Organic waste valorisation into bioenergy and bioproducts through a cascade combination of bioprocesses

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Food is lost in every step of the food “life cycle”

World wastes about 17% of all the food produced (United Nations)

1 billion tonnes of food waste is generated per year

Production, processing and consumption are responsible for 75%

Fruits and vegetables wastes generated in the early stage of the food supply chain account for 30% of annual food losses in Europe
FOOD WASTE…. A BIG ISSUE

RETHINK THE WAY THAT FOOD IS PRODUCED AND CONSUMED

Source Reduction
- avoid generating food waste

Feed People In Need
- donate extra food to food rescue charities, soup kitchens and shelters

Feed Animals
- divert food scraps to animal feed

Composting and Renewable Energy
- unavoidable food waste converted to compost & energy

Landfill
- last resort for disposal

800 million people suffer from hunger and undernourishment

Food waste and water resources
25% of the world’s freshwater is used to grow food

Food waste and land
28% of the world's total agricultural area

Food waste and climate change
30% of greenhouse gas emissions
High management cost
Recover C (N & P) from wastes for energy and biochemicals production purposes

1. Develop bioprocesses that allows maximizing product portfolio (biorefinery)

2. Identification of microbial indicator of process efficiency

3. Improve the robustness of microbial systems (evolutionary engineering)
Short-chain fatty acids (SCFAs):
- Acetic acid
- Propionic acid
- Butyric acid
- Valeric acid
- Hexanoic acid

Hydrogen ($H_2$)
Ethanol (EtOH)

Maximum organic wastes valorization
Cascade combination of bioprocesses

Organic waste → Anaerobic Fermenter → SCFAs rich effluent → Anaerobic Digester → Biogas

1. Organic waste
   - 80% Carbohydrates
   - 8% Proteins
   - T = 55 ºC
   - HRT = 21 d
   - OLR = 2.3 g SV/L d
   - pH = 5.8
   - Inoculum adapted to temperature

2. SCFAs rich effluent
   - 50% Carbohydrates
   - 40% Proteins
   - T = 35 ºC
   - HRT = 20 d
   - OLR = 1.4 g COD/L d
   - pH = 7
   - Inoculum adapted to temperature + pH

Biogas → Bioproducts + Bioenergy
Cascade combination of bioprocesses

Organic waste

80% Carbohydrates
8% Proteins

Microalga

Tomato

Lettuce

SCFAs rich effluent

Solid spent

Anaerobic Fermenter

1

Total SCFAs = 24 g/L
Bioconversion = 50%

HBu = 65.6 %
HAc = 24.4 %

2000 $/tonne
600 $/tonne

Previous studies

Microalga
Tomato
Lettuce


Common values in literature
18 – 35 %

Anaerobic fermenter:
1. 50 % bioconversion into organic acids
2. 22 g EtOH / L
3. 140 L H₂/kg organic matter
Cascade combination of bioprocesses

**Anaerobic fermenter:**
1. 50% bioconversion into organic acids
2. 22 g EtOH / L
3. 140 L H₂/kg organic matter

**Anaerobic digester:**
4. 190 L CH₄/kg organic matter
5. Digestate → biofertilizer

80% Carbohydrates
8% Proteins

**Organic waste**

**SCFAs rich effluent**

**Solid spent**

**50% Carbohydrates**
40% Proteins

**CH₄ = 190 L CH₄/kg COD_FW**

54% Biodegradibility

vs.

**300 L CH₄/kg VS_FW**

Common values in literature for RAW organic waste

350-400 L CH₄/kg VS_FW

*Renewable and Sustainable Energy Reviews 133, (2020) 110138*
Microbial community analysis

Organic waste

- 80% Carbohydrates
- 8% Proteins

1. Anaerobic Fermenter
   - SCFAs rich effluent
   - Solid spent

2. Anaerobic Digester
   - 50% Carbohydrates
   - 40% Proteins

Biogas

<table>
<thead>
<tr>
<th>Inoculum 55 °C</th>
<th>AF 55°C</th>
<th>Index</th>
<th>Inoculum 35 °C</th>
<th>AD 35 °C</th>
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<td>1098</td>
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<td>895</td>
<td>544</td>
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<td>2.500</td>
<td>Shannon</td>
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Adapted to temperature but not to pH

Adapted to temperature but not to substrate

Biodiversity
Microbial community analysis

Organic waste
80% Carbohydrates
8% Proteins

Anaerobic Fermenter

1

SCFAs rich effluent
Solid spent

Anaerobic Digester

2

Biogas

PHYLUM

80% Carbohydrates
50% Carbohydrates
40% Proteins
Microbial community analysis

Organic waste

80% Carbohydrates
8% Proteins

Anaerobic Fermenter

1

SCFAs rich effluent

Solid spent

Anaerobic Digester

2

Biogas

GENUS

Acidic pH

Carbohydrates

80% Carbohydrates
8% Proteins

B42
undefined Enterobacteriaceae
S1
Ruminococcus
Anaerobaculum
undefined Chromatiales
Sulfurimonas
Thermoanaerobacterium
undefined Alcaligenaceae
undefined TIBD11
undefined SHA-98
undefined MBA08
Clostridium
Alkaliphilus
Leuconostoc
undefined Marinilabraceae
Enterococcus
Rummelbacillus

Inoculum
55 °C

AF
55 °C

Inoculum
35 °C

AD
35 °C

W22
Sphaerochaeta
undefined ABY1
undefined Comamonadaceae
undefined SB-1
Sedimentibacter
T78
undefined Anaerolinaeae
Paludibacter
Bacteroides
undefined Lactobacillales
undefined Bacteroidales
undefined Bacillales
FINAL REMARKS

- Cascade combination of bioprocesses

Think about AD as a multiproduct technology

- pH tuning can mediate product selection by promoting specific microorganisms with high industrial interest

Thermoanaerobacterium

SCFAs
Ethanol
H₂
Biogas
Biofertilizer
Thanks for your attention

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