domestic energy

A crop should combines energy and food on the same plot:
- addresses food, fuel, fodder, fiber (FFF)
- suits arid and semi-arid conditions
- C4 - with efficient photosynthesis
A ‘closed loop’/‘zero waste’ system is established in China

Sweet sorghum for feed & ethanol mode in ShanXi Province
$2 mil. Is invested by a garo company

Sweet sorghum for ethanol & feed mode in Inner Mongolia
$9 mil. Is invested by a coal company

Nov. 2007, Financial Incentive Policy for Bioenergy was issued by MOF and NDRC total five ministries, China - to support 20-40% investment of biofuel & bio-based product producers using non-food feedstocks; $400/hectare subsidies for farmers.
45% of fibrous residues (1.18t) for boiler fuel, 55% (1.42t) to feed 1 cattle, and nutrition report is as the following:

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Dry matter</th>
<th>Crude Protein content</th>
<th>Crude fiber</th>
<th>Neutral detergent fiber</th>
<th>Acid detergent fiber</th>
<th>Crude ash</th>
<th>Calcium</th>
<th>Phosphate</th>
<th>Total energy MJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermented bagasse</td>
<td>19.21</td>
<td>0.83</td>
<td>6.56</td>
<td>13.34</td>
<td>9.29</td>
<td>1.29</td>
<td>0.05</td>
<td>0.02</td>
<td>3.37</td>
</tr>
<tr>
<td>(wet sample)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn silage</td>
<td>24</td>
<td>1.47</td>
<td>4.59</td>
<td>9.89</td>
<td>5.76</td>
<td>1.34</td>
<td>0.06</td>
<td>0.06</td>
<td>16.44</td>
</tr>
<tr>
<td>Fermented bagasse</td>
<td>94.22</td>
<td>7.26</td>
<td>30.12</td>
<td>63.75</td>
<td>40.62</td>
<td>22.5</td>
<td>0.32</td>
<td>0.13</td>
<td>11.91</td>
</tr>
<tr>
<td>(dry sample)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Why Sweet Sorghum

Sweet sorghum is suitable in more areas

Potential adaptation of S. bicolor
Why Sweet Sorghum

- Sweet Sorghum may produce grain, sugar, ethanol, electricity, and feed without adversely impacting existing food crops or requiring the clearing of new land to grow fuels crops.

- Grown in drier areas (waste lands or sandy soils) with only limited water and fertiliser as compared to sugar cane and other crops:
  
  1 ton sorghum: 11 ton water
  
  1 ton sugarcane: 48 ton water (data from ICRIST)

- Sweet sorghum is significantly salt-tolerant, permitting it to be grown in high-salinity soils that are often unusable for other crops (e.g., in high salinity)

- High yield stalks: 70 ton/ha/harvest, 4 months per harvest

- Producing additional food (3 ton/ha/harvest) without the necessity to displace existing crops, such as corn.
Why Sweet Sorghum

In certain situations sweet sorghum will have a lower feedstock cost than sugarcane.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Feedstock cost</th>
<th>Processing</th>
<th>Co-generation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Case</strong></td>
<td></td>
<td></td>
<td></td>
<td>HYPOTHETICAL</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>$1.36</td>
<td>$0.29</td>
<td>$0.0</td>
<td>$1.65</td>
</tr>
<tr>
<td>Sweet sorghum</td>
<td>$1.09</td>
<td>$0.39</td>
<td>$0.0</td>
<td>$1.48</td>
</tr>
<tr>
<td><strong>Co-generation</strong></td>
<td></td>
<td></td>
<td></td>
<td>HYPOTHETICAL</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>$1.36</td>
<td>$0.29</td>
<td>$0.38</td>
<td>$1.27</td>
</tr>
<tr>
<td>Sweet sorghum</td>
<td>$1.09</td>
<td>$0.39</td>
<td>$0.53</td>
<td>$0.95</td>
</tr>
</tbody>
</table>

Lower inputs and higher biomass provide an advantage to sweet sorghum against sugarcane in some geographies.

Note: Does not assume a ratoon crop. 10% TSR for sweet sorghum. Feedstock production costs based on U.S.
Advantages of Advanced Solid State Fermentation (ASSF)

- **Short process**
  
  Directly ferment stalks to ethanol, 2/3 equipment compare to liquid state fermentation process (LSF)

- **Less fermentation time**
  
  24hr vs 36 hr for liquid process, and 55 hr for corn ethanol

- **Less water consumption and less waste water**
  
  1 ton water required vs 5+ ton for liquid process

- **Less energy consumption**
  
  About 300kwh/ton ethanol vs 800kwh/ton ethanol for liquid process

- **Less total investment cost**
  
  About 75% investment vs liquid process

- **Simple operation**
  
  Low educated labor for operation
Solid State Fermentor with mass transfer and heat transfer from bench scale to pilot plant
Moving particles in industrial fermentor

Why ASSF
## Energy balance of the whole process

*(based on 1 ton of fuel ethanol)*

<table>
<thead>
<tr>
<th>Energy input</th>
<th>Energy output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity: 373 Kwh (GJ)</td>
<td>1.343</td>
</tr>
<tr>
<td>ethanol producing 230 Kwh (GJ)</td>
<td>0.828</td>
</tr>
<tr>
<td>distiller pelletizing 143 Kwh (GJ)</td>
<td>0.515</td>
</tr>
<tr>
<td>4.52 t steam for distillation (GJ)</td>
<td>11.92</td>
</tr>
<tr>
<td>5.0 t hot air for drying distiller (GJ)</td>
<td>0.50</td>
</tr>
<tr>
<td>Total (GJ)</td>
<td>13.85</td>
</tr>
<tr>
<td>1.18t pellets (GJ)</td>
<td>17.31</td>
</tr>
<tr>
<td>1t ethanol (GJ)</td>
<td>29.30</td>
</tr>
<tr>
<td>Total (GJ)</td>
<td>46.61</td>
</tr>
</tbody>
</table>

The energy **input/output ratio** during ethanol production process is 1 : 22, hence ethanol produced from sugar crops by ASSF can be regarded as ADVANCED BIOFUEL defined by U.S.A. “Energy Independence and Security Act of 2007”
The sorganol production cost of is estimated at $463.3/t ethanol at the sorghum stalk cost of $20/t.

The capital cost is around $9 million for the ethanol plant with the capacity of 10,000t/a.
USGC to Japan and the Philippines: Why not Sorghum?
June 3, 2010 Global Update www.grains.org
Constraints and solutions

**Constraints**
- There is lack of cost-effective conversion technologies.
- Less financial support to demonstration plants.

**Solutions**
- R&D is the priority
- Governments should support to build demonstration plants
- Incentive policies to encourage venture capitals flow into IFES
FAO can help Africa to make great opportunity using sweet sorghum

As African economies strain under the burden of importing oil this session will examine the critical issues of how African countries can lessen their energy dependence, improve their balance of payments, create new jobs and industry in a sustainable manner without impacting food production.

Where billions of dollars were going to overseas oil producers, some can now be invested locally- in poor rural communities to benefit Africa
Using 2,000 hectares land to grow sweet sorghum to produce 10,000 tons of ethanol per year, and generate 18 million Kwh electricity.

During this module, the energy input of ethanol is only fossil fuel in plantation and transportation, has much environmental benefit.
Benefits of ethanol & power production using sweet sorghum feedstock and ASSF Technology in tandem:

- Low cost production of ethanol from Sweet Sorghum using single or multi-modular plants.
- Export and local consumption, creating jobs for local communities.
- Provides other bi-products, such as fertilizer, animal feed, pellets for use for cooking, elimination of trees cutting and power generation.
- Provides rural electrification for the villages.
## Production Cost for Ethanol ($/t)

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Cost (USD)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Feedstock</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>stalks</td>
<td>235.2</td>
<td>Sweet sorghum stalks,</td>
</tr>
<tr>
<td></td>
<td>Other materials</td>
<td>26.5</td>
<td>Enzymes+yeast</td>
</tr>
<tr>
<td>2</td>
<td>Utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>water</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>electricity</td>
<td></td>
<td>Self supply</td>
</tr>
<tr>
<td></td>
<td>steam</td>
<td></td>
<td>Self supply</td>
</tr>
<tr>
<td>3</td>
<td>Labor</td>
<td>57</td>
<td>120people,</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance</td>
<td>31.6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Depreciation</td>
<td>102.9</td>
<td>14 years</td>
</tr>
<tr>
<td>6</td>
<td>Admin. expense</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>finance</td>
<td>40.5</td>
<td>Interest @4%</td>
</tr>
<tr>
<td>8</td>
<td>Ethanol sale value</td>
<td>848.1</td>
<td>Price: @67cent/liter</td>
</tr>
<tr>
<td>9</td>
<td>Electricity sale value</td>
<td>70.9</td>
<td>1200kw Price: 5.9cent/kwh</td>
</tr>
</tbody>
</table>

No tax (VAT, business tax, income tax) has been included.
Typical Project Data

Plant location: Africa
Plant capacity: 12mil liter ethanol (99.5\%v)
Total installed cost: US$ 15 million
Sweet sorghum stalk required: 160,000t/a
Land area required: 2,300ha @ 70ton/ha

Finance Data
Capital loan interest 4%
Construction period: 12 months
Stalk price: $14.7 per ton at plant
Ethanol price (ex-works): $67cent per liter
Electricity price: 5.9cent/kwh
IRR: 21\% @no business and income tax
The US-Sino Joint Center for biofuel Research was established on 19 Aug 2008

B. At the discretion of either Party, this Annex may be terminated upon 6 months advance notice in writing to the other Party.

Done at Houston, Texas, this day of August 19, 2008, written in English and Chinese and in duplicate, each text being equally authentic.

FOR THE DEPARTMENT OF AGRICULTURE OF THE UNITED STATES OF AMERICA (USDA)

Gale Buchanan
Under Secretary for Research, Education and Economics, USDA

FOR THE MINISTRY OF SCIENCE AND TECHNOLOGY OF THE PEOPLE’S REPUBLIC OF CHINA (MOST)

Liu Yanhua
Vice Minister of MOST

Copies of correspondence and documentation between ARS and MOST should be sent to:
Thank You