Comparison of single-stage and temperature-phased anaerobic digestion of sugar beet by-products

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Lignocellulosic biomass

1 tonne of Sugar beet processed → 70 kg of exhausted dried pulp
≈ 250 kg of exhausted pressed pulp

Total global production in 2014
267 Mt

20 Mt of dry SBP

Animal feedstock supplement
Lignocellulosic biomass

Bioenergy = Anaerobic digestion technology
ANAEROBIC DIGESTION = BIOLOGICAL PROCESS

- **Complex biopolymers**
  - Carbohydrates
  - Proteins
  - Fat/oil

- **Simple monomers**
  - Sugars
  - Aminoacids

- **Volatile fatty acids**
  - Alcohols

- **Acetic acid**

- **H_2**
- **CO_2**

- **CH_4**
- **CO_2**

**HIDROLYSIS**
**ACIDOGENESIS**
**ACETOGENESIS**
**METHANOGENESIS**

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SINGLE STAGE ANAEROBIC DIGESTION PROCESS

Complex biopolymers
- Carbohydrates
- Proteins
- Fat/oil

Simple monomers
- Sugars
- Amino acids

Volatile fatty acids
- Alcohols

Acetic acid

HIDROLYSIS
ACIDOGENESIS
ACETOGENESIS
METHANOGENESIS
TWO PHASED ANAEROBIC DIGESTION PROCESS

DARK FERMENTATION
- Complex biopolymers
  - Carbohydrates
  - Proteins
  - Fat/oil
- Simple monomers
  - Sugars
  - Aminoacids
- Volatile fatty acids

ACIDOGENESIS
- Acetic acid

HIDROLYSIS
- Sugars
- Aminoacids

METHANOGENESIS
- H₂
- CO₂
- CH₄
- CO₂

ACETOGENESIS
- Acetic acid

METHANOGENESIS
- H₂
- CO₂
- CH₄
- CO₂

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TWO PHASED ANAEROBIC DIGESTION PROCESS

DARK FERMENTATION

- Simple monomers
  - Sugars
  - Amino acids

METHANOGENESIS

- Volatile fatty acids
- Acetic acid
- Acetogenic
- Methanogenic

HIDROLYSIS

- Complex biopolymers
  - Carbohydrates
  - Proteins
  - Fat/oil

ACIDOGENESIS

ACETOGENESIS

METHANOGENESIS

CH₄

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OBJETIVE
SINGLE STAGE VS TWO-PHASED ANAEROBIC DIGESTION OF SUGAR BEET BY-PRODUCTS
Experimental design

Run I
Single stage

HRT = 20 days
OLR = 3.4 ± 0.2 (gVS/Lr*d)

Acidogenic

HRT = 10 days
OLR = 6.6 ± 0.4 (gVS/Lr*d)

Methanogenic

HRT = 20 days
OLR = 2.5 ± 0.2 (gVS/Lr*d)

Run II
TPAD

35°C

55°C

65°C

35°C
Experimental design

**Run I**
Single stage

- **HRT = 20 days**
- **OLR = 3.4 ± 0.2 (gVS/Lr*d)** at 35°C

**Run II**
TPAD

- **HRT = 10 days**
- **OLR = 6.6 ± 0.4 (gVS/Lr*d)** at 55°C
- **HRT = 20 days**
- **OLR = 2.5 ± 0.2 (gVS/Lr*d)** at 35°C

Acidogenic

- **55°C**
- **HRT = 10 days**
- **OLR = 6.6 ± 0.4 (gVS/Lr*d)**

Methanogenic

- **35°C**
- **HRT = 20 days**
- **OLR = 2.5 ± 0.2 (gVS/Lr*d)**
Semi-continuous stirred tank digesters

- Biogas collection
- Mixing system
- Temperature monitoring
- Feeding/Effluent
- Heater plate
Single stage anaerobic digestion assays

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Accumulated methane (L)

- **Mesophilic**
- **Thermophilic**

MPR = 0.55 LCH\(_4\)/L\(_r\) *d

MPR = 0.30 LCH\(_4\)/L\(_r\) *d

45%
**Results & Discussion**

**Single stage anaerobic digestion assays**

**Mesophilic**
- pH = 7 - 7.8
- VS removal (%) = 83%

**Thermophilic**
- pH = 7.5 - 8
- VS removal (%) = 66%
Combination 1: Thermophilic acidogenic - mesophilic methanogenic

HPR = 0.45 (LH2/Lr*d)

MPR = 0.19 LCH4/Lr*d
**Combination 1: Thermophilic acidogenic - mesophilic methanogenic**

**Results & Discussion**

**Two-phased anaerobic digestion assays**

- **Acidogenic digester**
  - pH = 5.5 - 6
  - VS removal (%) = 46%

- **Methanogenic digester**
  - pH = 7.5 - 8
  - VS removal (%) = 70%
Combination 1: Thermophilic acidogenic - mesophilic methanogenic

**Acidogenic digester**

- pH = 5.5 - 6
- VS removal (%) = 46%

**Methanogenic digester**

- pH = 7.5 - 8
- VS removal (%) = 70%

Acetoclastic methanogens inhibition
Two-phased anaerobic digestion assays

Combination 2: Hyperthermophilic acidogenic - mesophilic methanogenic

<table>
<thead>
<tr>
<th>HPR</th>
<th>0.11 LH2/Lr*d</th>
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<tr>
<td>MPR</td>
<td>0.09 LCH4/Lr*d</td>
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Combination 2: Hyperthermophilic acidogenic - mesophilic methanogenic

**Background Experimental procedure**

**Results & Discussion**

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Acidogenic digester

Methanogenic digester

- **pH = 5.5 - 6.5**
  - VS removal (%) = 23%

- **pH = 7.5 - 8.5**
  - VS removal (%) = 72%
Two-phased anaerobic digestion assays

Combination 2: Hyperthermophilic acidogenic - mesophilic methanogenic

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Acidogenic digester

- pH = 5.5 - 6.5
- VS removal (%) = 23%

Methanogenic digester

- pH = 7.5 - 8.5
- VS removal (%) = 72%

Acetoclastic methanogens inhibition
Two-phased anaerobic digestion assays

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Two-phased anaerobic digestion assays

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Thermophilic acidogenic

Palmitate

Lignocerate

Mesophilic methanogenic

LCFAs concentrations (mg/L)

Hyperthermophilic acidogenic

LCFAs concentrations (mg/L)

LCFAs concentrations (mg/L)

Mesophilic methanogenic

LCFAs concentrations (mg/L)
Is the TPAD suitable for sugar beet by-products??

Single stage ✓

Next step

Co-digestion:
Including a livestock co-substrate in the TPAD assays (pig slurry and cow manure)
Thank you for your attention