Effective anaerobic digestion of fish waste, manure and lignocelluloses, with and without digestate recirculation.

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- Results
- Conclusions

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Introduction

Co-digestion benefits

- Different substrates have different lipids, proteins, carbohydrates compositions
  - lipids: glycerol, milk whey, slaughterhouse waste, fish waste
  - proteins: fish waste, industrial organic waste, food waste
  - carbohydrates: lignocellulose, manure

so co-digestion helps to reach the feasible yield of 30 m^3 biogas/m^3 biomas treated for the biogas plants (Danish centralized biogas platform)

..but what can go wrong when co-digesting so different materials?

- VFA and LCFA inhibition
- NH_3 at toxic levels
- accumulation of substances (microelements, heavy metals)
- accumulation of recalcitrant fractions inside digester

Thus, long term experiments with (semi)continuous systems are crucial!

Materials & Methods

› Industrial fish waste (category 2 animal byproduct): high in proteins and lipids

› lignocellulose biomass (*Salix viminalis* sp.): carbon rich, low nitrogen load

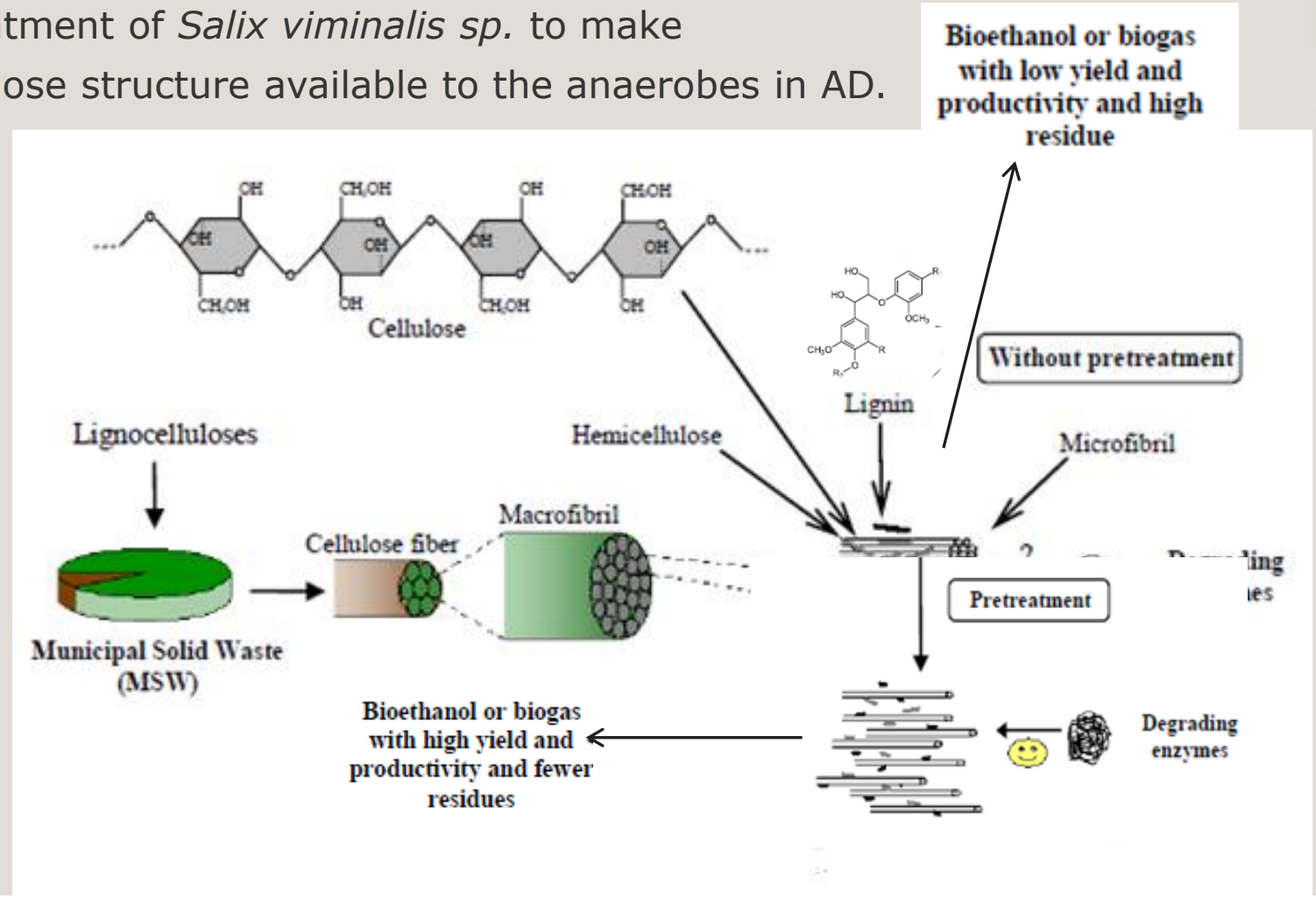
› Cattle manure: balanced nitrogen and carbon

Materials & Methods

	pH	TS %	VS %	NH_4^+-N (mg/L)	COD (mg/L)	Total-N (mg/L)	C% (d/w)	N% (d/w)	C/N
Salix v.(steam exploded)	3.7	21.9	21.6	_____	191350 (mg /Kg)	_____	51.17	0.59	87
Manure	7.6	11.0	9.0	1340	52805	2200	45.80	2.02	23
Fish waste	3.9	25.9	25.0	1590	377500	13500	53.62	9.75	6
Inoculum Åna	7.8	6.9	5.5	_____	35425	4900	40.57	3.93	10
Inoc. reactors	7.8	3.9	3.0	3230	_____	_____			

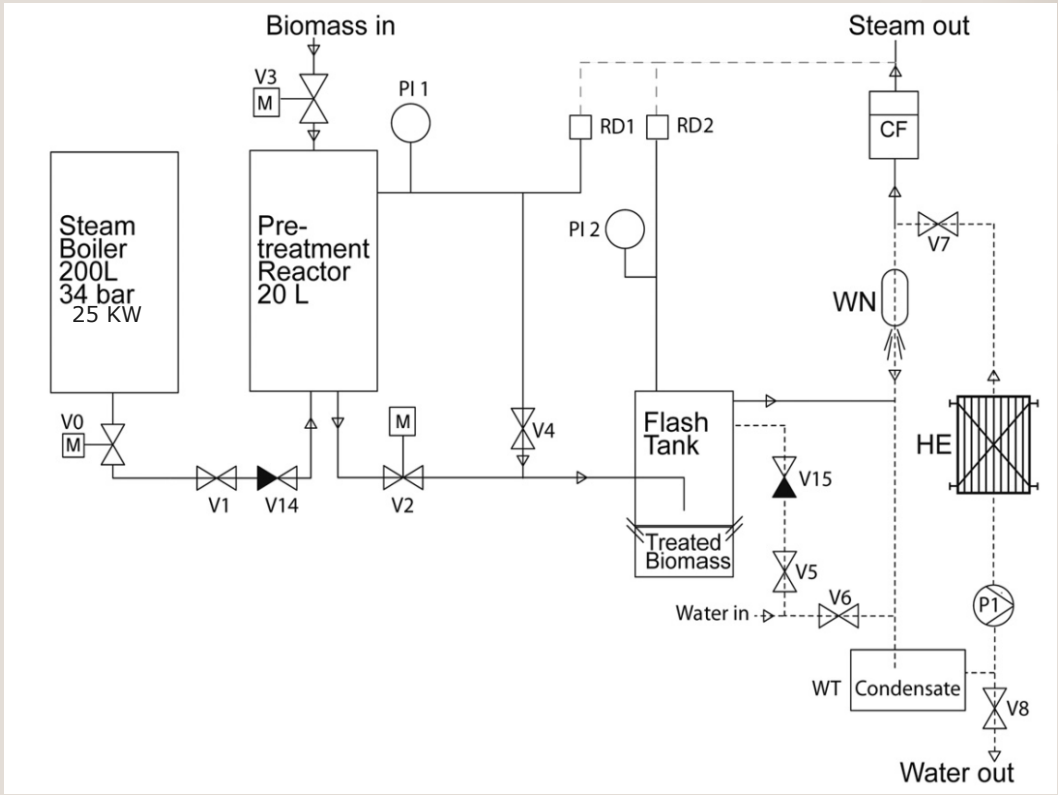
Materials & Methods

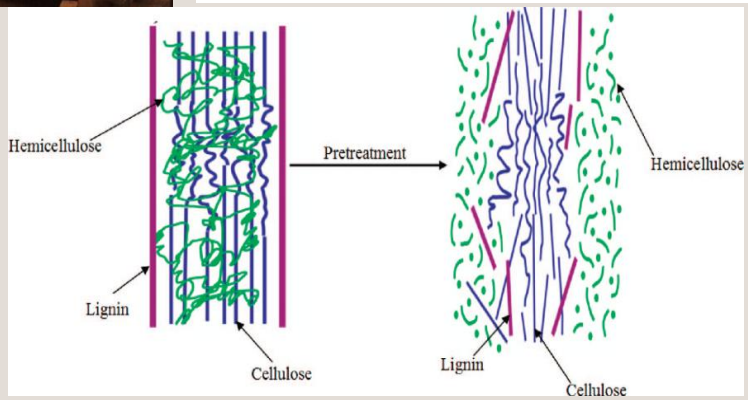
› Pre-treatment of *Salix viminalis sp.* to make lignocellulose structure available to the anaerobes in AD.



Source: Taherzadeh and Karimi, 2008. *Pretreatment of Lignocellulosic Wastes to Improve Ethanol and Biogas Production: A Review*. *Int. J. Mol. Sci. 9, 1621-1651;* ISSN 1422-0067.

Materials & Methods





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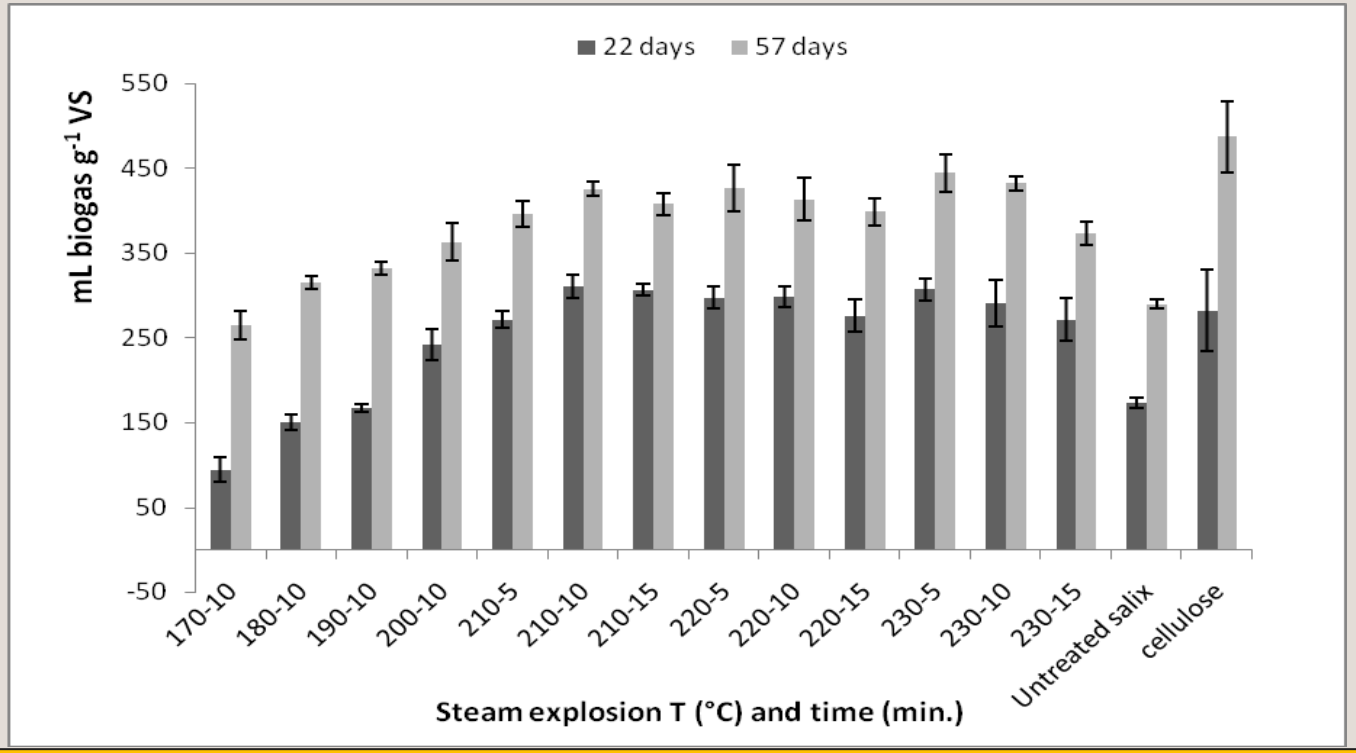
(Sources: Horn et al. (2011), *Biomass Bioenerg.* 35, 4879-86; Kumar et al. (2009), *Ind. Eng. Chem. Res. 48,* 3713–3729).

Materials & Methods
….on pre-treatment of Salix (BMP) previous results

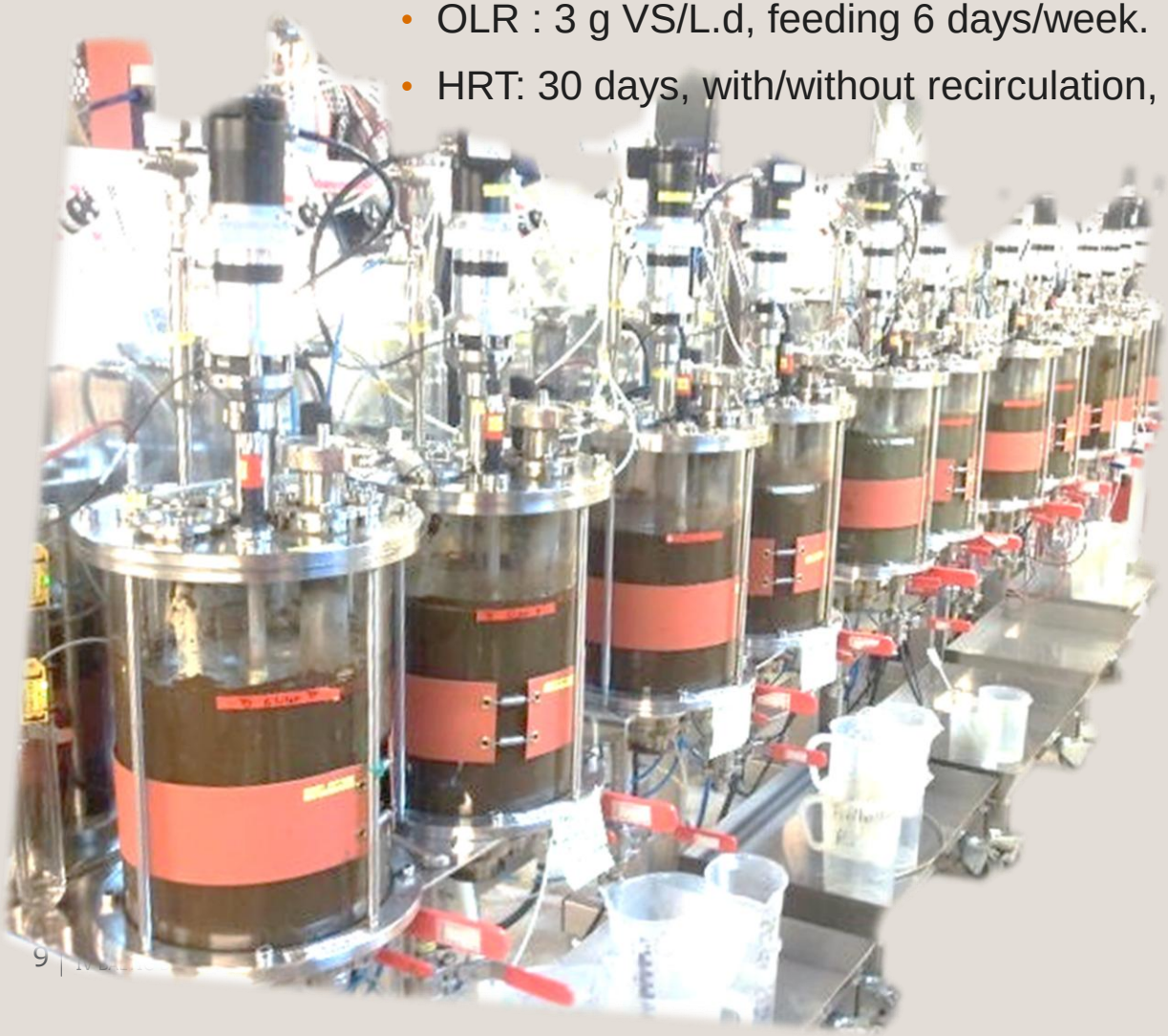


- Steam explosion proved to be an effective pre-treatment for *Salix* , methane yield increased up to 50 %.
- Higher and relatively similar methane yield values were obtained for all the treatment temperatures above 210 ºC.
- 210 ºC – 10 minutes were chosen as the pre-treatment conditions for *Salix* in next experiment.

Materials & Methods

The (semi) continuous systems for AD:

- 6 L working volume CSTRs Dolly© (BELACH BIOTEKNIK, SWEDEN)
- Mesophilic (37 ± 1 C °)
- OLR : 3 g VS/L.d, feeding 6 days/week.
- HRT: 30 days, with/without recirculation, followed min. 3HRT.



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Materials & Methods

Recirculation

A
Salix+manure(40/60)

B
Salix+manure+fish (40/20/20)

C
Salix+manure(40/60)

D
Salix+manure+fish(40/20/20)

Return:
Liquid fraction
(DM 4 %)

Raw effluent:
ca. 6 % DM, 5%
VS.

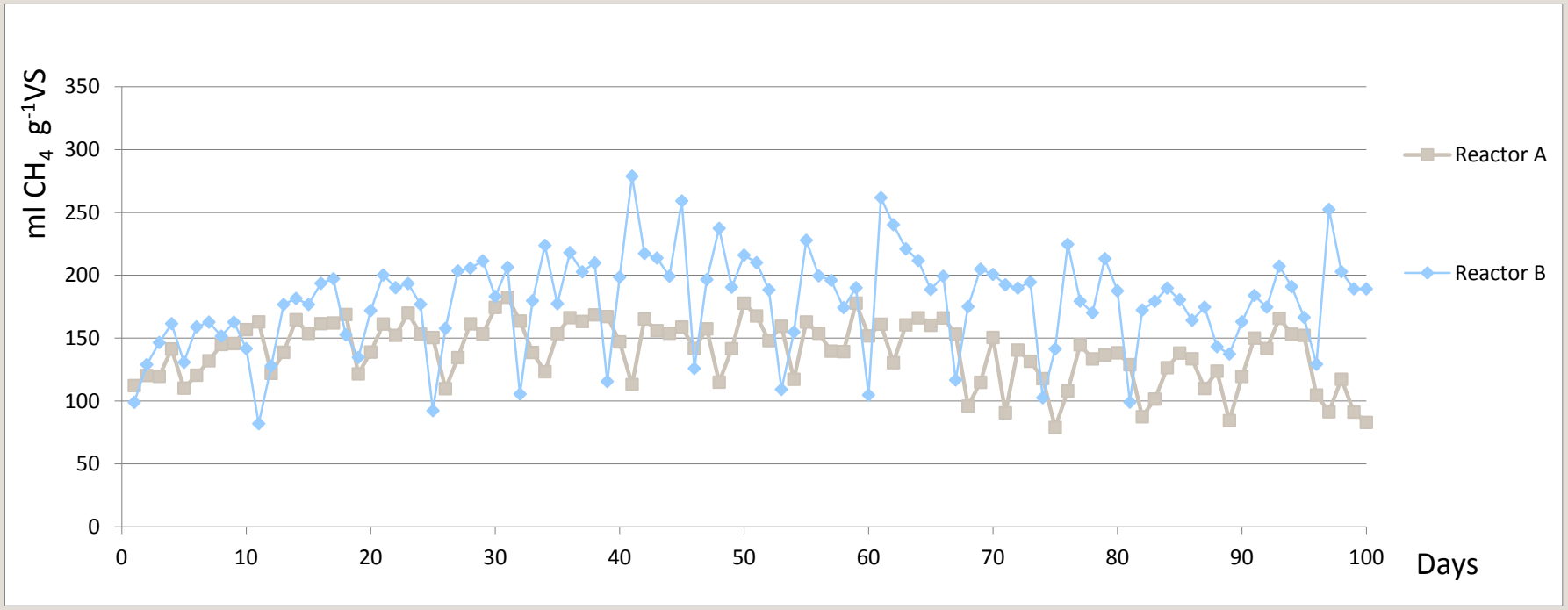
Dry matter reduction
30%, VS reduction
32%.

mesh 2.5 mm

mesh 1 mm

Results

Salix+manure (A) – Salix+manure+fish (B)



After adapation (first high VFA content), methane production was 30% higher when fish waste was added as co-substrate.

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Results

Effect of recirculation:

- Increased methane production by 16% (Reactor A vrs. C) when pore size was 2.5 mm
- Increased methane production only 6 % (Reactor B vrs D) when pore size was 1 mm

Possible causes:

Chemically:

- Increased nutrients conc.-→ buffer capacity-→ robustness to imbalances
- Increased retention time for non-easily degradable fractions-→ recovery of residual methane potential trap normally in fibers/lignocelluloles fractions (can be up to 30%)

Microbiologically:

- Increased microbial biomasss conc.--→ enhanced degradation

- It is also known that bacteria strains that adapt better to high NH_3 levels posses longer doubling times, so longer retention times may benefit they presence.

- Recirculation with a finer pore size showed that less VS in the recycled fraction lead to a lower increase in methane but higher stability (less recalcitrant matter accumulated in long term)--→ a compromise between higher yield or higher stability has to be found!

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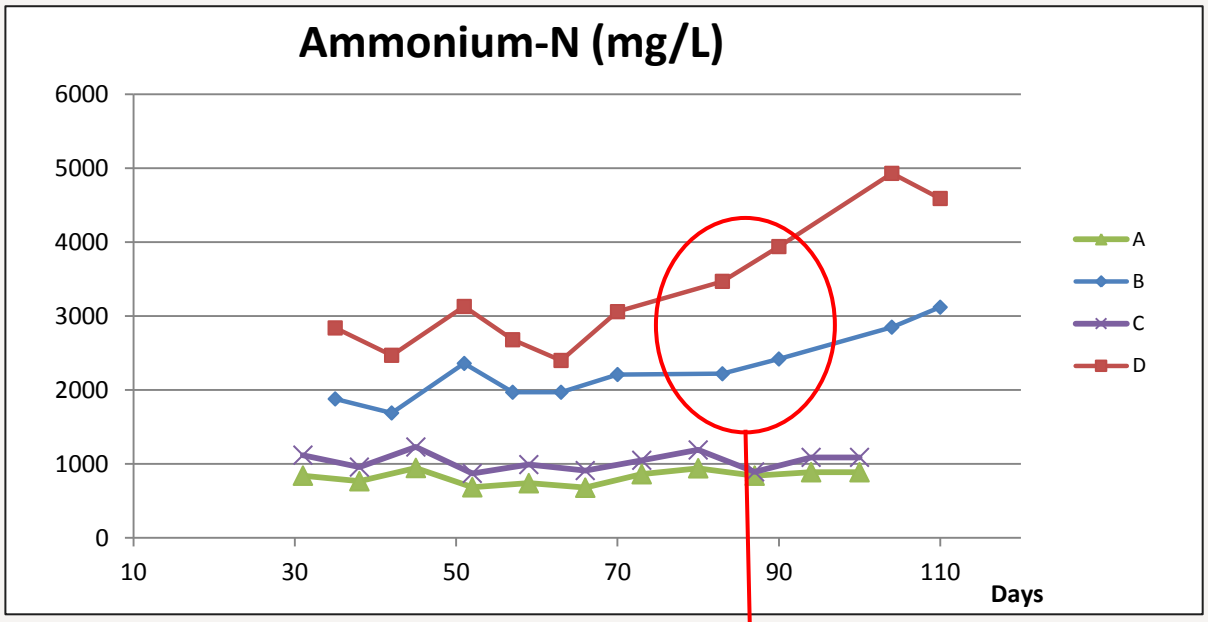
Results

Ammonium-N (NH_4^+-N)



Possible shift to syntrophic acetate oxidation (SAO)

SAO pathway:

$$CH_3COO^- + 4H_2O \rightarrow 2HCO_3^- + 4H_2 + H^+$$

$$4H_2 + HCO_3^- + H^+ \rightarrow CH_4 + 3H_2O$$

Acetate oxidizers and hydrogenotrophic bacteria, less afected by NH_3 (vrs. acetoclastic methanogens)
These bacteria were detected !

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Conclusions

- Addition of fish as co-substrate lead to 30 % increase in the yield. NH_4^+-N content was also increased by fish, and more with recirculation, leading to a richer biorest.
- Fish adds rapidly degradable matter (proteins/lipids) that combined with carbohydrates gave an stable process and yield.
- Recirculation can lead to increase of both stability and production, but if the separation (filtration) step is not optimized it can also lead to accumulation of recalcitrant compounds in the long term, so this must be controlled.
- Reuse value-added products such as category 2 animal byproducts is important, helping also in increase availability of substrates for co-digestion, increase the yield and increase the nutrient content of the final biorest as biofertilizer.

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Effects of steam explosion and co-digestion in the methane production from *Salix* by mesophilic batch assays

Maria M. Estevez [a,*], Roar Linjordet [b], John Morken [a]

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Biogas production and saccharification of *Salix* pretreated at different steam explosion conditions

Svein J. Horn [a,*], Maria M. Estevez [b], Henrik K. Nielsen [c], Roar Linjordet [d], Vincent G.H. Eijsink [a]

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Semi-continuous anaerobic co-digestion of cow manure and steam-exploded *Salix* with recirculation of liquid digestate

Maria M. Estevez [a,*], Zehra Sapci [a,b], Roar Linjordet [c], Anna Schnürer [d,e], John Morken [a]

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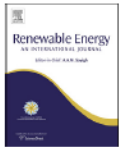

Incorporation of fish by-product into the semi-continuous anaerobic co-digestion of pre-treated lignocellulose and cow manure, with recovery of digestate's nutrients

Maria M. Estevez [a,*], Zehra Sapci [a,b], Roar Linjordet [c], John Morken [a]

The experimental work was carried out as part of doctoral thesis research (2009-2013) and post doctoral research at:

Department of Mathematical Sciences and Technology

Norwegian University of Life Sciences

&

Bioforsk Jord og Miljø

Microbiological analyses were carried out at Sveriges Lantbruksuniversitet, Uppsala

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Dziękuję !
Thank you for your attention!

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