Integration of Anaerobic Digestion and Pyrolysis (AD-Py) for Biomethane Production in a Circular Bioenergy System

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Role of integrated AD-Py in the circular biogas system
AD-Py: How?

**Controlled Pyrolysis**

- **Lignocellulose**
- **Solid digestate**
- **Bio-oil**

**Aqueous pyrolysis liquid**

- **Pyrochar**
- **Syngas**

**Methanogenesis**

- **Bacteria**
- **Archaea**
- **R-COOH R-COH**

**Pyrochar**

- (direct electron transfer? functional groups?)

**Anaerobic Digestion**

- **Biogas**
- **Liquid digestate**

**Biorefinery**

- **CO\(_2\)**
- **H\(_2\)**

**Lignocellulose**

- **CH\(_3\)COOH**
- **CO\(_2\)**

**Production of Bio-oil**

- **R-COOH R-COH**

**Pyrochar**

- **CO\(_2\)**
- **H\(_2\)**
AD-Py: What’s the advantages?

• overcome the recalcitrant feature of lignocellulose feedstock
• avoid problematic land application for digestate management
• reduce groundwater contaminant
• Improve energy recovery in a circular bio-economy

AD-Py: What’s the problem?

**Challenges**

- Unsatisfactory selectivity for targeted pyrolysis products
- Low biodegradability of aqueous pyrolysis liquid
- Unclear energy recovery and environmental benefits of the integrated system

**Strategies**

- Optimizing the pyrolysis conditions for desired pyrochar
- Using pyrochar as an additive to enhance biomethane production
- Assessing the techno-economic and environmental benefits of the optimized system
My Research

Objective 1: Evaluate the **dominant factors** determining the pyrolysis reaction network and the **derived pyrochar properties**.

- **Raw & digested biomass** (grass/seaweed)
  
  **T1.1 Pyrolysis under different conditions**

- **Syngas**
  - Gas Chromatograph (GC)

- **Liquid products**
  - GC

- **Pyrochar**
  - Scanning Electron Microscope (SEM), N\textsubscript{2} adsorption, X-ray Photoelectron Spectroscopy (XPS), Fourier Transform Infrared Spectroscopy (FTIR)

**T1.2 Characterization**

- Surface area and porosity analyzer

**Expected results:** dominant factors and the properties of pyrochar
My Research

Objective 2: Identify the role of pyrochar in AD and correlate the effects of pyrochar with its specific physicochemical properties (especially the surface area, functional group, and electrical conductivity).

Expected results: role of pyrochar in AD and the related properties

BMP system

Pyrochar enhanced digestion model

\[ \text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{O} = \text{CH}_3\text{COOH} + 4\text{H}^+ + 4\text{e}^- \]

\[ 4\text{H}^+ + 4\text{e}^- + \frac{1}{2}\text{CO}_2 = \frac{1}{2}\text{CH}_4 + \text{H}_2\text{O} \]

\[ i = k \cdot \frac{\text{current}}{\text{area}} \cdot (E_{\text{meas}} - E_{\text{syn}}) \]
Objective 3: Demonstrate the **technical and environmental benefits** of the optimized AD-Py system and identify the **bottlenecks** in this system from a techno-economic perspective.

**T3.1 Optimizing the integrated AD-PY system**

- Pyrochar design
- Fermentation optimization
- Microbe acclimatization

**T3.2 Techno-economic assessment**

- Resource & inventories
- Costs & profits
- Environmental impacts

**Expected results:** biomethanation increased by 20-40%
Expected Output of My Research

- To **identify the interactions between AD and Py processes** in terms of the role of pyrochar in AD and the impacts of specific properties of pyrochar.

- To **increase the biomethane production by 20%-40%** in an optimized AD-Py system through optimization of fermentation conditions and directional design of pyrochar.
Thank you for your attention!