Material Attributes of MSW that Impact the Quality for Hydrothermal Processes (HTP): Pathways and Feedstock End-Uses

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Wan-Ting (Grace) Chen
University of Massachusetts Lowell
OUTLINE

• Introduction
  • The PERL group at UMass Lowell
  • Material characteristics in MSW
  • Hydrothermal processing (HTP)

• High-ash MSW feedstock
  • Mixed-culture Algae from Wastewater
  • Plastic Waste

• High-fat MSW feedstock

• Recommendations
Hydrothermal Processes
Selective Solvent Extraction
Biodegradation

Plastics and Environment Research Laboratory

PERL

Raw Materials from Polymer
- Clean Fuels
- Solvents, Monomers
- Dyes, Flame Retardants
- Pristine Polyolefins
ONGOING RESEARCH PROGRAMS AT THE PERL GROUP

• Plastic Recycling
  • Hydrothermal processes to covert ocean plastic waste into fuels, aromatics, or monomers.
  • Smart solvent formulations to extract valuable plastics, additives, and metals.
  • Microplastic pollutants mitigation and separations.

• Bioplastic Development
  • Biodegradable mulch films from soy waste.
  • Degradation mechanism in packaging barrier materials.
  • Biobased polymers and biocrude oil converted from biowaste.

LCA/TEA
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TOTAL MSW GENERATION IN THE U.S. BY TYPES OF WASTE (2015)

- Paper: 25.9%
- Wood: 6.2%
- Glass: 4.4%
- Yard trimmings: 13.3%
- Food waste: 15.1%
- Plastics: 13.1%
- Metals: 9.1%
- Rubber, leather, and textiles: 9.3%
- Other: 3.6%

Total = 262 million tons
HYDROTHERMAL PROCESSES (HTP) MIMICS MOTHER NATURE’S MILLIONS-OF-YEARS PROCESS

Pros:
- Wet feedstocks
- Similar to crude oil
- Higher energy density

Cons:
- High Pressure

Diagram showing:
- Temperature (°C) on the x-axis
- Pressure (MPa) on the y-axis
- Hydrothermal Processes (HTP)
- Pyrolysis
- Gasification

Graph labels and data points indicating the process regions.
Hydrothermal Processes (HTP) of Different Types of MSW

Demonstratable Feedstock
- Animal Waste
- Algae
- Food Waste
- Sewage Sludge
- Plastic Waste

Reaction Temp.: 260 – 450°C
Reaction Time: 0–6 hr
Total Solid Content: 10-35 wt.%
Impurities (snail shells, silicate, plastic fillers)
Catalysts (e.g., Zeolites)

- Gas Product (< 10%)
- Post-HTP WW (20-40%)
- Solid Residue (10-30%)
- Biocrude Oil Product (20-50%)

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Elucidate the Effect of Ash Contents on HTP of High-Ash Biomass

**Hypothesis:** Biocrude oil quality would be negatively affected by increasing the ash contents in algal biomass (Chen et al., 2014a and b).

**Action items to examine the hypothesis:** Biomass with different amounts of ash contents was used to study the effect of ash contents on HTP.
Decreasing Ash Contents Increases the Heating Value of Biocrude Oil

Chen et al., Algal Research, 2017, 25, 297-306
Increasing Ash Content Decreased the Heating Value of Algal Biocrude Oil via HTP

Chen et al., Algal Research, 2017, 25, 297-306
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ON-GOING PROJECT: HTP OF POLYOLEFIN-BASED WASTE (PP WASTE AT 425°C FOR 4H)

Yield (wt.%) vs. Pure polyolefin

- Gas
- Solid
- Oil

Plastic container with inorganic fillers

Pure polyolefin

Yield (wt.%)
Elucidate the Effect of Ash Contents on HTP of High-Ash MSW Feedstock

**Hypothesis:** Biocrude oil quality would be negatively affected by increasing the ash contents in algal biomass, according to previous studies (Chen et al., 2014a and b).

**Action items to examine the hypothesis:** HTL of pure algae with different amounts of representative ash contents was conducted to examine the effect of ash contents on HTL processes.

**Summary:**
1. HTP can tolerate high-ash biomass (<40%) while producing decent quality of biocrude oil.
2. Ash contents may catalyze the oil formation under HTP.

Chen et al., Algal Research, 2017, 25, 297-306
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Elucidate the Effect of Biochemical Compositions on HTP of High-Fat Biomass

**Hypothesis:** Biocrude oil quality would be positively affected by increasing the crude fat contents in food waste biomass (Chen et al., 2018; Zhang & Chen, 2017).

**Action items to examine the hypothesis:** Food waste with different amounts of crude fat was used to study the effect of crude fat contents on HTP.

Zhang & Chen. Direct Thermochemical Liquefaction for Energy Applications, Chapter 5 2017, 127-168
Chen et al., Nature Sustainability, 2018, 1(11), 702-210
Zhang & Chen. Direct Thermochemical Liquefaction for Energy Applications, Chapter 5 2017, 127-168
IMPACT OF ASH CONTENT (SILICATE) ON HTP OF FOOD WASTE (280°C, 30 MIN)

Zhang & Chen. Direct Thermochemical Liquefaction for Energy Applications, Chapter 5 2017, 127-168
Elucidate the Effect of Biochemical Compositions on HTP of High-Fat Biomass

**Hypothesis:** Biocrude oil quality would be positively affected by increasing the crude fat contents in food waste biomass, according to previous studies (Chen et al., 2018).

**Action items to examine the hypothesis:** HTP of food waste with different amounts of crude fat was conducted to examine the effect of crude fat contents on HTP.

**Summary:**
1. When the crude fat increased, the biocrude oil yield increased.
2. HTP can tolerate high ash content (<40%) MSW feedstock (food waste).

**Unresolved questions:**
1. What are the most abundant ash contents in MSW?
2. What is the impact of different ash contents?
   - How the major ash content interacts with other biomolecules under HTP?
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RECOMMENDATION--1

- More research is needed to elucidate the contamination-tolerance levels for plastic additives under HTP.
  - Study the impact of the impurities in plastic waste on HTP.
  - Plastic additives such as plasticizers and flame retardants that may be regulated.
RECOMMENDATION--2

• More research is needed to elucidate the interaction between food waste and plastic waste.
  • Once the plastic and food wastes are contaminated with each other, they cannot be recovered by conventional methods.
  • The existence of plastic waste slows down the composting/AD processes and pollutes the composting and AD products.
  • Identifying methods that can simultaneously deal with plastic and food wastes is a key.
REFERENCES


THANK YOU AND ANY QUESTIONS?

• We are seeking feedback, collaborations and commercialization partners.

• Feel free to contact us:
  • Prof. Wan-Ting (Grace) Chen, WanTing_Chen@uml.edu
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