Biogas from Energy Crops – Preliminary Results of Biomass Storage and Pre-treatment under Northern Conditions

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Methane from Energy Crops

Selection of Crops

Crop Cultivation

Harvesting
Size Reduction
Pre-Treatment (1)

Harvest Time

Storage
- Ensiling
- Dry Storage

Pre-Treatment
(2)

Biogas Production

Post-Treatment

Storage of Digestate & Post Gasification

Methane

Heat
Electricity
Traffic Fuel

Digestate

Pre-Treatment

Harnessing

Time
Reasons for Pre-storing Biomass for Biogas Production

- Short cultivation periods, storage needed up to 8 months

- Optimal methane yields per hectare with several harvesting times (methane yield / VS, biomass production per hectare)

- Energy produced when most optimum / needed
Methods for Pre-storing Biomass

- Aiming at low CH$_4$ potential losses (VS losses (non-structural carbohydrates))
- Storage as a pre-treatment: improving methane yields and methane production rates
- Simple and low cost techniques and management
- Potentially different options (scale) for
  - farm-scale vs. centralised digesters
  - co-digesting vs. crop digesting plants
  - dry vs. wet processes
Post-storing Digested Biomass for Biogas Production

Reasons for (covered) post-storing digested biomass
- Only short periods (3-4 months) potential for land application
- No other use for the digestate than land application
- Recovery of remaining methane potential, prevent methane losses / emissions

Post-storing digested biomass
- Up to 8-9 months, sufficient capacity
- Simple and low cost structures at ambient temperatures
- Stimulate methane recovery:
  - Post-treatment before post-storage
  - Low cost passive heating systems to increase temperature
- Different options for farm-scale vs. centralised digesters and for co-digesting vs. crop digesting plants
Storage of Crop Biomass

- Traditional methods: drying, ensiling

- Drying
  
  High losses of organic matter, subjectivity to weather conditions, dry material not suitable for biogas production

- Ensiling: soluble carbohydrates contained in plant matter undergo lactic acid fermentation: → pH drop → Inhibition of growth of detrimental micro-organisms

- The process can be controlled by
  - Preventing the growth of all micro-organisms (e.g. acids)
  - Stimulating the growth of lactic acid bacteria (e.g. bacterial inoculum or enzymes)
Storage trials

- Storage of timothy-clover grass and rye grass as silage in bales for 3-8 months in field conditions with and without additives
- Systematic follow-up of the chemical characteristics, CH$_4$ potential and mass
- Finally, after 6-8 month storage co-digested with manure in farm digester
Storing – laboratory studies

- Grass (75 % timothy *Phleum pratense*, 25 % meadow fescue *Festuca Pratensis*), 30 % TS, VS/TS 0,9, lignin 15 % of TS, 0.23 m$^3$CH$_4$/kgVS, 64.2 m$^3$CH$_4$/tFW

- Stored in 5 L laboratory silos for 3 months at 20$^\circ$C, and for 6 months at 20 and 5 $^\circ$C without and with additives:
  - Formic acid
  - Enzymes
    - Xylanases and cellulases
  - Lactic acid bacteria
    - *Lactobacillus rhamsonus* and *Propionibacterium freudenreichii*
  - Mixed culture from a farm biogas reactor
Specific methane yields (per original VS)

- No additive
- Formic acid
- Enzyme
- Lactic acid bacteria
- Mixed culture

- Fresh crop
- After addition of storage additive
- After 3 months at 20°C
- After 6 months at 20°C
- After 6 months at 5°C
Storing Grass - Results

- Storage without additives led to losses of 17-39 % in methane potential.

- Most additives increased the initial methane yields (partially acting as substrate) and decreased the methane potential losses during storage.

- Without additives storage time (3-6 months) and temperature (5 -20°C) had major impacts on methane potential, but not with additives.
Pre- /Post-treatment of Energy Crops

- **Objectives:**
  - Increase methane yields or / and methane production rates:
    - in biogas digesters: 35°C, HRT 20-40 days
    - during post-storage/methanation (several months at 5-20°C)

- **Impacts:**
  - Increasing available surface area for microbial action
  - Breaking polymeric chains to more easily accessible soluble compounds
  - Promoting subsequent biodegradation
Pre-treatment Laboratory Trials

- Substrate: timothy-clover grass (also tops of sugar beets, straw)
- Physical
  - autoclaving, water incubation
- Biological
  - enzymes, composting, white-rot fungi
- Chemical
  - Alkalis (NaOH, Ca(OH)$_2$+Na$_2$CO$_3$), peracetic acid
Pre-Treatment Results

- Alkali treatments (NaOH, Ca(OH)$_2$ +Na$_2$CO$_3$)
  - 15 % increase in CH$_4$ yields
- Physical, biological, peracetic acid treatment
  - High losses of organic matter
  - No increase in methane yield


Viinikainen, T., Lehtomäki, A., Ronkainen, O. & Rintala, J. (in prep.): Effect of chemical pre-treatments on anaerobic digestion of energy crops and crop residues.