Torrefaction of Biomass to Enhance Fuel Properties

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Introduction

Depleting fossil fuel resources and GHG/Global Warming

Renewable energy, sustainable fuels

Biomass ➔ Carbon-neutral, local fuel; energy security

Technology barriers to their utilization as energy source

Torrefaction
Torrefaction Process Concept

- **Biomass**
  - **Drying**
  - **Torrefaction**
  - **Heat exchanger**
  - **Dedusting, Condensation, Fan for recycl.**
- **Flue gas**
- **Air**
- **Fuel**
- **Combustion**
- **Gas recycle**
- **Cooling**
- **Torrefied biomass**
- **Addition of inert gas or flue gas**
- **Drying gases**
Introduction

Torrefaction gas

Biomass feedstock

Torrefaction 200 – 300 °C

Torrefied biomass

0.3M 0.1E

0.7M 0.9E
Objectives

- Study of Different characterizations of Lignocellulosic and Non-lignocellulosic biomass from Ontario before and after torrefaction.
- Optimization of torrefied conditions based on hydrophobicity
- Investigation of pelletization potential before and after torrefaction
- Ash analysis of biomass at different combustion temperature.
Methodology

Biomass Sample:
Willow, Oats and Poultry Litter

Characterization:
Proximate, Ultimate, Elemental, Energy Density and HHV

Ash Analysis at 800, 900, 1000°C
-SEM
-XRD
- Fusion Temp

Investigation of Pelletization Potential
-Making Force
-Breaking Force

Torrefaction
-Varied O₂
-Temperature (200-300°C)
-Residence Time (15-60min)

Hydrophobicity
-Optimum Torrefaction Temperature
-Moisture Uptake

Comparative Study of Torrefied and Raw Biomass:
Characterizations, Hydrophobicity, Pelletization, Ash
Experimental Set up (Drying + Proximate)

- **Apparatus:**
  - Programmable Muffle Furnace
  - Thermocouple with stainless steel probe
  - Crucible
  - Desiccator
  - Weighing Balance
Experimental Set up (Torrefaction)
Experimental Set up (Torrefaction)

Apparatus:
- Locally designed and fabricated Reactor
- Connecting cables and fittings
- N2 gas
- Gas Analyzer
- Preheater
- Gas Flow Meter
- Thermocouples
- Temperature Controllers (2)
- Desiccator
- Electric weigh balance
Experimental Set up (Pelletization)

- Handle of Pellet
- Modified Parr Pellet Press 2812 pellet
- Heating Tape over die
- Temperature Controller CNiS8DH33
- Omega Process Gauge controller (CNiS6DH33)
- Strength Meter Omega LC1001-500
Experimental Result (Proximate analysis)

Comparative Study of Mass Yield at different Temp with 0% O2

- Poultry Litter
- Willow Pellets
- Oat Pellets

Mass Yield Yield in %

Temperature in Centigrade

250
275
300
Experimental Result (Proximate analysis)

- Poultry Litter
- Willow Pellets
- Oat Pellets

<table>
<thead>
<tr>
<th>Temperature in Centigrade</th>
<th>Energy Yield in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>80</td>
</tr>
<tr>
<td>275</td>
<td>80</td>
</tr>
<tr>
<td>300</td>
<td>60</td>
</tr>
</tbody>
</table>
Experimental Result (HHV)

HHV (MJ/kg)

- Poultry Litter
- Willow Pellets
- Oat Pellets

Temperature in °C

- Raw
- 250°C
- 275°C
- 300°C
Experimental Result (Hydrophobicity-All)

Comparative Study of Hydrophobicity

- Poultry Litter
- Willow Pellets
- Oat Pellets

Moisture Equilibrium (%)

Temperature (°C)

250  275  285  300
Experimental Result (Moisture Uptake-all)

Moisture Equilibrium (%) vs Temperature (°C)

- Poultry Litter
- Willow Pellets
- Oat Pellets

- 250°C
- 275°C
- 300°C
Experimental Result (Pelletization-Making)

The graph shows the pressure in MN/m² at different torrefaction temperatures. The pressures measured are as follows:

- **Raw**: 10.00 MN/m²
- **210**: 15.00 MN/m²
- **250**: 30.00 MN/m²
- **275**: 70.00 MN/m²
- **300**: 90.00 MN/m²

The torrefaction temperatures are 210, 250, 275, and 300, respectively.
Experimental Result (Pelletization-Breaking)

- **Breaking Force (N)**
  - Raw: 1200 N
  - 210 °C: 800 N
  - 250 °C: 200 N
  - 275 °C: 100 N
  - 300 °C: 10 N

**Temperature (°C)**
- Raw
- 210
- 250
- 275
- 300
Experimental Result (Ash Fusion Temp)

Ash Fusion Temperature of Poultry Litter, Willow and Oat Pallets

- Initial Deformation (IT) (°C)
- Softening Temperature (ST) (°C)
- Hemispherical Temperature (HT) (°C)
- Fluid Temperature (FT) (°C)
Experimental Result (Elemental Ash Analysis)

Elemental Ash Analysis of Poultry Litter, Willow and Oat Pellets

- SiO2
- TiO2
- Al2O3
- Fe2O3
- MnO
- MgO
- CaO
- K2O
- Na2O
- P2O5
- Cr2O3

Percentage in Ash Basis

Name of Elements
Experimental Result (Ash Fusion Temperature)

Ash Fusion Temperature of Poultry Litter, Willow and Oat Pallets

![Graph showing Ash Fusion Temperature of Poultry Litter, Willow and Oat Pallets]
Applications

Residential and commercial heating

Power generation
- Biomass Co-firing in large scale coal-fired power plants
- Competes with coal in terms of price as well as performance
- Higher co-firing rates possible (compared to biomass)
- Most practical option to meet provincial mandate to phase out coal by 2014

Steel production
- TB with LHV in the range of 25 MJ/kg required

Biomass-to-liquid fuel
- Transportation fuels (Fischer–Tropsch process)

Export
- Large markets exist in US & Europe
### Conclusions

- **Torrefied biomass can be used for co-firing with coal in thermal power plant, heating system and combustion system.**

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Torrefied Pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heating Value</strong></td>
<td>25 GJ/T</td>
<td>22 GJ/T</td>
</tr>
<tr>
<td><strong>Ash</strong></td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Sulphur</strong></td>
<td>3%</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Nitrogen</strong></td>
<td>1.5%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Chlorine</strong></td>
<td>0.05%</td>
<td>0.01%</td>
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</table>
## Conclusion

<table>
<thead>
<tr>
<th>Characterization</th>
<th>Lignocellulosic</th>
<th>Non-Lignocellulosic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mass Yield</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>2. Energy Yield</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>3. Hydrophobicity</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Moisture Uptake</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>5. Pelletization</td>
<td>Possible</td>
<td>Possible only with binder</td>
</tr>
<tr>
<td>6. HHV</td>
<td>High 20-24MJ/Kg</td>
<td>Low 12MJ/Kg</td>
</tr>
<tr>
<td>7. Ash Composition</td>
<td>High Silica components</td>
<td>High Calcium component</td>
</tr>
<tr>
<td>8. Ash Fusion</td>
<td>Low 1100-1200°C</td>
<td>High 1400°C</td>
</tr>
</tbody>
</table>
Recommendations

- Try to use torrefied biomass pellets for co-firing with coal in thermal power plant, heating system and combustion system.

- Run small businesses for pellet making: Raw and Torrefied both

- Need to explore further on economic viability and sustainability of the technology
Thank you

Any Questions?