Enhancing the Biochemical Methane Potential of Microalgae via Biomass Pretreatment

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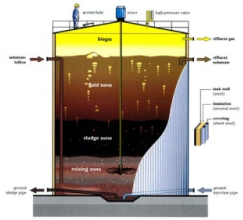
In a very close future.....

- Climate change and CO_2 emission cuts……
- Depletion of fossil fuel reserves and global energy crisis……
- Global Water Crisis……..

No problem man!!

- **Microalgae for bioenergy production**
- **Microalgae for CO_2 capture**
- **Microalgae for Wastewater Treatment**

Green Energy Production
during wastewater treatment



Biogas

Biodiesel

Bioethanol

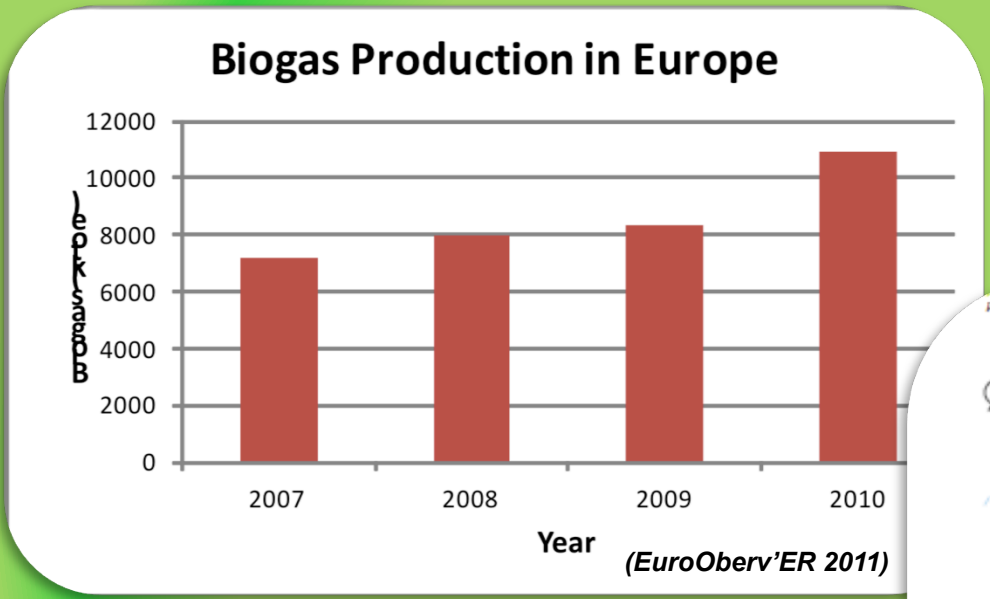
Biodiesel & Bioethanol

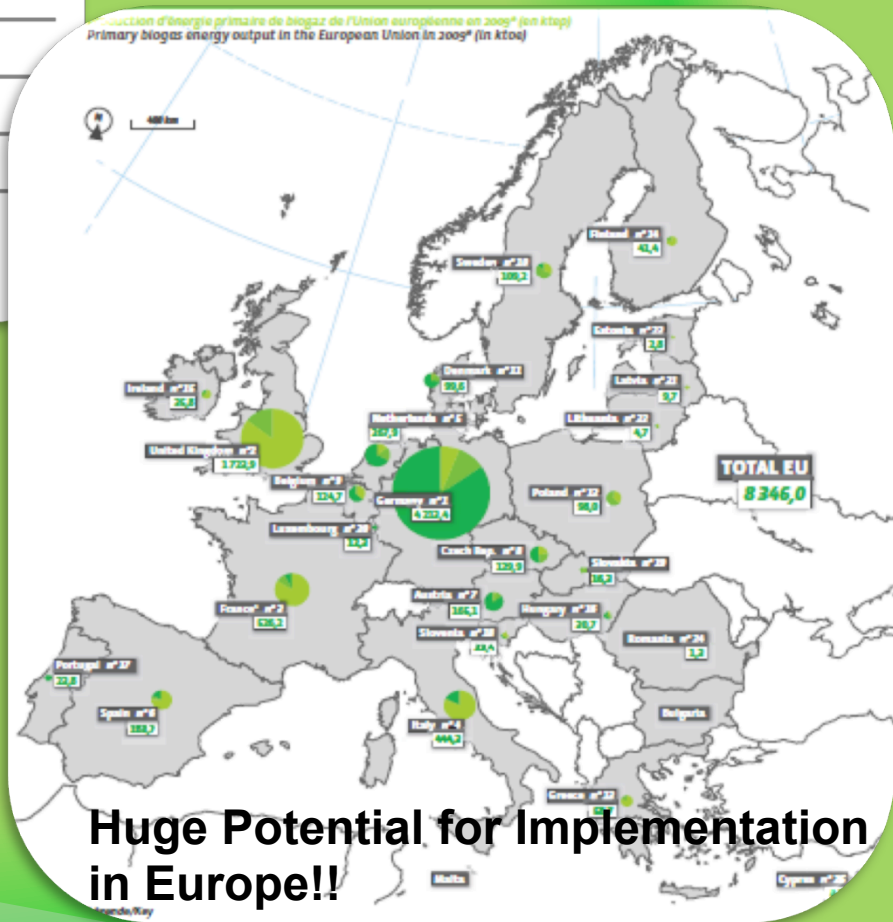
- Require high quality biomass
- Axenic microalgae cost (5-20 €/kg)
- Need for methanol (transterification)
- Need for Energy-intensive distillation
- Glicerine as byproduct

Biogas

- Use of residual biomass
- No need for microalgae drying
- Simple Technology
- Nutrients Recovery Potential
- No additional waste

Biogas as a promising green energy source





Huge Potential for Implementation in Europe!!

Limitations of Microalgae Digestion
Research niches

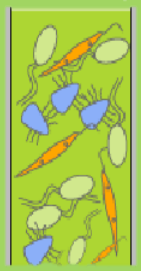
- Few Systematic studies exploring the Biochemical Methane Potential (BMP) of microalgae

- Strong cell walls → Low CH_4 productivities

Microalgal Biomass Pretreatment

Enhancement of the Anaerobic Digestion of Microalgae

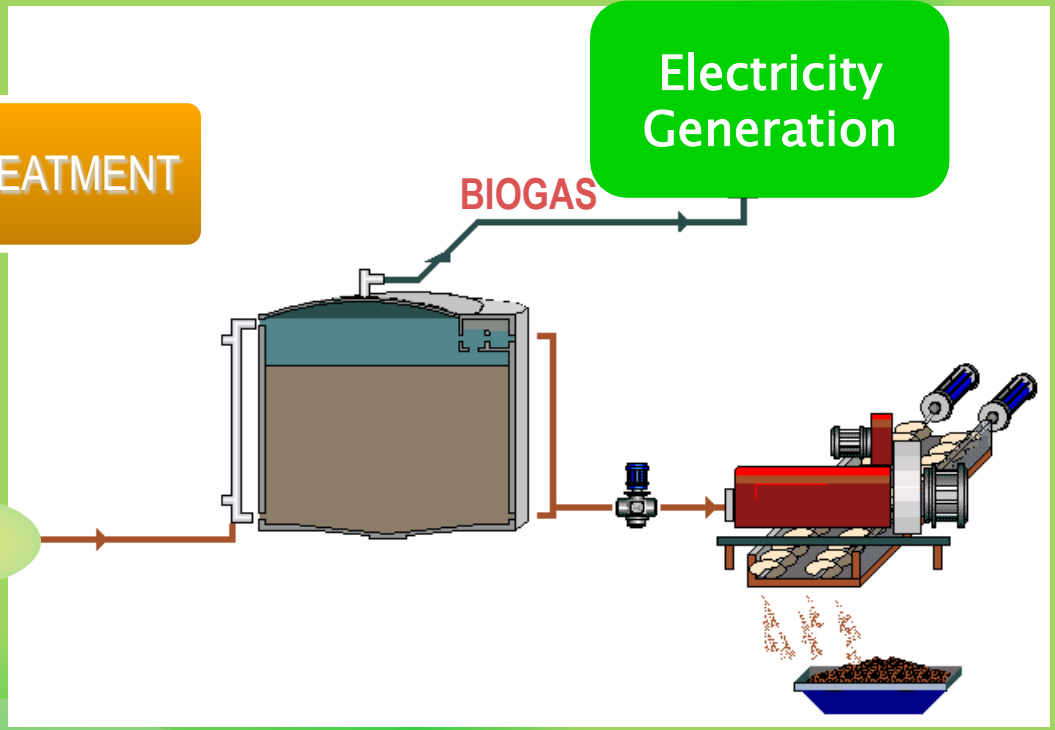
Strategy



CELL DISRUPTION PROCESSES

IMPROVE THE HYDROLYSIS:

Solubilisation of the organic matter of microalgae in order to make the organic compounds more biodegradable



Several Technologies Available but…

High pressure homogenizers
Impact grinding
Stirred ball mills
Ultrasonic homogenizer
High performance pulses
Lysat centrifuge
Gam

What's the most effective pre-treatment for microalgae?

Pre-
tments

THERMAL

Thermal hydrolysis

sis
Ozo

Objectives

Objective 1:

Evaluation of the Influence of Substrate/Inoculum Ratio, Microalgae Concentration, Microalgae species on the BMP

Objective 2:

Evaluation of the Influence of microalgae pre-treatment on the BMP

Materials & Methods
Microalgae

Three different microalgae:

Microalgae A: *Clamydomonas* (40%), *Scenedesmus* (20%), *Nannocloropsis* (40 %)

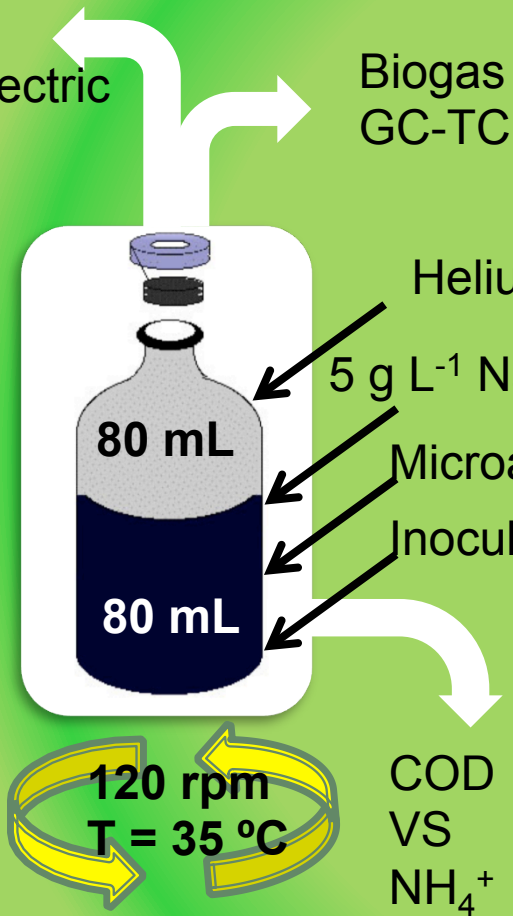
Microalgae B: *Acutodesmus* (58%), *Oocystis* (36%), *Nitzchia* (5%)

Microalgae C: *Microspora*

Anaerobic inoculum from sludge digesters:

Materials & Methods

Biochemical Methane Potential Tests



S/I — [Microalgae] = 10 g kg^{-1}

- 0. 5
- 1
- 3

Concentration (g L^{-1}) — S/I =1

- 3
- 10
- 20

Pretreatments — [Microalgae] = 10 g kg^{-1} S/I = 1

- Thermal hydrolysis
- Ultrasound
- Biological Treatment

Materials & Methods
Pretreatments

Thermal Hydrolysis (15')
T1 = 110 °C (1.2 bar)
T2 = 140 °C (3.2 bar)
T3 = 170 °C (6.4 bar)

Ultrasound
U1:10.000 KJ $kgTS^{-1}$
U2:27.000 KJ $kgTS^{-1}$
U3:40.000 Kj $kgTS^{-1}$
U4:57.000 Kj $kgTS^{-1}$

Biological
500 mL in 2 L Bottles
B1 = 12 h
B2 = 24h

Monitoring

- CODt & CODs
- NH_4^+

$$S_D = \frac{COD_S - COD_{So}}{COD_T - COD_{So}} \times 100$$

Results & Discussion

Influence of S/I ratio and type of microalgae

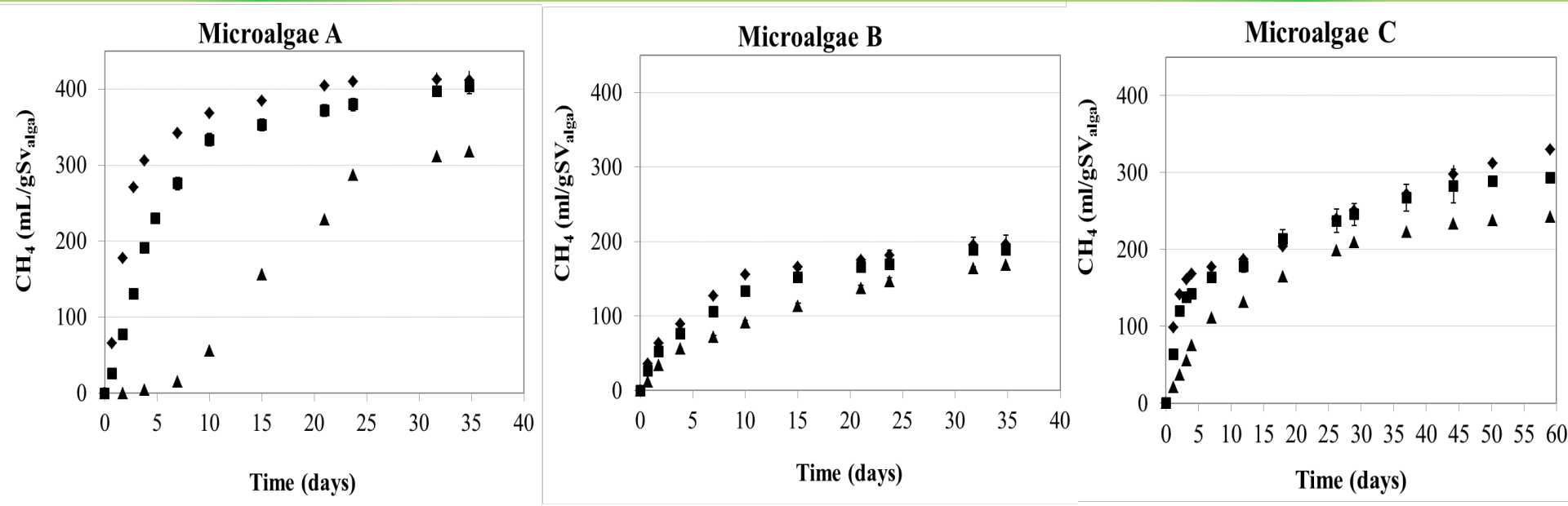


Figure 1: Time course of methane productivity at a S/I ratio of 0.5 (◆), 1 (■) and 3 (▲)

Microalgae species do matter.....
Optimum S/I to determine the BMP = 0.5
Microbial inhibition at a S/I of 3

Results & Discussion

Influence of Biomass Concentration

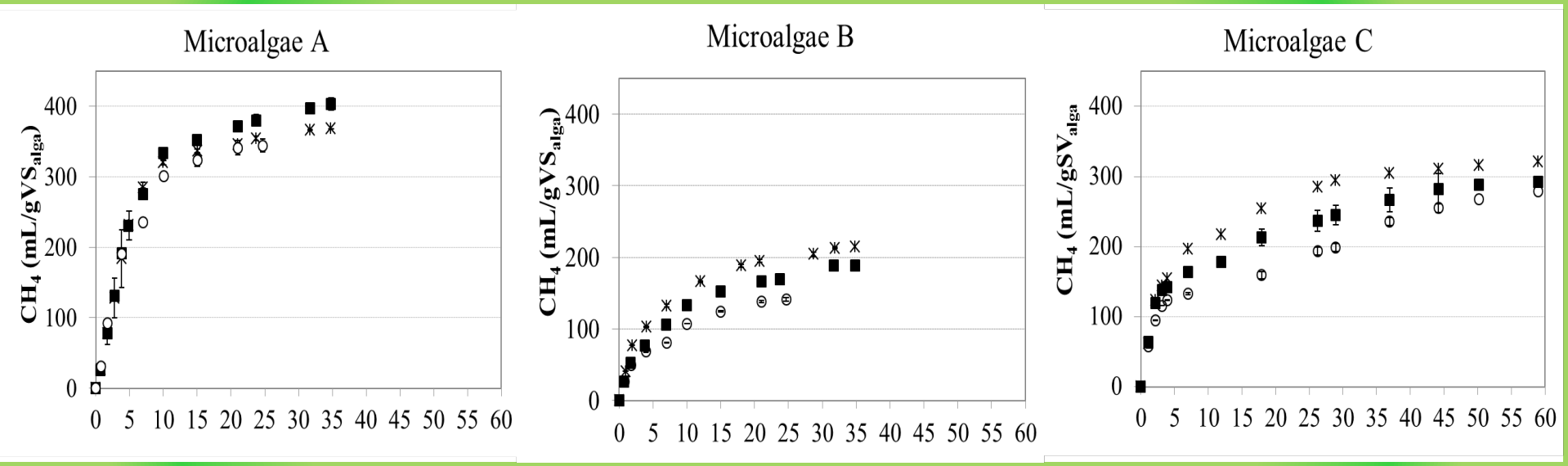


Figure 2: Time course of CH_4 productivity at 3gTS/kg; (o), 10gTS/kg (■) and 20gTS/kg (∗);

Microalgae species do matter.....

Optimum biomass concentration of 20 g kg TS^{-1}

Results & Discussion
Nitrogen release

Table 1
Influence of the S/I ratio and biomass concentration on the final ammonium concentrations, ammonium released and biodegradability for microalgae A (VS/TS = 0.79), B (VS/TS = 0.83) and C (VS/TS = 0.90).

Microalgae	S/I ratio	TS concentration (g/kg)	Total ammonium (mg-N/L)	Ammonium released (mg $N/gVS_{algae\ added}$)	Ammonium released (mg $N/gVS_{algae\ eliminate}$)	Biodegradability (%)
A	0.5	10	1159 ± 5	118 ± 1	170 ± 7	70 ± 2
	1.0	10	951 ± 7	102 ± 1	149 ± 5	68 ± 2
	3.0	10	697 ± 16	84 ± 3	156 ± 3	54 ± 1
	1.0	20	1485 ± 5	48 ± 0	79 ± 1	60 ± 0
	1.0	3	393 ± 40	80 ± 3	128 ± 8	62 ± 1
B	0.5	10	1079 ± 7	103 ± 3	344 ± 10	30 ± 2
	1.0	10	817	81	283	27 ± 2
	3.0	10	561 ± 47	64 ± 8	251 ± 31	26 ± 0
	1.0	20	1331 ± 21	31 ± 2	93 ± 7	33 ± 0
	1.0	3	374 ± 11	67 ± 4	346 ± 28	20 ± 0
C	0.5	10	1141 ± 33	64 ± 8	97 ± 9	66 ± 2
	1.0	10	848 ± 34	48 ± 7	79 ± 6	60 ± 4
	3.0	10	594 ± 23	50 ± 3	102 ± 6	50 ± 0
	1.0	20	1138 ± 8	19 ± 1	27 ± 1	70 ± 1
	1.0	3	333 ± 12	13 ± 4	22 ± 7	59 ± 0

Final $[NH_4^+] < 1500$ mg N/L → No inhibition
No correlation of NH_4^+ release with S/I , [biomass] or type of microalgae

Results & Discussion

Influence of Biomass pretreatment

Pretreatment	Pretreated microalgae A		
	S_D (%)	N-NH_4^+ (mg/L)	TN (mg/L)
Control	0	7	112
U1	14	5	239
U2	28	30	537
U3	30	32	361
U4	32	30	378
B1	11	57	233
B2	9	34	239
T1	9	6	191
T2	16	22	258
T3	32	25	433

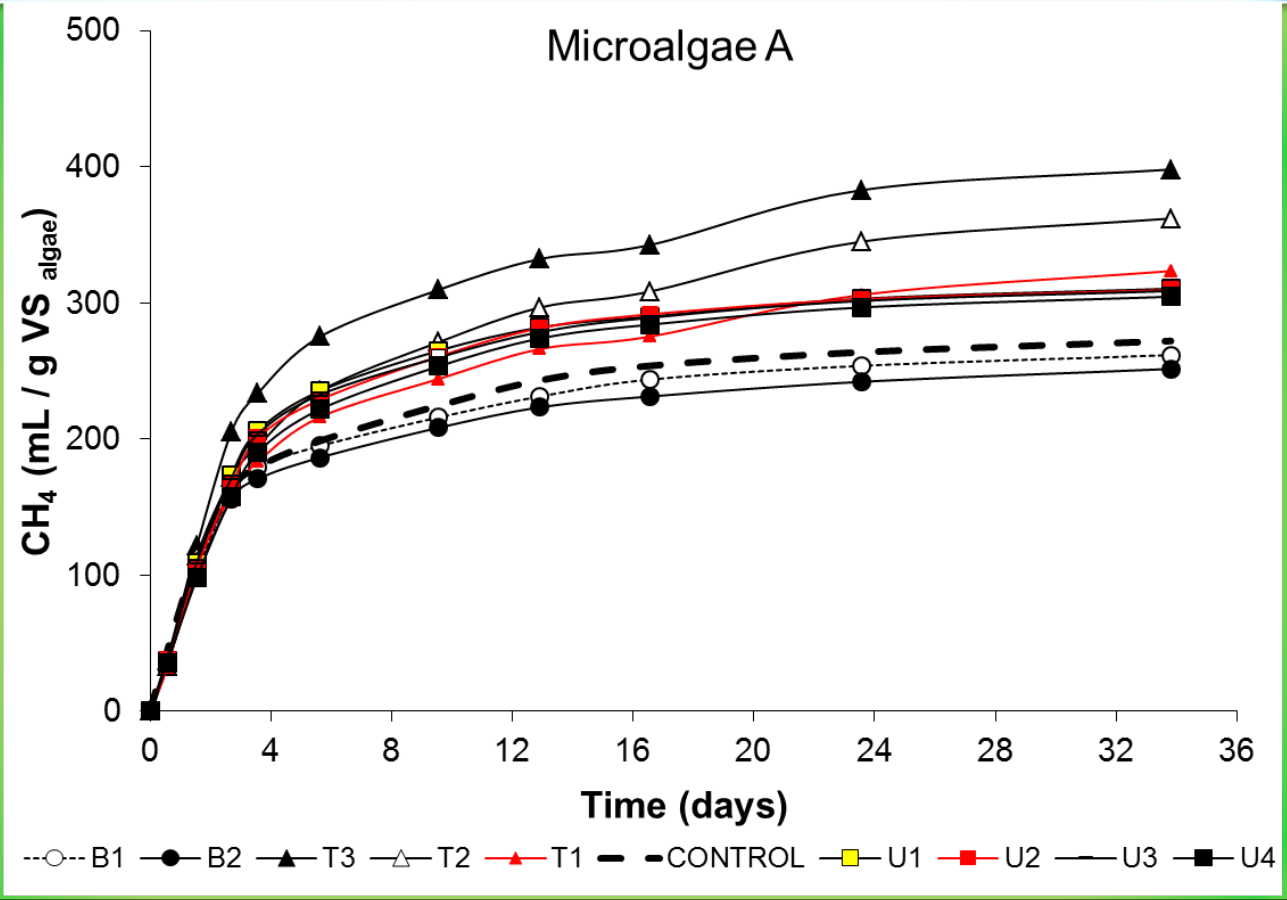
Pretreatment	Pretreated microalgae B		
	S_D (%)	N–NH_4^+ (mg/L)	TN (mg/L)
Control	0	28	47
U1	24	134	
U2	48	54	333
U3	53	66	602
U4	60	55	634
B1	21	80	320
B2	19	89	355
T1	22	28	254
T2	37	70	436
T3	63	42	594

Pretreatment	Pretreated microalgae C		
	S_D (%)	N–NH_4^+ (mg/L)	TN (mg/L)
Control	0	23	23
U1	30	40	199
U2	56	26	420
U3	57	79	450
U4	62	100	514
B1	29	22	244
B2	29	59	257
T1	38	34	190
T2	39	40	263
T3	40	43	399

TN also increases at increasing energy inputs
Nitrogen release mainly as organic N

Results & Discussion

Influence of Biomass pretreatment



TH supported best CH_4 production rates during the first 4 days

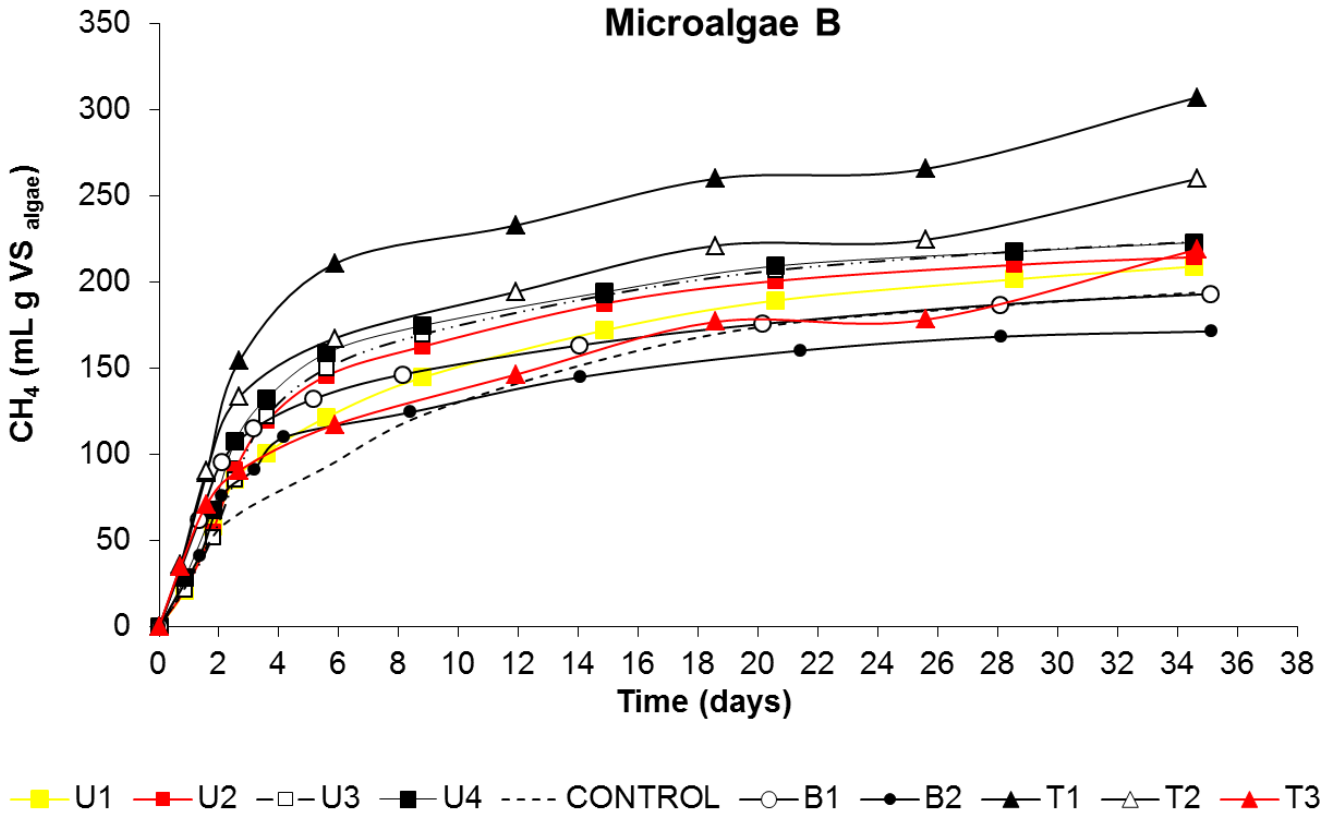
Biological pre-treatment reduced the final CH_4 productivities

Highest Increase in final CH_4 productivity for TH at 170 y 140 ºC

No effect of energy input during ultrasound

Results & Discussion

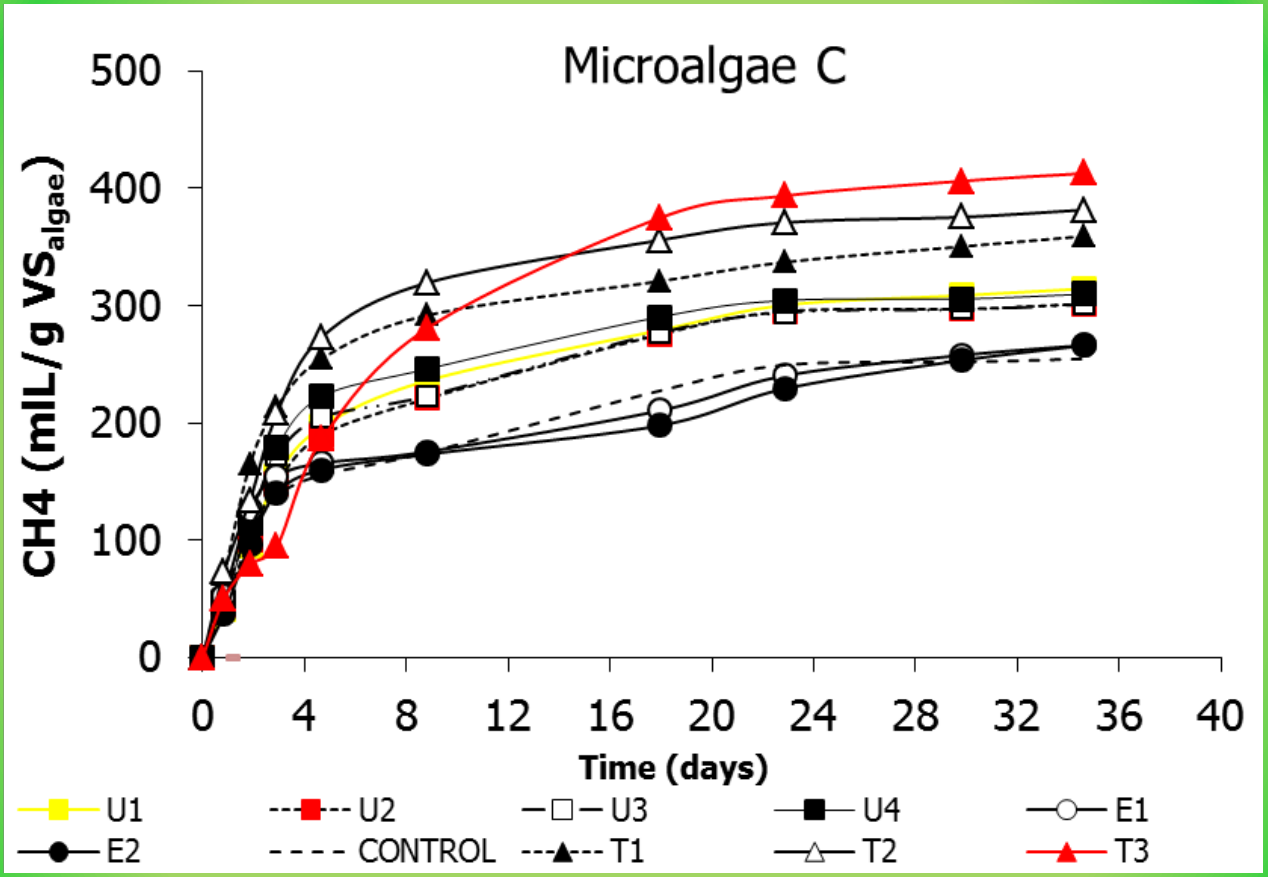
Influence of Biomass pretreatment



TH supported higher CH_4 production rates during the first 4 days
Biological pre-treatments reduced final CH_4 productivities
Highest Increase in final CH_4 productivity for TH at 170 y 140 ºC
No effect of energy input during ultrasound

Results & Discussion

Influence of Biomass pretreatment



TH supported best CH_4 production rates during the first 4 days
Biological do not increase final CH_4 productivity
Decreased CH_4 productivity at increasing T
No effect of energy input during ultrasound

Conclusions

- Microalgae species significantly influences CH_4 productivity (190-400 mL g VS^{-1})
- An optimum S/I of 0.5 for BMP assays
- NH_4^+ released was independent from the S/I ratio and microalgae concentration
- No correlation between the solubilization factor and CH4 productitivty
- Thermal hydrolysis the most effective Pre-treatment (60%)
- Biological pretreatment decrease CH_4 productivity
- **The effect of ultrasound independent from the energy input**

Acknowledgments

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More information:

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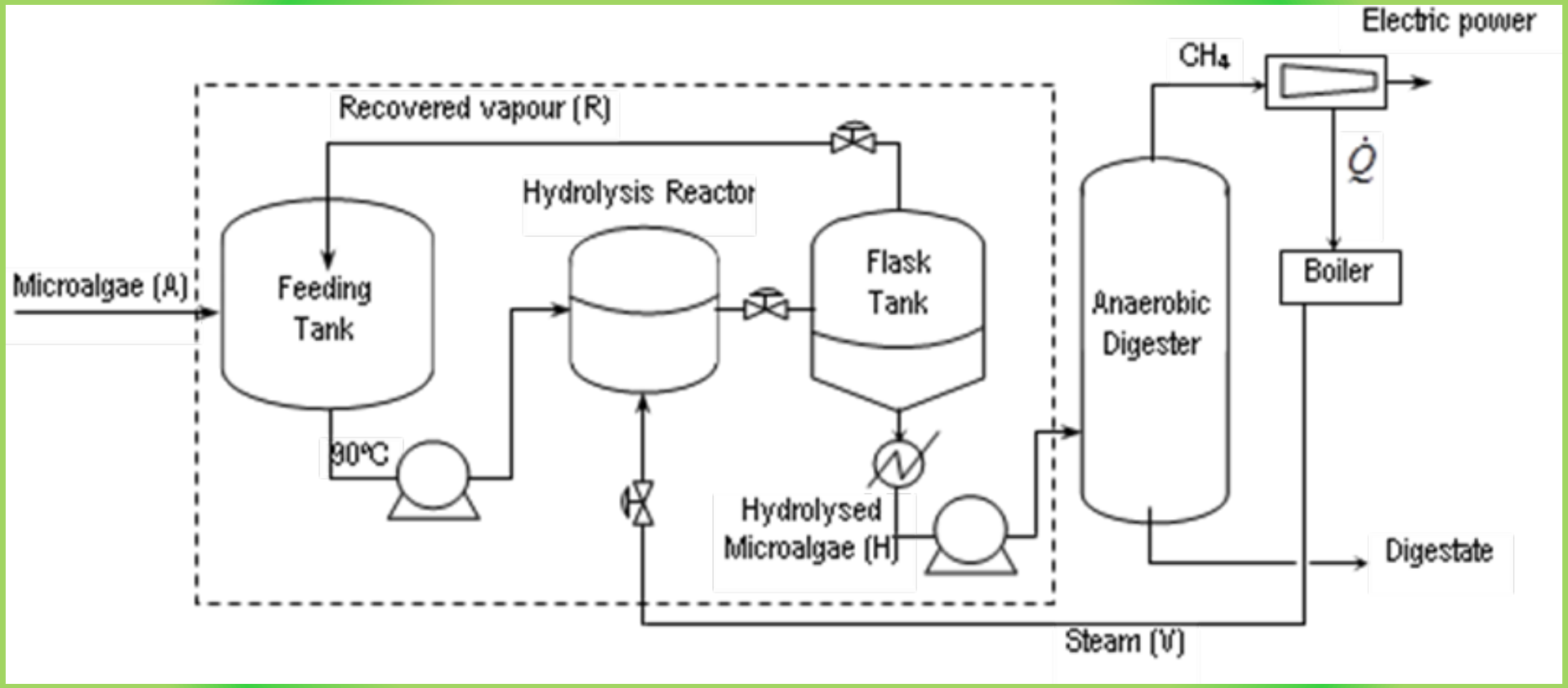
Electric power
CH4
Recovered vapour (R)
Hydrolysis Reactor
Microalgae (A)
Feeding Tank
Flask Tank
Anaerobic Digester
Boiler
Q̇
90°C
Hydrolysed Microalgae (H)
Digestate
Steam (V)