Energy potential of waste(water) through Anaerobic Digestion processes

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Energy potential of waste(water) through Anaerobic Digestion processes
The need for energy

Energy potential of waste(water) through Anaerobic Digestion processes
Anaerobic digestion (AD) – What is it?

- Acetic acid
- Hydrogen
- Methane
- Carbon dioxide
- Amino acids
- Alcohols
- Sugar
- Long chain fatty acids
- Volatile fatty acids
- Hydrolysis
- Acidogenesis
- Acetogenesis
- Methanogenesis
AD – Potential outcomes

Energy potential of waste(water) through Anaerobic Digestion processes
AD – Biochemical methane potential (BMP)

BMP is expressed in L of methane produced per kg of volatile solids (VS) of waste (L kg\(^{-1}\))
Potential of the land

Lignocellulosic waste from forests, mainly shrub, is widespread available at relatively low cost

Response surface design to study the influence of inoculum, particle size and inoculum to substrate ratio on the methane production from *Ulex* sp.

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*Ulex europaeus* is one of the 30 most invasive plant species in the world according to the World Conservation Union (IUCN)
Potential of the land

The total forest area in Europe is $1.1 \times 10^9$ ha. Considering that 20% of total forest area is shrub and that only 60% of the total shrub land area can be used for energy exploitation, the energy potential of the land is up to 7 EJ yr$^{-1}$. The biochemical methane potential (BMP) is 313 L CH$_4$ kg$^{-1}$ VS and the maximum initial methane production rate (k) is 47 L CH$_4$ kg$^{-1}$ VS d$^{-1}$. These values highlight the potential for anaerobic digestion processes to harness energy from waste materials through the production of biogas.
**Potential of the seas – *Gracilaria vermiculophylla***

*Gracilaria vermiculophylla* is a species of red seaweed, originally from Japan, and recently found in European waters as an invasive specie.
Potential of the seas – *Gracilaria vermiculophylla*

**Physical pre-treatments**
- Washing
- Milling
- Drying

**Thermo-chemical pre-treatments**
- Temperature
- Pressure
- Alkaline agent
- Time

**Statistical approach**

**Washed** and **milled** sample was chosen for other assays, due to the best performance in terms of methane production.

380 L CH₄ kg⁻¹ VS
Potential of the seas – *Gracilaria vermiculophylla*

### Anaerobic co-digestion

- **Crude glycerol**
  - 599 L CH₄ kg⁻¹ VS
  - 96% of conversion

- **Sewage sludge** + **Crude glycerol**
  - 611 L CH₄ kg⁻¹ VS
  - 86% of conversion

The mixture of wastes from different sources helps to balance the C:N ratio.
**Potential of the seas – *Sargassum sp.***

*Sargassum sp.* is a brown macroalgae widely distributed in tropical and subtropical seas.

Crude glycerol and waste frying oil were used as co-substrates.

Optimization of biogas production from *Sargassum sp.* using a design of experiments to assess the co-digestion with glycerol and waste frying oil.

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Potential of the seas – *Sargassum* sp.

Statistical approach, with three variables

- Concentration of *Sargassum*
- Concentration of co-substrate
- Type of co-substrate

541 L CH$_4$ kg$^{-1}$ VS

150 L CH$_4$ kg$^{-1}$ VS d$^{-1}$

Up to 581 EJ yr$^{-1}$
Potential of the seas – *Sargassum* sp.

Biohythane production from marine macroalgae *Sargassum* sp. coupling dark fermentation and anaerobic digestion

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Potential of the seas – *Sargassum* sp.

Hydrogen dark fermentation at hyperthermophilic and extremely thermophilic conditions has been associated to higher productivities

![Extreme thermophilic bacteria – *Caldicellulosiruptor saccharolyticus*](image_url)

**Sargassum productivity**
6-33 ton VS ha\(^{-1}\) yr\(^{-1}\)

**Sargassum**
Estimated harvesting 12 ton VS ha\(^{-1}\) yr\(^{-1}\)

**Biohythane production**

1\(^{\text{st step}}\) Biohydrogen
1.1x10\(^6\)LH\(_2\) ha\(^{-1}\) yr\(^{-1}\)
12 GJ ha\(^{-1}\) yr\(^{-1}\)

2\(^{\text{nd step}}\) Biomethane
6.5x10\(^6\)LCH\(_4\) ha\(^{-1}\) yr\(^{-1}\)
230 GJ ha\(^{-1}\) yr\(^{-1}\)

Potential ocean area >25x10\(^6\) km\(^2\)
600 EJ yr\(^{-1}\)
Potential of the seas – *Ulva* sp.

Anaerobic co-digestion of sewage sludge and macroalgae with continuous and intermittent addition of glycerol

*Ulva* sp. is characterized by a low content of lignin and a high fraction of hemicellulose, being therefore, a suitable substrate for anaerobic digestion.
Potential of the seas – *Ulva* sp.

**Phase IV**

- **R1** (control): 2.37 L d\(^{-1}\), 151 L kg\(^{-1}\)
- **R2** (continuous addition of cGly): 5.22 L d\(^{-1}\), 253 L kg\(^{-1}\)
- **R3** (intermittent addition of cGly): 4.63 L d\(^{-1}\), 224 L kg\(^{-1}\)

**Phase V**

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- **TS** – Total solids
- **k** – Methane production rate (L of methane produced per d)
- **MP** – Methane production (L of methane produced per kg of COD of substrate in the feed)
Potential of the industry waste

Waste and wastewater management and disposal represent a significant cost factor.

In case of brewery, the volume of waste reach 1/3 of the volume of produced beer.
Potential of the industry waste

Trub
10% of the total waste volume

Spent grain
90% of the total waste volume

486 L CH$_4$ kg$^{-1}$ VS

Up to 16 PJ yr$^{-1}$
Potential of the industry waste

At same ratio of the production

Crude Glycerol was tested at different concentrations

582 L CH$_4$ kg$^{-1}$ VS

Up to 37 PJ yr$^{-1}$
Future perspectives

Energy potential of waste (water) through Anaerobic Digestion processes

Conversion processes

Anaerobic digestion

BIOGAS

HYDROGEN

Fertilizer

Residues valorization

Crops/Residues
Thank you for your attention

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