How to preserve the energy potential of organic residues during storage?

Focus on anaerobic digestion – agri-plants

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A few words about anaerobic digestion (AD)...

- Anaerobic digestion (AD) is accepted worldwide as a promising energy production technology for a green and sustainable future.

- The process is based on the biochemical conversion of a large range of complex organic matter to biogas,

- In fact, the AD process is much more complicated and the primitive technical design illustrated in this slide need to be improved!
A few words about anaerobic digestion (AD)...

- AD process is a combination of technical operations including
  1. Pretreatment
  2. Digestion
  3. Liquid-solid separation
  4. Liquid and digestate post-treatment

- For biogas production, this optimization can not only get the AD process, but also the **downstream systems**, i.e. the biomass selection, pretreatments and **storage**
Why the agricultural wastes storage?

- Nowadays, the diversification of AD inputs is wide, to recover energy from almost all types of organic wastes, feedstocks manures, forages or catch/energy crops

**Continuous** feeding of AD plants vs **Part of biomass seasonally** produced

Otherwise, although the need for continuous feeding of biogas plants every day, throughout the year, some of these agricultural/industrial wastes or crops are seasonally produced, leading **storage requirements, in some cases even of extended durations.**
Ensiling, hay, and open air-storage are three methods commonly used for biomass conservation before AD. The last one is mostly applied for agricultural wastes, due to the simplicity and low cost of the operation. However, open-air storage facilities are important source of ammonia and odor emissions, and should lead to substantial energy losses.

These drawbacks can be reduced if an efficient ensiling is carried out. According to the literature, ensiling lead to full conservation of biochemical methane potential (BMP) of specific catch crops even after 1 year.
Ensiling: biochemical-based preservation

Four step process

<table>
<thead>
<tr>
<th>Initial aerobic period</th>
<th>Anaerobic fermentation</th>
<th>Stable phase</th>
<th>Feed-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption of oxygen trapped in the system</td>
<td>Competition between anaerobic microorganisms</td>
<td>Anaerobic conditions and stable low pH</td>
<td>Aerobic organisms are reactivated</td>
</tr>
</tbody>
</table>

Control of feedstock properties → Success of silage

- % Moisture
- % Water Soluble Carbohydrates
- Buffering capacity...

![Graph showing pH over Storage duration (days)]

e.g.: Acidification vs. Storage period
Objective: Identify the best management practices for agricultural biomass storage before anaerobic digestion

FEEDSTOCKS:

Catch crop 1 « winter »
triticale, peas, vicia and fodder radish

Catch crop 2 « summer »
sunflower, sorghum, peas, vicia and Trifolium

Cattle manures:
1 and 2

CONDITIONS:

1- Open-air storage and ensiling for catch crops and cattle manures.
2- Co-ensiling of cattle manures with several additives
Objective: Effects of the storage method on the preservation of organic matter (VS) and Bio-Methane Potential (BMP)

Experimental approach

- **Batch reactors:** 4 L silos
- **Storage duration:** 3 or 4 months
- **Stable temperature:** 25°C
- **Analyses:** pH, VS, BMP...

Gas analysis: kinetics; composition

Biomass evolution: before and after storage (TS, VS, COD, pH, ORP, soluble carbohydrates - sugar, hem, cell, VFAs etc...)
1- Long-term storage: Ensiling vs. Open-air

**ORGANIC MATTER (VS)**

- pH < 5
- pH < 6
- pH > 8
- pH > 9

**BIO-METHANE POTENTIAL (BMP)**

- pH > 9
- pH > 9
- pH > 9
Long-term storage
How to store CATTLE MANURE?

Additional tests → tracks for a successful ensiling

**Fresh cattle manure**
- pH: 8.0
- Soluble carbohydrates: 0%
- Dry matter content: 13%

**Manure**: raw material without available sources of acidification in ensiling!!

**pH evolution**

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**Critical pH**
Objective: Effects of silage additives on the preservation of organic matter and BMP of cattle manure

- Similar experimental approach (25°C; 4 months)
- Two different cattle manures: CM1 / CM2

Silage additives / Co-substrates:

- **Wheat straw (WS)**: for CM1 and CM2
  - Moisture decrease
- **Formic acid (FA)** 2%wt: for CM2
  - Fermentation Inhibitor
- **Glucose (G)** 10%wt: for CM2
  - Fermentation Stimulant
Co-ensiling trials
Towards the efficiency of manure preservation

Preservation of **ORGANIC MATTER** and **BIOMETHANE POTENTIAL**

<table>
<thead>
<tr>
<th>Condition</th>
<th>pH Range</th>
<th>Conservation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM1+WS</td>
<td>pH: 8.3 -&gt; 5.5</td>
<td>100%</td>
</tr>
<tr>
<td>CM2+WS</td>
<td>pH: 8.3 -&gt; 8.4</td>
<td>80%</td>
</tr>
<tr>
<td>CM2+WS+FA</td>
<td>pH: 3.5 -&gt; 6.9</td>
<td>90%</td>
</tr>
<tr>
<td>CM2+WS+G</td>
<td>pH: 7.9 -&gt; 3.7</td>
<td>100%</td>
</tr>
</tbody>
</table>

**CM**: Cattle Manure  
**WS**: Wheat Straw  
**FA**: Formic Acid  
**G**: Glucose
Conclusions

- **Ensiling**: mandatory for preservation of the methane potential

- However, ensiling of fresh **cattle manure** leads to substantial **energy losses** in the long term:
  Cattle manure properties: lack of easily available substrate for fermentation, high water availability, non-adapted buffering capacity...

- Finally, **co-ensiling** with a substrate containing high concentration of **available carbohydrates** appears to be the most resourceful method to **optimize cattle manure storage** before biogas production
Thank you for your attention!

Rémy!
We need straw rolls!
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Thank you for your attention!

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Long-term storage
Ensiling vs. Open-air

Effects of storage condition on pH

<table>
<thead>
<tr>
<th>Condition</th>
<th>pH after storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch crop 1</td>
<td>Ensiling: 5.0</td>
</tr>
<tr>
<td>Catch crop 2</td>
<td>Ensiling: 5.0</td>
</tr>
<tr>
<td>Cattle manure</td>
<td>Ensiling: 8.0</td>
</tr>
</tbody>
</table>