

Distributed Thermochemical Biomass Conversions

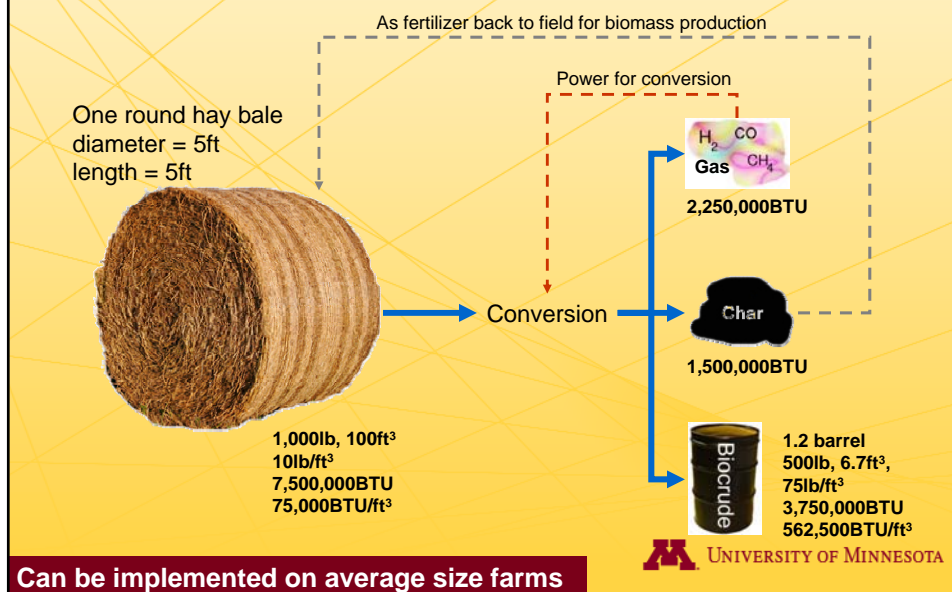
Roger Ruan, Ph.D.
Professor and Director

Center for Biorefining and
Department of Bioproducts and Biosystems Engineering

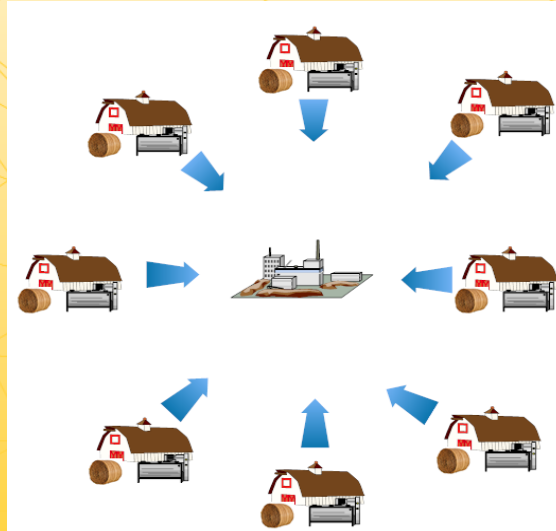


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Bale to Barrel DBCS



Distributed Biomass Processing Scheme

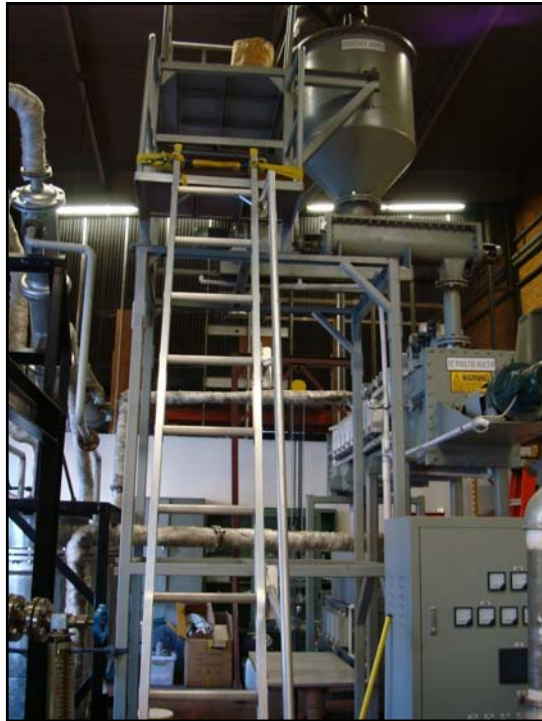


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Microwave-assisted pyrolysis (MAP)

- Totally closed system
- No air or nitrogen gas added for fluidization:
 - minimum gas volumes generated
 - high calorific value on gases
- No need to grind the sample
- Low carry over contaminants, low syngas and bio-oil contaminations
- Better temperature control
- Low capital cost and highly scalable

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Continuous microwave assisted pyrolysis system

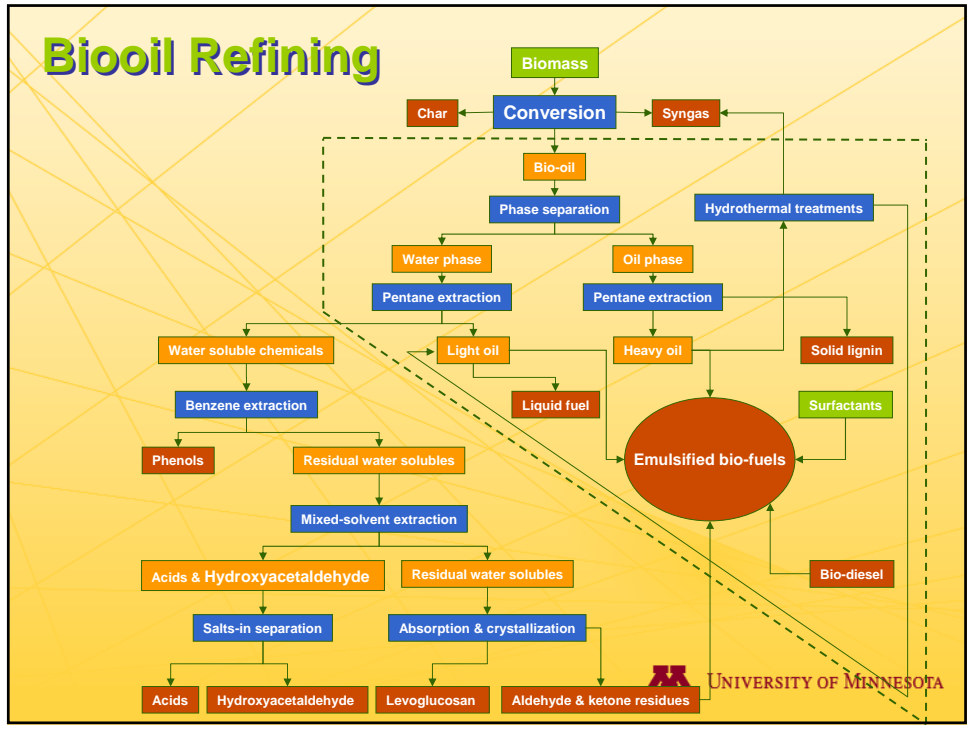
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Challenges and Potential Solutions

- Biooil refining
- Catalytic pyrolysis
- Catalytic reforming
- NTP assisted catalytic reforming
- Hydrothermal pyrolysis

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Biooil Refining



Heavy and Light Oil Fractions



Left to right: (1) light oil #2; (2) Light oil #1; (3) Heavy oil

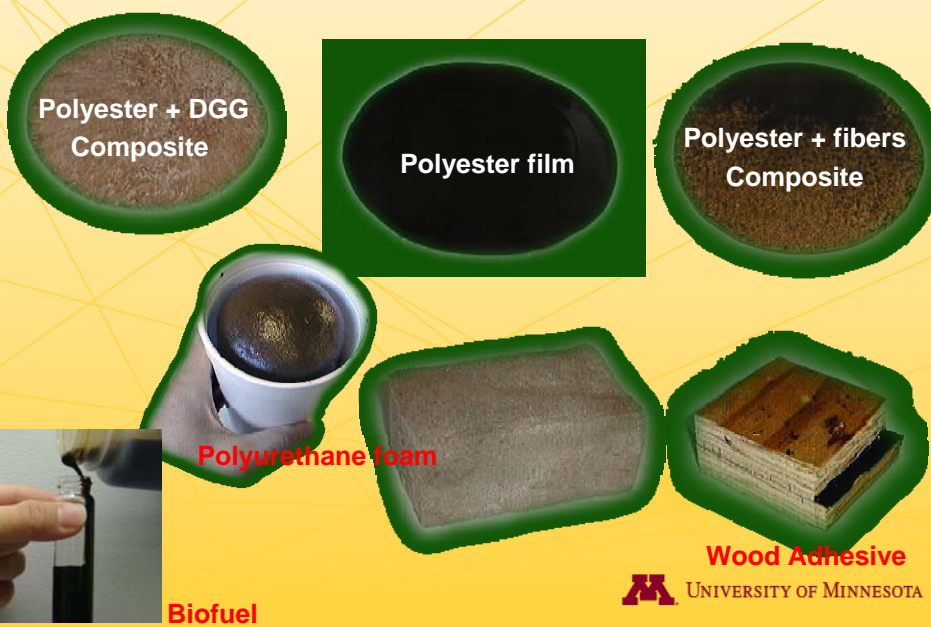
Blend of Light Oil and Gasoline



Blends of light oil (L) with gasoline (G)

Left to right : (1) 1/5(L/G); (2) 2/5; (3) 3/5;
4) 4/5; (5) 5/5; (6) gasoline; (7) light oil.

Biorefining of Biooils and Liquefied Biomass



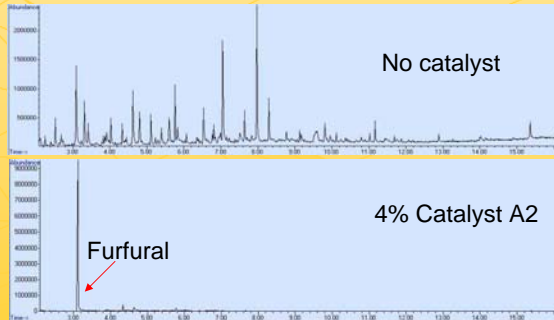
Catalytic Microwave Pyrolysis in a Continuous System

Effect of temperature and catalyst on products (Dry basis)

Temperature /°C	Catalyst	Bio-oil /%	Char /%	Gas /%
475	-	42.0	35.1	22.9
375	-	39.6	38.9	21.5
325	-	38.5	43.6	17.9
375	Catalyst A2	38.8	41.3	19.9

Sample: Corn cob
Feeding rate: 20Kg/h
Size: <1.2cm

Addition of catalyst A2 helps corn cob pyrolysis to produce a chemical-furfural.



Catalytic Reforming

e.g., Catalytic Cracking of Fatty Acids and Canola Oil and Volatile Pyrolytic Gas and Biooil

Materials and Methods

- Feedstocks (fatty acids and vegetable oil, and bio-oil)
- Catalyst screening
- Temperature effects
- Hydrogen partial pressure effects
- others

Product Analysis

Liquid products:

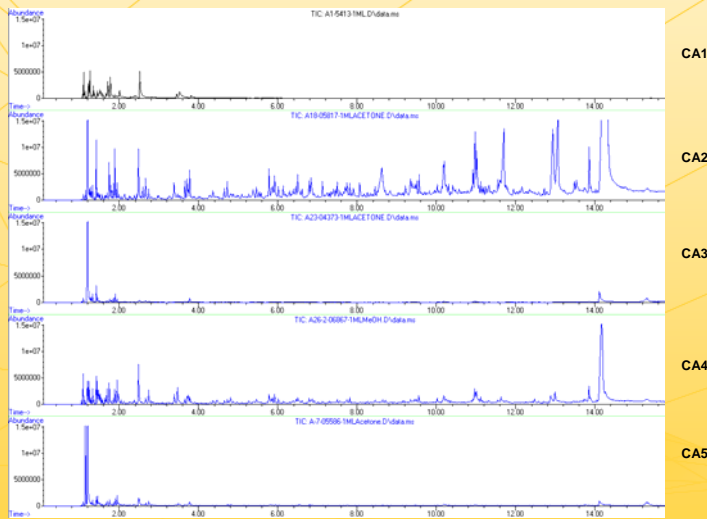
GC-MS (composition), Bomb calorimeter (heating value), pH, Carl Fischer moisture analyzer

Gaseous products: micro-GC

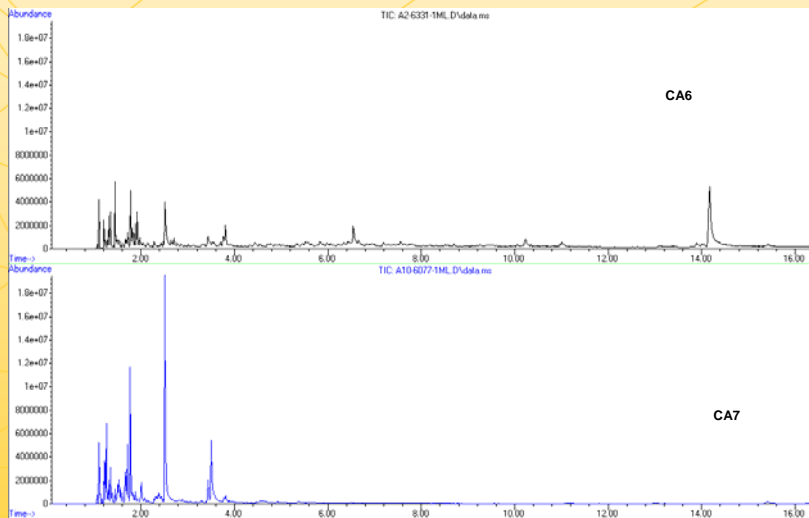
Solid residues: Bomb calorimeter (heating value), elemental analyzer, particle size analyzer;

Catalyst characterization: ChemBET analyzer (BET, TPD/TPO/TPR etc.)

Catalytic Cracking of Oleic Acid

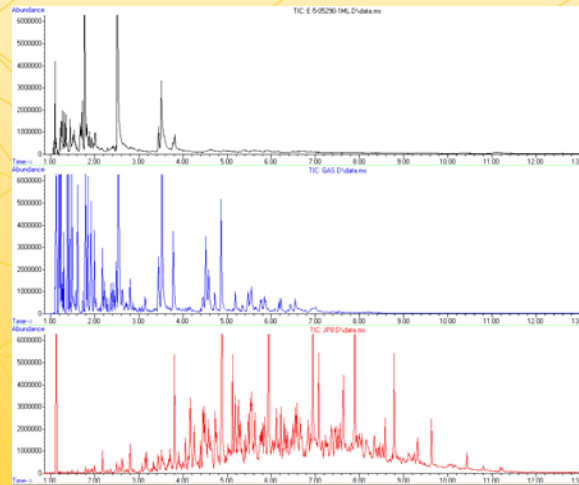


Catalytic Cracking of Linoleic Acid



Catalytic cracking products

vs.
Gasoline and JP-8

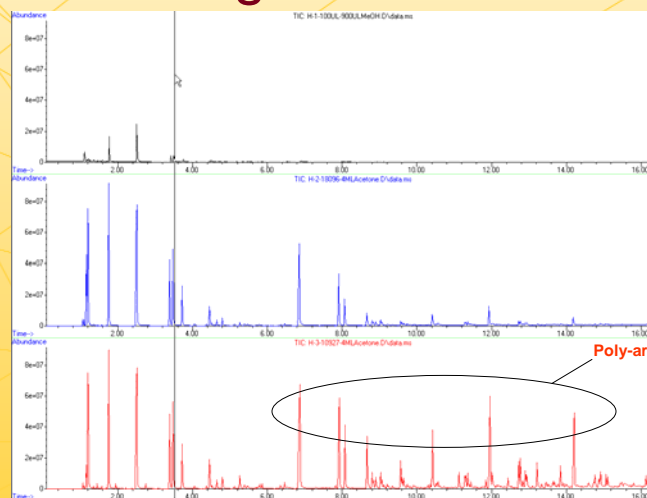


CA8, Canola oil

Gasoline

JP-8

Catalytic cracking and Hydrotreating of canola oil



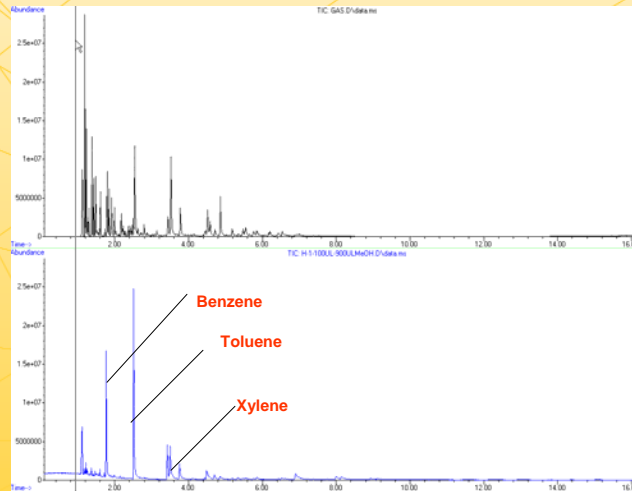
CA13

CA14

CA15

Poly-aromatics

Catalytic cracking and hydrotreating of canola oil, perfect gasoline blends or chemicals



Catalytic reforming conclusions

- Catalytic cracking is a promising route to produce gasoline components; fatty acids feedstocks can be converted into simple hydrocarbons (mainly BTX);
- Hydrotreating is useful to Hydrodeoxygenation for biomass conversion

NTP-Assisted Catalytic Reforming

- Catalytic reforming of syngas has become a useful way to produce biofuels and other chemicals
- Conventional catalytic reforming usually requires high temperature and high pressure
- Catalysts can perform very well at low temperature and pressure with assistance of Non-thermal Plasma (NTP).

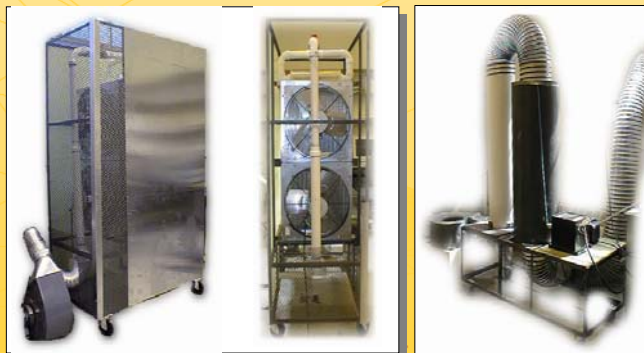
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Pulsed Corona Discharge Reactors



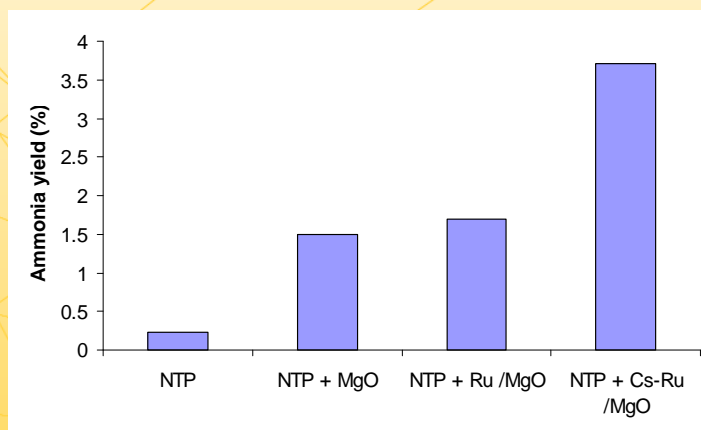
Silent discharge reactors

NTP Reactors



Ionizations of Nitrogen and Hydrogen with NTP-Assisted Catalysis

- $N_2 \rightarrow 2N^+$
- $H_2 \rightarrow 2H^+$
- $N^+ + H^+ \rightarrow NH^+$
- $NH^+ + H^+ \rightarrow NH_2^+$
- $NH_2^+ + H^+ \rightarrow NH_3^+$

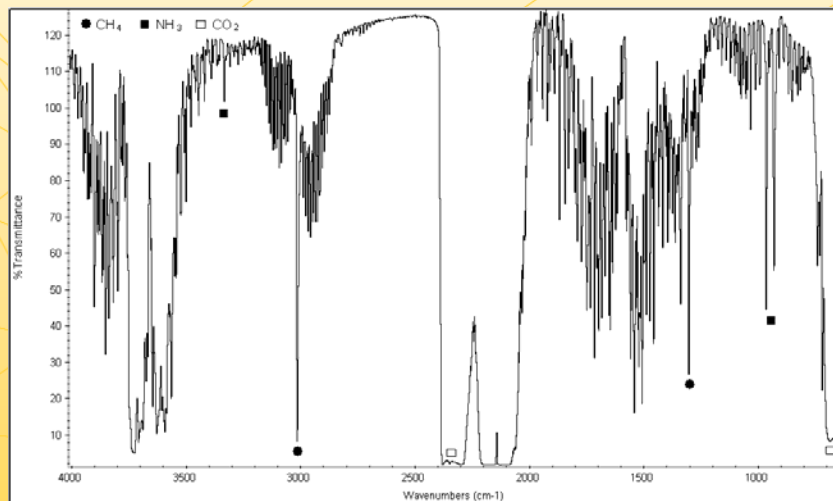


Ammonia synthesis under different conditions.

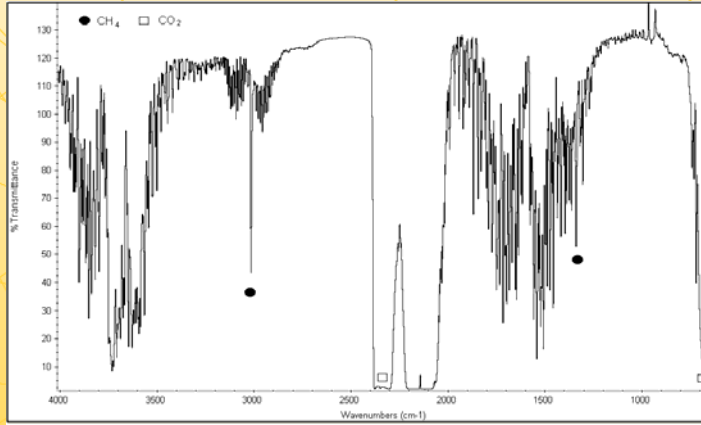
($V_{N_2}:V_{H_2}=1:3$, N_2 and H_2 total flow rate 60ml/min, voltage 5000V, frequency 8000Hz. Temperature , fresh catalyst initial activity)

Example - Ammonia Production

- 12% + ammonia produced at 150 ° C and atmospheric pressure
- Potential to reach higher concentration with further optimization of catalysts and conditions
- Low capital, operation, and maintenance costs

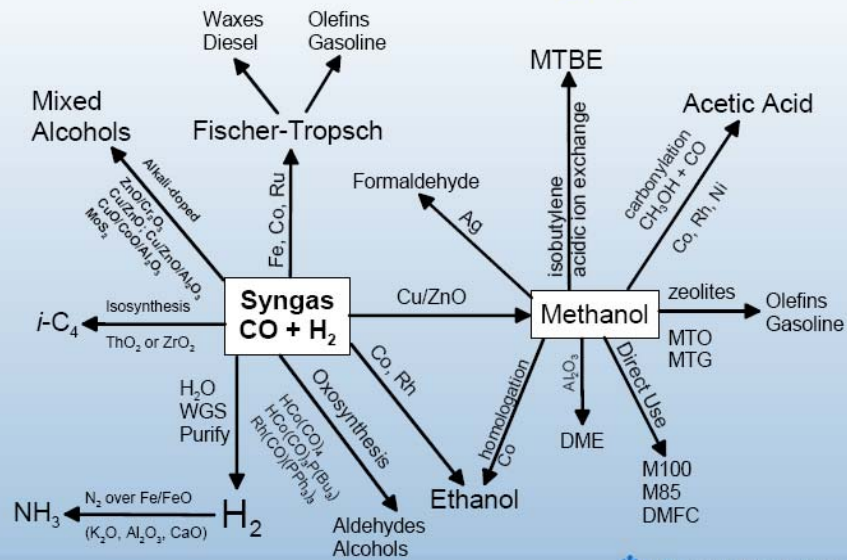


FT-IR spectrum of NTP reaction of N₂, CO, H₂ and/or H₂O vapor.



FT-IR spectroscopy of NTP reaction of CO and H₂O vapor.

Products from Syngas



Hydrothermal Catalytic Pyrolysis

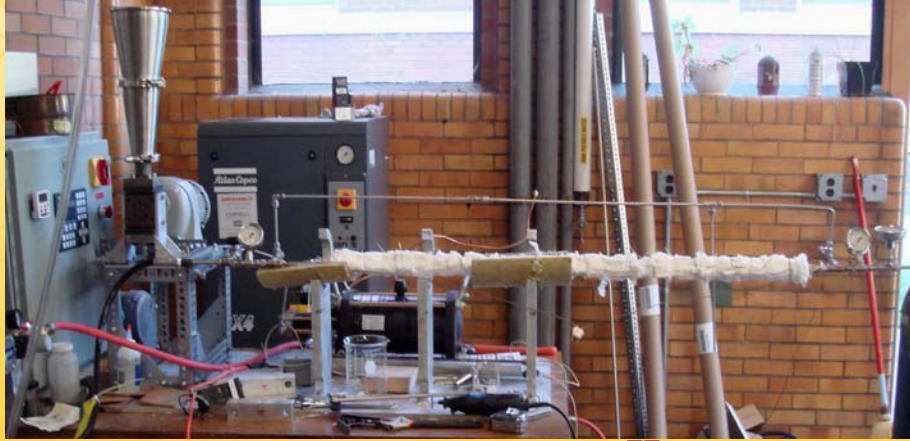
e.g. Direct Conversion of Algae to Liquid Fuel

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Continuous Hydrothermal Biomass Pyrolysis System



Continuous hydrothermal system –
straightened out and lengthened – attached
to Gear pump with black tubing at left.

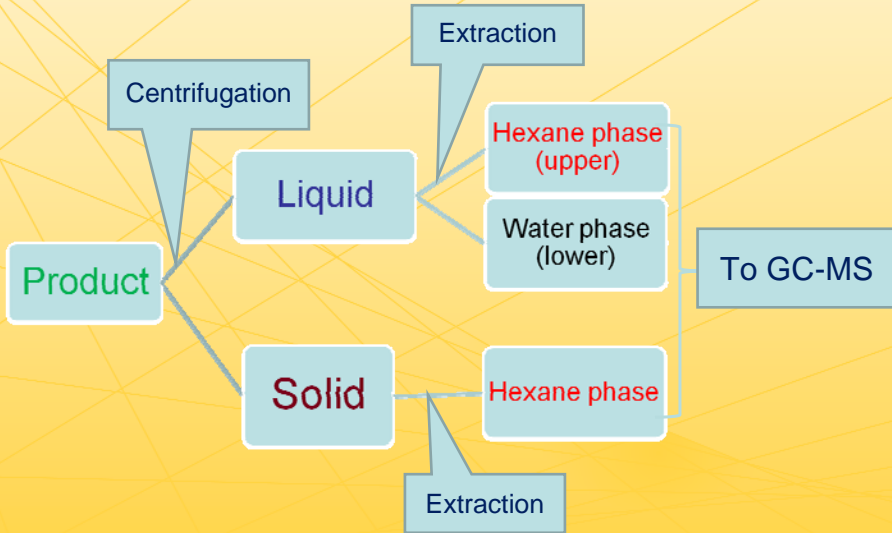


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Product analysis

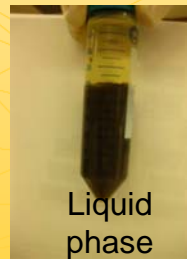


Bio-oil product

centrifugation



extraction

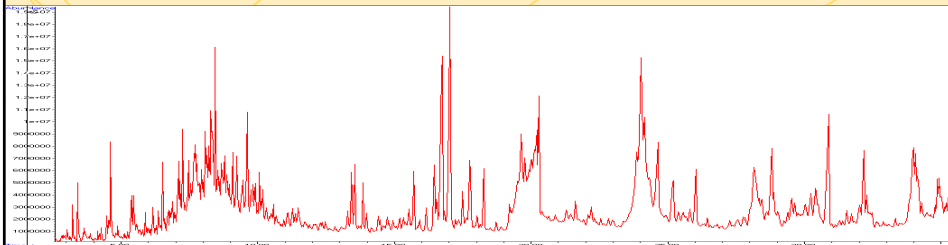


Liquid phase

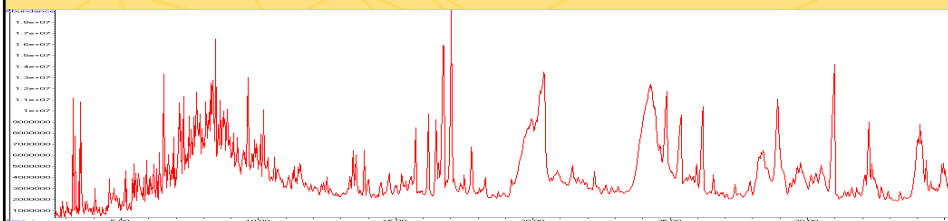


Solid phase

Results



(Reaction 1)



(Reaction 2)

Observations:

- A .Most extractable solid compounds are hydrocarbons, the carbon range from C7- C20 which can be use as the feedstock of gasoline and green diesel.
- B. Peaks appears from 2.5min – 10 min are mainly C7-C10; 10 min- 25 min are mainly C15-C20 , long chain acids are also found in this area. Ester are mainly found after 25 min.

GC-MS result of hexane phase after extraction



Compounds in hexane phase and water phase mostly are heterocyclic compounds, compared with the result of solid phase, most N compounds are in liquid phase of the product.

Direct Conversion of Algal Biomass into Biofuels



Algae slurry was pumping into the reactor



Algal biofuel product coming out the reactor

Acknowledgments:

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Questions?

R. Roger Ruan, Ph.D.

**Yangtze Scholar Distinguished Guest Professor
Nanchang University and
Professor and Director
Center for Biorefining
Department of Bioproducts and Biosystems Engineering
Department of Food Science and Nutrition
University of Minnesota
1390 Eckles Ave., St. Paul, MN 55113
ruanx001@umn.edu
612-625-1710
Biorefining.cfans.umn.edu**

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