Feedstocks, Characteristics, Preparation and Pretreatment

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Fast Pyrolysis of Biomass
A Specialists’ Workshop
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Europahotel, Ghent, Belgium
T R Miles Technical Consultants, Inc.

• Design and develop energy and environmental processes.

• Industries
  - Biomass energy
  - Pollution control
  - Materials handling
  - Feed, Food, and Fuels
TRM Thermochemical Reference Projects

• 1946-1974 – Industrial wood and straw processing, ethanol, boiler fuels, gasification
• 1974-1980s – bench and pilot systems: USDOE Thermochemical Program/PNL, Ensyn, Framatome, etc.
• 1990s – scale up, GTI/PICHTR/Westinghouse, Commercial gasifiers
• 1997-2014 – Industrial Wood and Straw handling and processing systems for thermal conversion
  • Boilers to 400,000 pph; Gasifiers to 5 MWe, Design to 35 MWe
  • Biomass process development: sizing and densification; pyrolysis of wood, grasses and mixed waste plastic; gasification and staged combustion
  • Other materials handling, pollution controls
Questions

• Feedstocks
  • What have we learned about feedstocks for fast pyrolysis?
  • Does the type of feedstock matter?
  • What are the best feedstocks for fast pyrolysis?
  • Do scale, cost, production, yield, or product composition matter in feedstock selection? What scale up data exist for feedstocks?

• Characteristics
  • What feedstock characteristics are best suited to fast pyrolysis? How well are feedstocks characterized in research? Does characterization follow EU or other protocols?
  • What characteristics increase or decrease oil and char yield or value?
  • Is there an operating window for product yield based on feedstock size, moisture, ash, or type? Can research simulate feedstock effects on industrial production?

• Preparation
  • Does feedstock preparation improve fast pyrolysis operation or yield? Size? MC? Density?
  • Does feedstock preparation matter? Where is the data?

• Pretreatment
  • Do mechanical, thermal or chemical pretreatments improve operation or product yield?
  • What data exists for effects of pretreatment?
Key Feedstock Issues for Sustainable, Commodity Scale, Fast Pyrolysis

- Process Goals & Objectives
  - Products, Yields, Composition
  - Simple, Reliable, Maintainable Plant Operation
  - Scale, Scale-up, Capacity, Cost and Capacity Factor Targets
  - Plant Process Operating Window: Temperature, Pressure, MC, Ash
  - Co-products – energy, Biochar, activated carbon, flavour, foliar growth enhancement

- Feedstocks
  - Sources: Wood vs Grasses; Residues vs Energy Crops
  - Quantities, availability, and cost
  - Suited to Reactor and Feed System – suspension, entrained, fluidized bed

- Characteristics
  - Quality assurance: EU Fuel standards and protocols
  - Particle Morphology for Ease of Handling, Efficiency
  - Volatility, Composition (wood, bark, straw, husks)
  - Ash composition – alkali, sulphur, chlorine, calcium, silica, tramp tolerance

- Preparation
  - Production flow - How much processing?
  - Sizing (250 micron -20 mm), Milling: Chips, Microchips, Crumbles, Flakes, Dust
  - Drying, target MC (5-15%), volatiles, Heat Treat Temperature and time (115 °C, 280 °C, 350-450 °C)
  - Densification – granules (Uniform Dense Format), pellets

- Pretreatment
  - Chemical catalyst, thermal – blending, soaking
  - Decentralized fast pyrolysis, co-production with torrefaction or slow pyrolysis
Feedstocks: Process Goals & Objectives

• Products, Yields, Composition
• Simple, Reliable, Maintainable Plant Operation
• Scale, Scale-up, Capacity, Cost and Capacity Factor Targets
  • What minimum scale is needed for pyrolysis, carbonization and post processing? Are feedstocks available at scale?
  • Market absorption – ability of market to take volumes of products and co-products.
• Plant Process Operating Window: Temperature, Pressure, MC, Ash
• Cost/benefit of Co-products – energy, Biochar, activated carbon, flavour, foliar growth enhancement
Scale: Biofuels, Energy, Chemicals and Char Share
Feedstock Infrastructure at 250-1,000 tpd

Energy and Heat
25-50 MWe Combustor and Boiler 200-400,000 tpy

Liquid Fuel
200-400 ML Ethanol Plant

Pellets and Heat 15,000-500,000 tpy

Torrefaction, Oil, Char 50,000-500,000 tpy

www.biogreen-energy.com

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Commercial Projects Demonstrate Feedstock Systems at Scale

• Current Feedstock Suppliers Deliver to Diverse Competing Markets

• Wood - sizing, densification, torrefaction
  • Independent Power Producers, 50 MWe 450,000 tpa – hog fuel, chips, microchips
  • Export Pellets 500,000 tpa
  • Torrefaction/”Black” Pellets

• Grasses – harvest, handling, processing
  • Cellulose to Ethanol (BTL) 200,000-400,000 tpa, Abengoa Kansas, Poet,
  • Co- firing 200,000-400,000 tpa, Chariton Valley, Iowa,
Feedstocks

Sources: Wood vs Grasses; Residues vs Energy Crops

Quantities, availability, and cost
  • Availability: residues or dedicated crops from forests and fields
  • Large resource managers – millions of tons required

Competition – pellets and export markets

Feedstock suited to Reactor and Feed System – suspension, entrained, fluidized bed
Sources: Low Cost Feedstocks Drive Commodity Scale Production

• Same feedstocks as all Biobased fuels (ethanol, butanol, acetic acid, furfurals, diesel) and chemicals production (xylitol) with Residuals (lignin).

• Industrial Co-processes
  • Combustion
  • Gasification
  • Densification

• Fast Pyrolysis as a Co-process of Activated Carbon

• Wood Industry Residuals Limited
  • Dry wood trim
  • Chipped wood waste, sawdust

• Urban Woodwaste Available
  • 150,000 tpa/pop 2 million; 1 MM tpa

• Future Feedstocks From
  • Organics recycling: landscape and tree service prunings, and recycled urban wood
  • Forest residues from restoration forestry and stewardship contracts
  • Field Crops and agricultural residues
  • Manures and refuse derived fuels
Characteristics

• Quality assurance: EU Fuel standards and protocols
• Particle Morphology for Ease of Handling, Efficiency
• Volatility, Composition (wood, bark, straw, husks)
• Ash composition – alkali, sulphur, chlorine, calcium, silica, tramp tolerance
• Performance characterization of high ash feedstocks (straws, bark, manures.)
WOODY MATERIALS

CHIPS from Thinnings, Clear Cut, Plantations, Woodlots

GREEN: 50% Moisture, 10.5 kJ/g, 336 kg/m³ (4500 Btu/Lb, 21 Lb/c.f.)
DRY: 15% Moisture, 17.4 kJ/g, 192 kg/m³ (7500 Btu/Lb, 12 Lb/c.f.)
C - 50%, H - 6%, O - 42%, N - 1%, Ash 1-2%
12 Month Supply, Store Outside, $20-$25/Green Ton, $130 U.S./T.O.E.

HOG FUEL from Sawmill Residues

Same Properties, Diminishing Supply, 3-10% Ash, $15/Green Ton, $78/T.O.E.
**Preparation**

- **Production flow** - How much processing?
- **Sizing (250 micron -20 mm)** - Chips, Microchips, Crumbles, Flakes, Dust
- **Drying**, target MC (5-15%), volatiles, Heat Treat Temperature and time (115 °C, 280 °C, 350-450 °C)
- **Densification** – granules (Uniform Dense Format), pellets
FEEDSTOCK PROCESSING

Fig. 5.8 Wood Chip Preparation for Conversion
Does Data Show That Thin Fuels Improve Thermal Decomposition?

(WEE CHIPS
5 - 10 mm long
.8 - 1.6 mm thick
192 kg/m³ dry bulk density

HARDWOOD CHIPS & PINS
16 - 22 mm long
1.2 - 3.2 mm thick
224 kg/m³ dry bulk density
.48 - .6 specific density

SOFTWOOD CHIPS & PINS
16 - 22 mm long
3 - 6 mm thick
176-192 kg/m³ dry bulk density
.3 - .48 specific density

PELLETS
6 - 20 mm long
6 - 20 mm thick
600 kg/m³ dry bulk density
1.0 specific density

GROUND PELLETS OR ROLL DENSIFIED FLAKES
2.5 mm diameter or less
(< 8 mesh)
450 kg/m³ dry bulk density
.9 - 1.0 specific density

(Idaho National Lab: “Uniform Dense Format” 2008)

T R Miles, 1983
38° angle controls thickness. By "carding" or splitting off, hardwood chips are thinner.

DROP FEED WOOD CHIPPER

8-15 HPH/TON (Dry Equivalent)
### Feedstocks, Characteristics, Preparation and Pretreatment

<table>
<thead>
<tr>
<th></th>
<th>HARDWOOD</th>
<th>SOFTWOOD</th>
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</thead>
<tbody>
<tr>
<td>45 mm Holes</td>
<td>OVERLARGE</td>
<td>1.5%</td>
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<tr>
<td></td>
<td></td>
<td>3.8%</td>
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<tr>
<td>10 mm Slots</td>
<td>SOFTWOOD</td>
<td>7.5%</td>
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<tr>
<td>8 mm Slots</td>
<td>Hardwood</td>
<td>3.8%</td>
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<td>7 mm Holes</td>
<td>ACCEPTS</td>
<td>34%</td>
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<td>52%</td>
</tr>
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<td>3 mm Holes</td>
<td>PIN CHIPS</td>
<td>60%</td>
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<tr>
<td></td>
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<td>36%</td>
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<tr>
<td>Pan</td>
<td>FINES</td>
<td>1.5%</td>
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<tr>
<td></td>
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<td>1.5%</td>
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<tr>
<td></td>
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<td>100%</td>
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</tbody>
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**Diagram:**
- Everett Metal Products Chip Classifier
  - K and K Metal Fabricators, Inc
- Canadian Pulp & Paper Assn.
  - Proposed New Method DX35
- T.R. Miles Chip Sample
  - Jan. 1982

**Text:**
- 5.10 Wood Chip Characterisation by Current Pulp Mill Practice
Is the added power requirement for milling justified?

Wood
Grass
Refuse
Supplies of Wood Industry Residuals are Limited
Sawdust is a Good Research Feedstock But Has Higher Commercial Value for Alternative processes.

Ponderosa Pine
67% MC
Sawdust is Dried and Densified to Higher Value Products

- Residential Fuel
- Cat Litter
- Horse Bedding
- Hydromulch (Erosion Control)
- Remediation Fiber
Why densify? Is Voidage Important to Fast Pyrolysis?

Densify for handling and feeding.
Export Pellet Production Has Improved Dryer Efficiency

Low Temperature Belt Dryer
www.beltomatic.com

Rotary Dryer with Recycle
www.tsi-inc.net

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Pellet Demand Has Increased Dryer Capacity

Masisa (Porto Alegre, Brazil)
Ø24’x140’ Long Drum - 60 tons/hr (50% to 3% m.c.)

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Feedstocks, Characteristics, Preparation and Pretreatment
Markets Drive New Forms of Feedstock Preparation

- **Micro-chips** <1/4 in; 2-4 mm x 4-6 mm
  - Produced at harvest for wood pellet industry
- **Crumbles™** <1/4 in 2 x 6 mm
  - Reprocessed chips or crop residues
  - Improved thermal processing and yield
  - Makes uniform char “chip”

Source: Peterson Pacific

www.forestconcepts.com

Source: Forest Concepts LLC
Good Industrial Experience With Micro Chips

• Easy handling, no bridging
• Eliminates sizing at plant.
• Dry directly without milling
• Final Milling before densification
Mixed Wood Residues Vary in Size and Thickness

Western Washington

www.forestconcepts.com
Diverse Char Size Char From Slow Pyrolysis of Mixed Residues

Western Washington

www.forestconcepts.com
Veneer or Chips Can be Reprocessed to Crumbles™

www.forestconcepts.com
Processed Crumbles™ Make Uniform high Value Char
Preliminary Pyrolysis Experience With Crumbles

• Good char formation in slow pyrolysis
• Improved char value in slow pyrolysis
• Limited experience with fast pyrolysis suggests faster drying and more uniform devolatilization. Verify.
• Is it worth preprocessing?
Are Non-woody Materials Suitable for Fast Pyrolysis?

NON-WOODY MATERIALS

STRAWS:  Cereals, Grass Seed, Flax, Oil Seeds
         15% Moisture, 16.3 kJ/g, 160 kg/m³ (7000 Btu/Lb, 10 Lb/c.f. [Bales])
         C - 47%, H - 6%, O - 40%, N - 1%, Ash 5-7%
         Seasonal Supply, Covered Storage, $40/Ton : U.S., $125/T.O.E.

STALKS, COBS, HULLS:  Corn, Sunflower, 30% Moisture, Outside Storage

BAGASSE:  70% Moisture, Stringy, Low Cost,

KENAF:  Stalks, 50% Moisture, Plantations,

COCONUT HUSK FIBRE:  20% Moisture, Fibrous Mat,

PEAT:  90% Moisture, Granular/Fibrous, Site Specific,

At 10% Moisture, 18.6 kJ/g, 160 kg/m³ (8000 Btu/Lb, 5 mm, 10 Lb/c.f.)
         C - 56%, H - 5%, O - 35%, N - 1%, Ash 3%
Rice Husk Char Value as Coproduct
Aito Nanohana EcoProject, Higashi-Omi City, Shiga
Kansai Corp 200 kilns 150 kg/hr, 1.2 MMBtu, 50 kg char/hr

700Y/10 kg
USD$0.41/lb
Industrial Mobile and Stationary Processing of Non-Wood materials has Improved

Biomass Handling

Grind Biomass

Rotor and Screen

Size and MC

Feedstocks, Characteristics, Preparation and Pretreatment

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Debaled and Ground Switchgrass is a good fuel for suspension firing.
Automated Process Options for Straws
(Switchgrass, Ottuma Generating Station Chariton Valley Biomass Project 2004)
Straw Processing for Suspension Firing
Switchgrass Processing in Iowa (2004)

- Teleboom loading
- Automated bale handling
  - Moisture, weight, reject, de-string, debale, metal removal, mill, blow, burn
Twine Remover & De-baler Infeed
Primary and Secondary Switchgrass Milling

Debaler Hammers 30,000 t/set

Screens 8,000 t/set

Attrition hammers 7,000 t/set

Steffen Systems 2 t Bale Hooks

400hp De-baler 12tph, 2in screen, Warren & Baerg
Are Refuse Derived Fuels Suited to Fast Pyrolysis?

RDF (Refuse Derived Fuel from Municipal Solid Waste)

- Fluff Form, 112 kg/m$^3$ (5-7 Lb/c.f.)
- At 35% Moisture, 10.5 kJ/g (4500 Btu/Lb)
- Dry - 16.3 kJ/g (7000 Btu/Lb)
- C - 51%, H - 7%, O - 32%, N - 1%, Ash 10-15%
- Some Chlorides, Sulphates, Trace Metals, Pb, Fe
- Cannot Store, Stable Supply, Must Densify, Clean RDF $15-20$/Ton, $60$/T.O.E.
- Must Gasify on Recovery Plant Site
- Gasification May Eliminate Toxics

T.O.E. = tonne oil equivalent = 42.5 million BTU, 40.3 million kJ
Should Pretreatment Be Considered for Industrial Production?

• Blending - catalyst
• Thermal – preheating
• Decentralized fast pyrolysis, co-production with torrefaction or slow pyrolysis
Markets are Emerging for Potential Char Co-products

- Retail Garden and Landscaping
  - Packaged consumer products
    - Compost and industrial byproduct char
    - Char suited to consumer needs
- Wholesale to
  - Landscape services – tree service
  - Specialty Crops, Horticultural, and Turf
- Bulk Char to Remediation, Erosion Control
  - Oilfield remediation and Filtration
  - Stormwater filtration
- Small scale agriculture - DIY
  - Community Supported Agriculture
  - Urban Farming
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www.gasifiers.bioenergylists.org  
www.biochar.bioenergylists.org

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Design and development of energy and environmental processes

Industries
- Biomass energy
- Pollution control
- Materials handling
- Feed, Food and Fuels