Value recovery from food waste (FW) by hydrothermal carbonisation (HTC) process

Guanhua Chen

Supervisors:
Prof. M Sohail
Dr. OOD Afolabi
Prof. CLP Thomas
Terms for this study

**Biomass**- organic matter from agricultural by-products and residues, woody waste or human waste for energy generation;

**Food supply chain**- describe the main stages and actors involving from producing food in the field to consuming food on our tables;

**Food loss**- refers to a decrease of food that was originally intended for human consumption, mainly taking place at production, postharvest and processing stages in the food supply chain;

**Food waste**- refers to a decrease of food that was originally intended for human consumption, mainly occurring at the end of the food chain (retail and final consumption);

**Hydrothermal carbonisation (HTC)**- a thermochemical process where biomass is treated under hot compressed water with applying elevated temperatures (180-250°C) to produce hydrochar.
Challenges

Demand for water, food and energy is increasing.

Competition between food and energy sector

Is there any possible that food waste can be recovered as an energy resource?
Findings in literature review

Biomass – a promising renewable resource to produce energy...

- Agricultural crops
- Forestry residues
- Animal residues
- Municipal solid waste
- Sewage
- Industrial residues
Throughout the world, food losses and waste total 1.3 billion tons per year.

Findings in literature review

(Sources: FAO, 2013; WRAP, 2012; BCFN, 2012)
Findings in literature review

Food loss and waste ⇝ Economic loss

30% of the world’s agricultural land is wasted

Water wasted in growing crops = all the world’s household water needs

8% of global greenhouse gas emissions

Zambezi river

Volga river
Findings in literature review

Where food is lost or wasted and How it happens?

Food loss
- Limitations on agricultural techniques
- Climate and environmental factors
- Compliance with regulations and standards
- Technical limits and limits on processing and production processes

Food waste
- Limits on the distribution system
- Deterioration of products and packaging
- Marketing and sales strategies
- Excess purchases
- Excess portions prepared
- Errors in food storage
Findings in literature review

What can we do?

Prevention
- Waste of raw materials, ingredients and product arising is reduced measured in overall reduction in waste.

Optimisation
- Redistribution to people
- Sent to animal feed

Recycling
- Waste sent to anaerobic digestion
- Waste composted

Recovery
- Treatment of waste with energy recovery

Disposal
- Waste treatment without energy recovery
- Waste sent to landfill
- Waste ingredient/product going to sewer

Food material hierarchy
Thermochemical conversion technologies

Dry
- Pyrolysis (450-600°C)
  - Biochar; Bio-oil
- Gasification (600-1000°C)
  - Syngas

Wet
- Hydrothermal process
  - Hydrothermal carbonisation (180-250°C)
    - Hydrochar
  - Hydrothermal liquefaction (300-350°C)
    - Biocrude
  - Hydrothermal gasification (>500°C)
    - Hydrogen
HTC is a thermochemical process where biomass is treated in hot compressed water at relatively mild temperature regimes (180-250°C) and autogenous pressure to produce hydrochar.

**Process conditions:**
- Temperature
- Residence time
- Feedstock
- Pressure

**Application:**
- Biofuel
- Adsorbent
- Energy storage
- Catalyst

(Sources: Libra *et al.*, 2011; Funke *et al.*, 2009)
Knowledge gap

• Most studies involving the use of HTC on sewage sludge, lignin and cellulose. Adopting HTC on food waste with the final stages of the FSC are largely unknown.

• Knowledge gaps on the characteristics of both hydrochar and liquid fraction products produced after the HTC process of Chinese FW under different reaction parameters

• Limited studies on creating a simplified simulation model of HTC process using experimental results and optimal existing process conditions based on model results
Research Questions

1. Does food waste have potential to generate **value-added products** by HTC process?

2. What are the effects of **operation conditions** on product (hydrochar and liquid) characteristics generated by HTC of food waste?

3. What is the **best reaction temperature and time** for improved energy recovery for maximum hydrochar yield and energy content?

4. What are the effects of fruit and vegetable waste (FVW) **moisture content** (solid loading) on hydrochar formation?

5. What are the **reaction kinetics** of food waste by hydrothermal carbonisation?
Objectives

To investigate the possibility of recovering value-added products in the form of solid fuel from HTC of FW for potential energy applications.

1. Identify the extent, impacts and management of food waste.
2. Investigate reaction mechanisms of HTC on biomass and review effects of the most common operation parameters on processing products.
3. Investigate the effect of reaction temperature and time on product (hydrochar) characteristics to optimise the operating conditions for food waste HTC.
4. Investigate the effect of FVW moisture content on the hydrochar formation by optimising the reaction temperature and time for greater solid yield.
5. Conduct detailed characterisation of products recovered from the HTC of FW to explore potential applications.
6. Determine the kinetics and parameters to ascertain the reaction order relating to HTC of food waste and use these data to develop a model to link the formation of the solids (hydrochar) particles with the reaction rate kinetics.
Methodology

Objective 1: Food waste issue - literature review

Objective 2: Mechanisms and operation conditions of HTC - literature review

Objective 3: Effects of reaction temperature and time - Experiments

Objective 4: Effects of moisture content - Experiments

Objective 5: Products characterisation - Experiments & Statistical analysis

Objective 6: Analysis - Statistical analysis & Simulation
Methodology

Objective 3&4&5
Lab experiments-based on experiments in Water Lab

- **Raw material** - mainly obtained from the canteen
- **Product characterisation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Regimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>180-240°C</td>
</tr>
<tr>
<td>Time</td>
<td>30, 60 mins</td>
</tr>
<tr>
<td>Pressure</td>
<td>Autogenous</td>
</tr>
</tbody>
</table>

HTC Reactor
<table>
<thead>
<tr>
<th>Year</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.1 Literature review</td>
<td>2.1 More specific literature review</td>
<td>3.1 Journal paper</td>
</tr>
<tr>
<td></td>
<td>1.2 Research aim and objectives</td>
<td>2.2 1st food waste collection</td>
<td>3.2 Writing thesis</td>
</tr>
<tr>
<td></td>
<td>1.3 Training on lab skills</td>
<td>2.3 Preliminary experiments in lab</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4 Preliminary experimental design</td>
<td>A) Data collection and analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.5 1st year report</td>
<td>B) Conference paper</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4 2nd food waste collection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5 Optimal experiments in lab</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A) Data collection and analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B) Conference paper</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C) Publish early research result</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.6 Validation experiments in lab</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A) Data collection and analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B) Simulation model</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.6 2nd year report</td>
<td></td>
</tr>
</tbody>
</table>
Reference


Thank you!