


Process & Technology Research in BRC – a brief overview

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Energimyndigheten

Biogas Research Center

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I BRC-labbet utvecklas framtidens biogas

”Den allt hetare klimatdebatten gör att intresset för biogas som bränsle ökar. I BRC:s laboratorium sliter forskarna för att göra produktionen så effektiv som möjlig – och för att kunna använda helt nya råvaror i framtiden”

https://liu.se/nyhet/framtidens-biogas

Utmaningar:

- Mer gas ur befintliga system
- Nya substrat

Biogas towards 2030

- Commercial biogas production is part of a closed cycle where food waste, sewage and residues from agriculture, forestry and industry provide renewable fuels, electricity, heat and biofertilizer
- Biogas can also be used to further extent as fuel and raw materials in industry, heavy transport and in shipping
- The production and use of biogas contributes to efficient use of society's resources including environmental, climate & social benefits

National biogas strategy & climate policy framework

- E.g. biogas is crucial for reducing emissions from transport by 70% by 2030 and reaching zero emissions of greenhouse gases by 2045
- **With a target of 15 TWh of biogas use per year 2030**, the biogas industry can contribute
- 2.1 TWh biogas was produced in 2017 & 2.7 million tonnes digestate
- **In order to meet the target, different measures as well as research & development are needed for increased biogas production & use**

Process & Technology Research in BRC 1 & 2

Primarily focus on improving profitability in existing biogas processes by:

- Identifying bottle-necks for process efficiency & stability
- Optimization of nutrient availability & reactor sludge properties, active biomass, capacity for increased organic loading and/or reduced retention time as well as better utilization of reactor volume
- Identifying residual organic matter & means to improve degradation of this material
- Increase knowledge of hydrolytic processes, protein engineering and applications of enzymes for improved biogas production

"Contribute to provision of knowledge and process- and technology development"

"Important changes in biogas processes that would lead to more profitable biogas companies?"

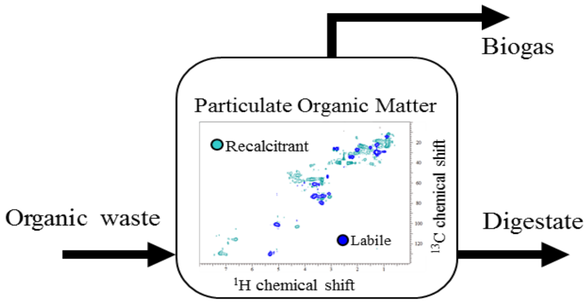
The experiments carried out in collaboration with BRC partners ...

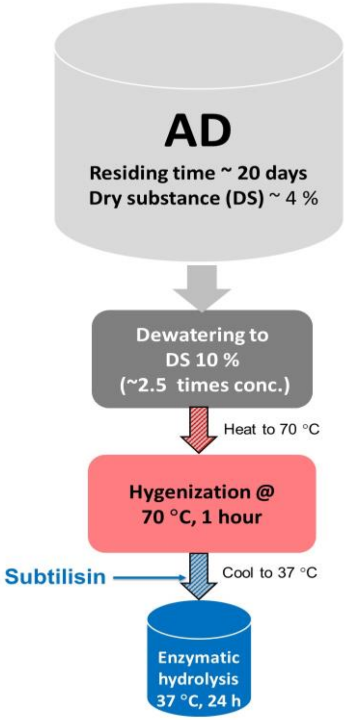
Tekniska verken, vmab, Gasum, NSR, PURAC, Scandinavianbiogas, biototal, LRF, Kemira, InZymes Biotech

Process &Technology oriented BRC-projects

- EP1 – Improvement of the biogas production process *(explorative project)*
- DP6 – Increased methane production & process stability in biogas reactors
- DP7 – Enzymatic increase in sludge digestability
- DP8 – Systems & technology for efficient use of biofertilizers
- RP1 – Improved hydrolysis as means to increase the overall degradability of organic material in anaerobic digestion for biogas production

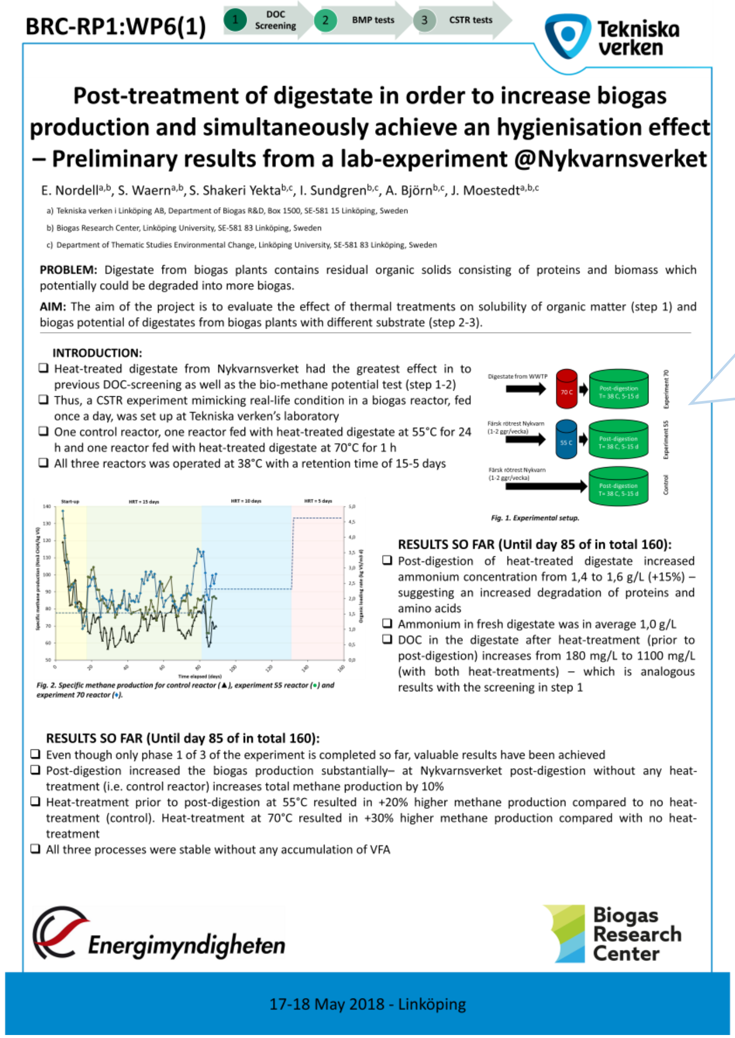
Examples of Outcomes:





- Importance & optimization of nutrient balances & trace element additives; may target unused methane potentials in different substrate profiles
- Increased understanding of microbial degradation pathways and rate-limiting steps, and important regulators (e.g. S:Fe)
- Process/reactor design to increase the active biomass for improved digestion (e.g. fat/lipids)
- Substrate and operational conditions as regulators of fluid properties in full-scale continuous stirred-tank biogas reactors affecting process- & energy efficiency
- Improved hydrolysis is of great importance, especially for the degradation of proteins and lignocellulose, which has largely been identified as under-utilized in digestates from full-scale biogas processes
- Posttreatment techniques & concepts (improved AD of lignocellulose, residual proteins)
- Challenge for successful application of enzymes is to extend their life-time in the current environments. Potential use of novel enzymes for proteinengineering.

Moderate heat treatment of various digestates for increased biogas production



BRC-RP1:WP6(1) — 1 DOC Screening — 2 BMP tests — 3 CSTR tests — Tekniska verken

Post-treatment of digestate in order to increase biogas production and simultaneously achieve an hygienisation effect – Preliminary results from a lab-experiment @Nykvarnsverket

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PROBLEM: Digestate from biogas plants contains residual organic solids consisting of proteins and biomass which potentially could be degraded into more biogas.

AIM: The aim of the project is to evaluate the effect of thermal treatments on solubility of organic matter (step 1) and biogas potential of digestates from biogas plants with different substrate (step 2-3).

INTRODUCTION:

- Heat-treated digestate from Nykvarnsverket had the greatest effect in to previous DOC-screening as well as the bio-methane potential test (step 1-2)
- Thus, a CSTR experiment mimicking real-life condition in a biogas reactor, fed once a day, was set up at Tekniska verken's laboratory
- One control reactor, one reactor fed with heat-treated digestate at 55°C for 24 h and one reactor fed with heat-treated digestate at 70°C for 1 h
- All three reactors was operated at 38°C with a retention time of 15-5 days

Fig. 1. Experimental setup.

Fig. 2. Specific methane production for control reactor (▲), experiment 55 reactor (•) and experiment 70 reactor (•).

RESULTS SO FAR (Until day 85 of in total 160):

- Post-digestion of heat-treated digestate increased ammonium concentration from 1,4 to 1,6 g/L (+15%) – suggesting an increased degradation of proteins and amino acids
- Ammonium in fresh digestate was in average 1,0 g/L
- DOC in the digestate after heat-treatment (prior to post-digestion) increases from 180 mg/L to 1100 mg/L (with both heat-treatments) – which is analogous results with the screening in step 1

RESULTS SO FAR (Until day 85 of in total 160):

- Even though only phase 1 of 3 of the experiment is completed so far, valuable results have been achieved
- Post-digestion increased the biogas production substantially– at Nykvarnsverket post-digestion without any heat-treatment (i.e. control reactor) increases total methane production by 10%
- Heat-treatment prior to post-digestion at 55°C resulted in +20% higher methane production compared to no heat-treatment (control). Heat-treatment at 70°C resulted in +30% higher methane production compared with no heat-treatment
- All three processes were stable without any accumulation of VFA

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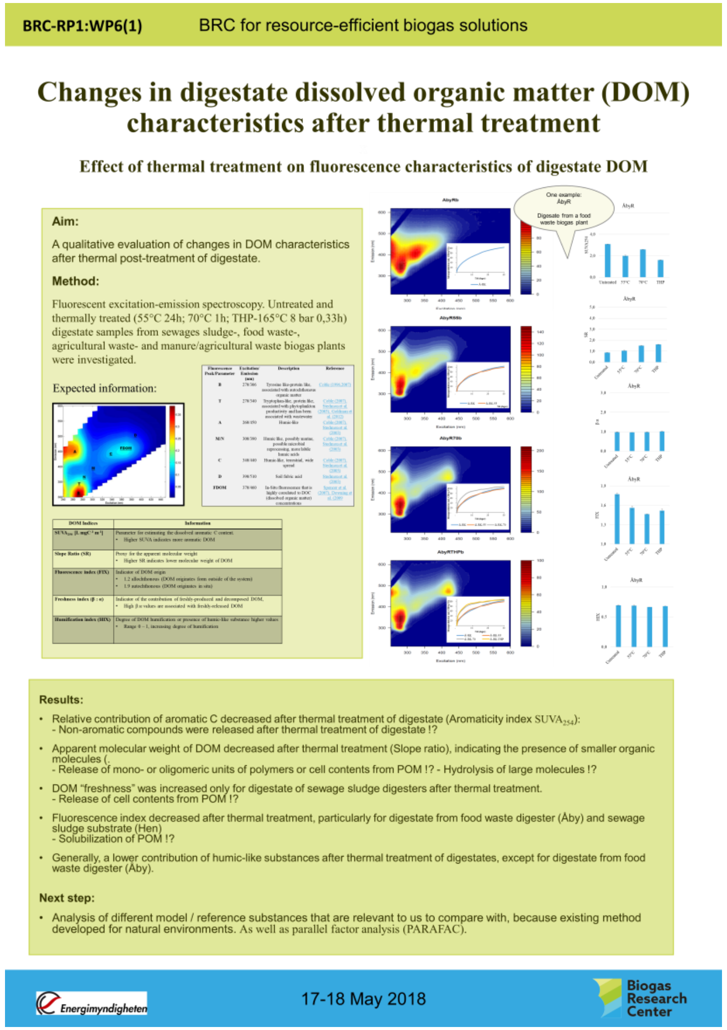
* Heat-treatment prior to post-digestion at 55°C and 70°C have resulted in +20% and 30% higher methane production, respectively, compared to no heat-treatment (control).

* Relative contribution of aromatic C decreased after thermal treatment of digestate.

* Hydrolysis of larger molecules → molecular weight of DOM decreased.



BRC-RP1:WP6(1) BRC for resource-efficient biogas solutions

Changes in digestate dissolved organic matter (DOM) characteristics after thermal treatment

Effect of thermal treatment on fluorescence characteristics of digestate DOM

Aim:

A qualitative evaluation of changes in DOM characteristics after thermal post-treatment of digestate.

Method:

Fluorescent excitation-emission spectroscopy. Untreated and thermally treated (55°C 24h; 70°C 1h; THP-165°C 8 bar 0,33h) digestate samples from sewages sludge-, food waste-, agricultural waste- and manure/agricultural waste biogas plants were investigated.

Expected information:

Results:

- Relative contribution of aromatic C decreased after thermal treatment of digestate (Aromaticity index $SUVA_{254}$):
  - Non-aromatic compounds were released after thermal treatment of digestate !?
- Apparent molecular weight of DOM decreased after thermal treatment (Slope ratio), indicating the presence of smaller organic molecules (.
  - Release of mono- or oligomeric units of polymers or cell contents from POM !? - Hydrolysis of large molecules !?
- DOM "freshness" was increased only for digestate of sewage sludge digesters after thermal treatment.
  - Release of cell contents from POM !?
- Fluorescence index decreased after thermal treatment, particularly for digestate from food waste digester (Åby) and sewage sludge substrate (Hen)
  - Solubilization of POM !?
- Generally, a lower contribution of humic-like substances after thermal treatment of digestates, except for digestate from food waste digester (Åby).

Next step:

- Analysis of different model / reference substances that are relevant to us to compare with, because existing method developed for natural environments. As well as parallel factor analysis (PARAFAC).

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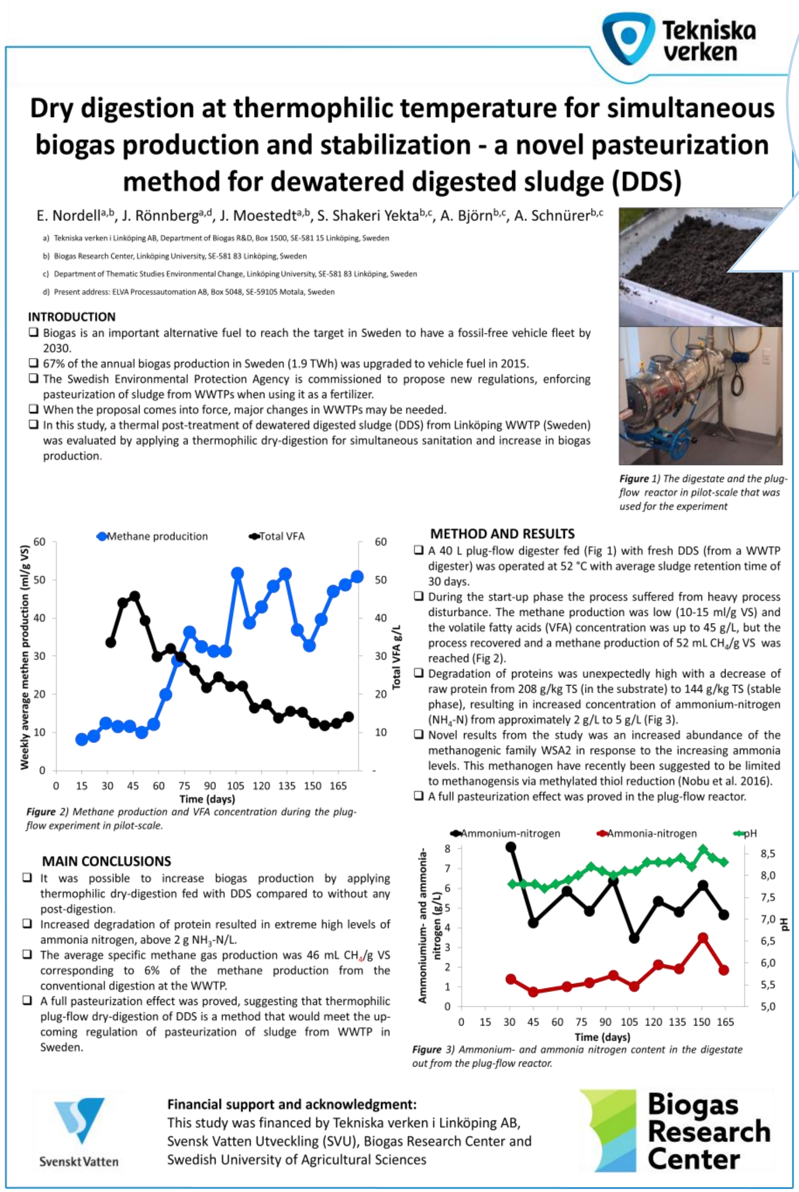
Effects of operational process parameters on hydrolysis



Dry digestion at thermophilic temperature for simultaneous biogas production and stabilization - a novel pasteurization method for dewatered digested sludge (DDS)

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INTRODUCTION

- Biogas is an important alternative fuel to reach the target in Sweden to have a fossil-free vehicle fleet by 2030.
- 67% of the annual biogas production in Sweden (1.9 TWh) was upgraded to vehicle fuel in 2015.
- The Swedish Environmental Protection Agency is commissioned to propose new regulations, enforcing pasteurization of sludge from WWTPs when using it as a fertilizer.
- When the proposal comes into force, major changes in WWTPs may be needed.
- In this study, a thermal post-treatment of dewatered digested sludge (DDS) from Linköping WWTP (Sweden) was evaluated by applying a thermophilic dry-digestion for simultaneous sanitation and increase in biogas production.

Figure 1) The digestate and the plug-flow reactor in pilot-scale that was used for the experiment

Figure 2) Methane production and VFA concentration during the plug-flow experiment in pilot-scale.

METHOD AND RESULTS

- A 40 L plug-flow digester fed (Fig 1) with fresh DDS (from a WWTP digester) was operated at 52 °C with average sludge retention time of 30 days.
- During the start-up phase the process suffered from heavy process disturbance. The methane production was low (10-15 ml/g VS) and the volatile fatty acids (VFA) concentration was up to 45 g/L, but the process recovered and a methane production of 52 mL CH_4/g VS was reached (Fig 2).
- Degradation of proteins was unexpectedly high with a decrease of raw protein from 208 g/kg TS (in the substrate) to 144 g/kg TS (stable phase), resulting in increased concentration of ammonium-nitrogen (NH_4-N) from approximately 2 g/L to 5 g/L (Fig 3).
- Novel results from the study was an increased abundance of the methanogenic family WSA2 in response to the increasing ammonia levels. This methanogen have recently been suggested to be limited to methanogensis via methylated thiol reduction (Nobu et al. 2016).
- A full pasteurization effect was proved in the plug-flow reactor.

Figure 3) Ammonium- and ammonia nitrogen content in the digestate out from the plug-flow reactor.

MAIN CONCLUSIONS

- It was possible to increase biogas production by applying thermophilic dry-digestion fed with DDS compared to without any post-digestion.
- Increased degradation of protein resulted in extreme high levels of ammonia nitrogen, above 2 g NH_3-N/L.
- The average specific methane gas production was 46 mL CH_4/g VS corresponding to 6% of the methane production from the conventional digestion at the WWTP.
- A full pasteurization effect was proved, suggesting that thermophilic plug-flow dry-digestion of DDS is a method that would meet the up-coming regulation of pasteurization of sludge from WWTP in Sweden.

Financial support and acknowledgment:
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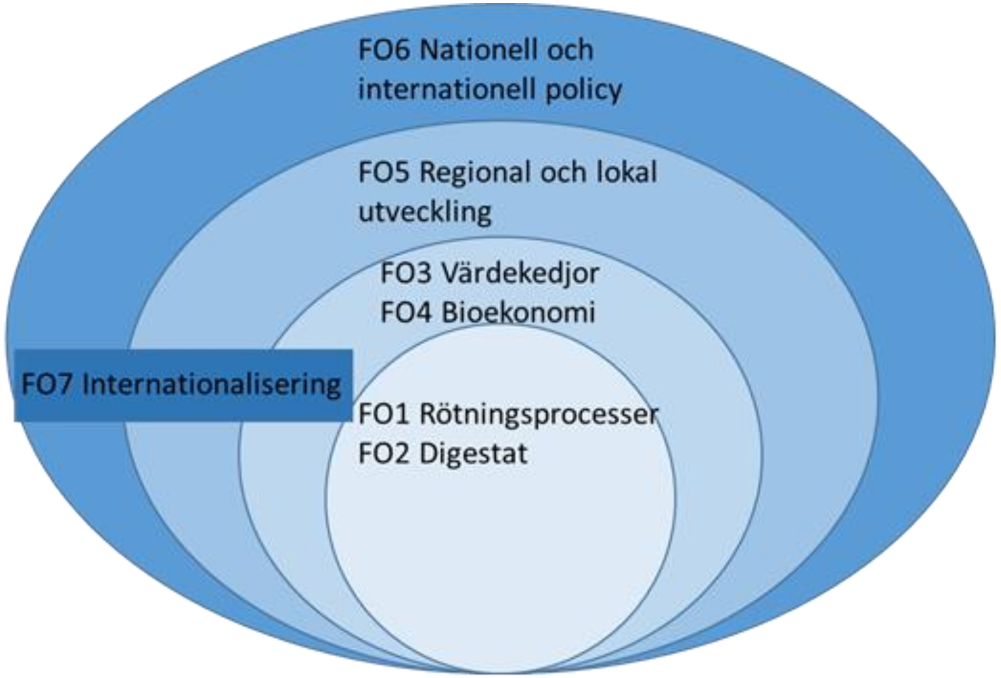
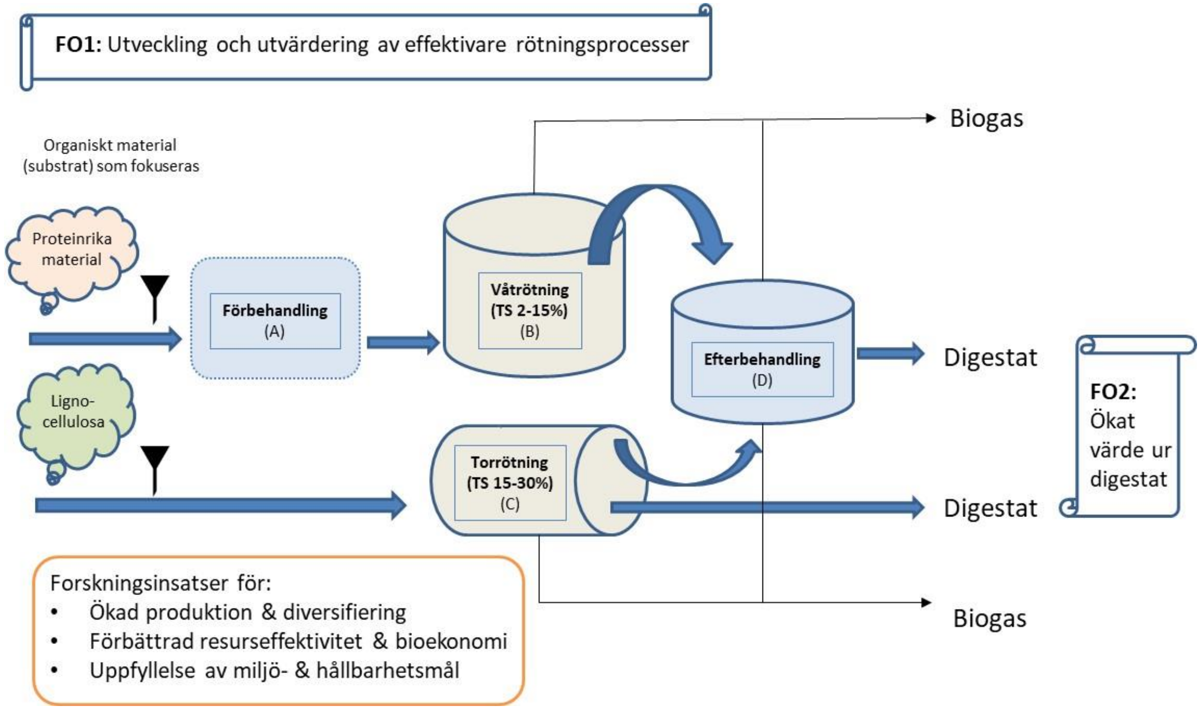
Thermophilic dry-digestion of digestate (WWTP) demonstrated to be effective for degradation of residual protein structures and at the same time provides a hygienization effect

Feasibility of OFMSW co-digestion with sewage sludge for increasing biogas production at wastewater treatment plants

Importance of sulfide interaction with iron as a regulator of microbial community in biogas reactors and its effect on methanogenesis, volatile fatty acids turnover, and syntrophic fatty acids degradation

Envision of Biogas Research within BRC3



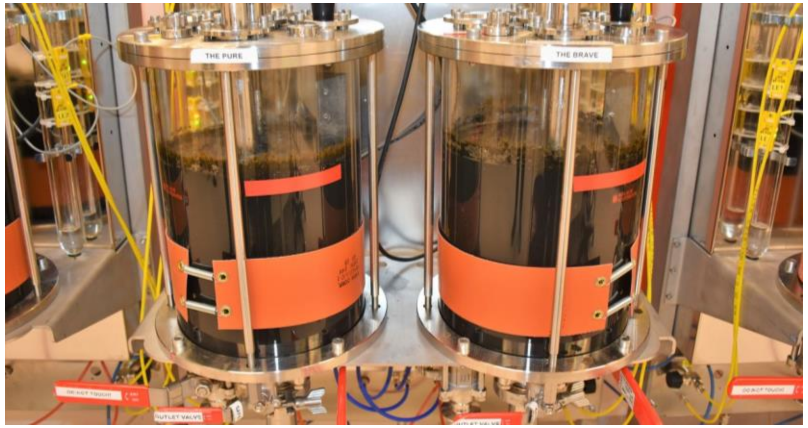


FO1 – Development & evaluation of AD processes
FO2 – Increased valorization of digestate
FO3 – Resource-efficient value chains for biogas solutions
FO4 – The role of biogas solutions in the bioeconomy
FO5 – The role of municipalities & regions in developing sustainable biogas solutions
FO6 – Evaluation scenarios for national & international policy
FO7 – Internationalization of Swedish biogas solutions

Proteinrika substrat och material rika på lignocellulosa avses fokuseras:

A) Enzymatisk för(mellan/efter)- behandling för ökad mikrobiell hydrolys
B) Näringsbalanser och substratkombinationer vid våtrötning
C) Processoptimering för torrötning
D) Tekniker och nya processlösningar för omsättning av restproteiner och lignocellulosalika strukturer genom efterbehandling.

& dess effekter på digestategenskaper & spridningsmöjligheter, tekniker för avvattning etc.



Thanks for listening -
Questions, Reflections & Discussion