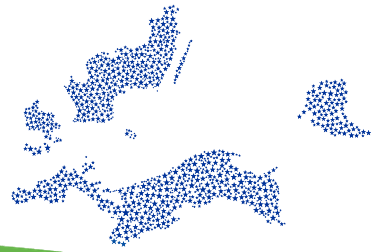
COASTAL BIOGAS

Cluster **O**n **A**naerobic digestion environmental **S**ervices and nu**T**rients remov**AL**

Co-digestion of algae in lab scale



Robert Aranowski, Iwona Cichowska-Kopczyńska

Roskilde, 12th November 2019

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Biomass potential in Poland

22-75 % of green algae

(*Cladophoraglomerata, Enteromorpha, Ulotrixspp,, Stigeocloniumspp, Ulvaflexuosa, Ulvaclathrata)*

17–71% of red algae

(*Ceramiumspp, Polysiphoniafucoides, Phyllophorabrodiaei)*

0–50% of brown algae

(Pilayella littoralis, Ectocarpusspp),

small amount of seagrass

(Zostera marina)

http://www.iswinoujscie.pl/artykuly/55663/

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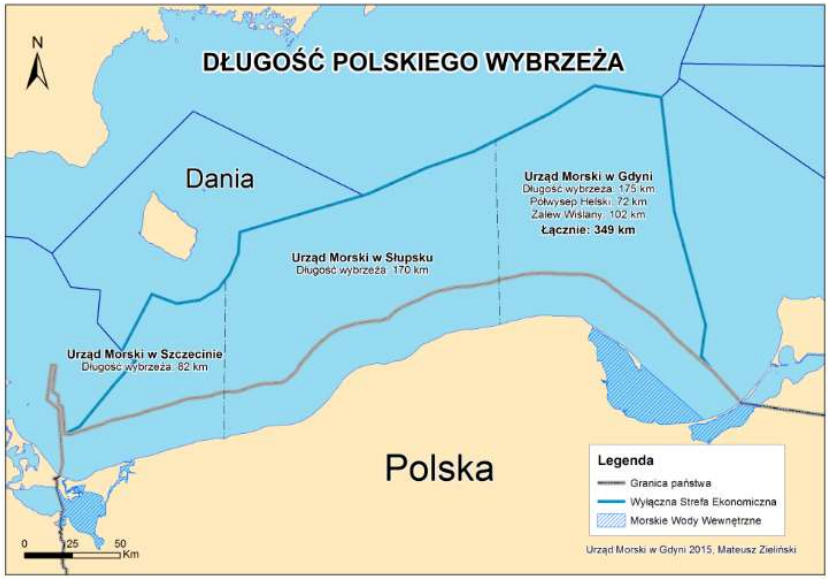
180-800 tonnes at the beaches
<700 tonnes in water

average of 550 tonnes

maximum of 9500 tonnes



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Parameter	Poland	Denmark	Germany	Sweden	Lithuania
Type of seaweed	Green, brown and red algae	Green, brown algae, sea grass	Green algae	Green, brown and red algae	Green, brown and red algae
Seaweed collection period	May October	May September	April October	May September	?
Reason for the collection of seaweed	purification of beaches	biogas production / purification of beaches	purification of beaches	mitigation of eutrophication	purification of beaches
Quantities of collected seaweed [tons/year]	9500	42 000	11 595	63 628	?

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Rikke Lybæk. Aquatic biomass for biogas plants - Realistic feedstock source or an academic idea - incl. full scale experiences from Solrød biogas plant, 2016, p. 13.

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Roskilde University
Universität Rostock
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Biomass collection

fot. by Iwona Cichowska-Kopczynska

fot. by Iwona Cichowska-Kopczynska

fot. by Robert Aranowski

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Biomass collection

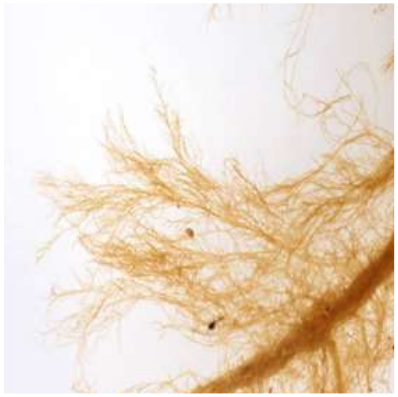
Enteromorpha plumosa

Chara globularis

Potamogeton pectinatus

Enteromorpha compressa

Pylaiella litoralis



Zostera marina

fot. by Iwona Cichowska-Kopczynska

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Characteristics of biomass

Symbol of Biomass	Type of algae	Total solids, [%]	Total volatile solids, [%]
G0	*Cattle amanure*	12.2	84.4
G1	*Enteromorpha compressa*	8.9	83.8
G2	*Enteromorpha plumosa*	7.2	79.7
G3	*Potamogeton pectinatus*	13.1	61.4
G4	*Zostera marina*	12.6	79.6
G6	Pheaophyta (mainly *Pylaiella litoralis*)	17.2	63.9

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Sand content in marine biomass

Symbol of Biomas	Type of algae	Sand content, [%]	Place of sampling
G1	Enteromorpha compressa	11.65	Shallow water
G2	Enteromorpha plumosa	4.96	Shallow water
G3	Potamogeton pectinatus	4.00	Shallow water
G4	Zostera marina	20.88	Beach
G6	Pheaophyta	7.80	Shallow water

The sand content was determined as the loss of total solids after washing the sample with fresh water:

$$\mathrm{SC} = \frac{TS_1 - TS_2}{TS_1}, [\%]$$

Where:
TS_1 – total solids before washing
TS_2 – total solids after washing

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Methodology of laboratory measurements of algae biogas potential

The procedure of determining the biogas potential

- Amount of biomass mixture used for test was approximately 100 g
- The volume of OxiTop reactors was 1.1 dm^3
- OxiTop®-C was equipped with B pressure transducers.
- The temperature of incubation was 37˚C.
- The reactors were mixed with magnetic stirrers at a rotation speed of about 180 min^{-1}.
- The pressure measurements were collected and stored using the OxiTop® Control OC 110 controller.
- The total solids of the biomass mixture at the start of experiment was approximately 8%
- The experiments duration no less then 30 day

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Methodology of laboratory measurements of algae biogas potential

The biogas cumulative volume production was calculated using following equation:

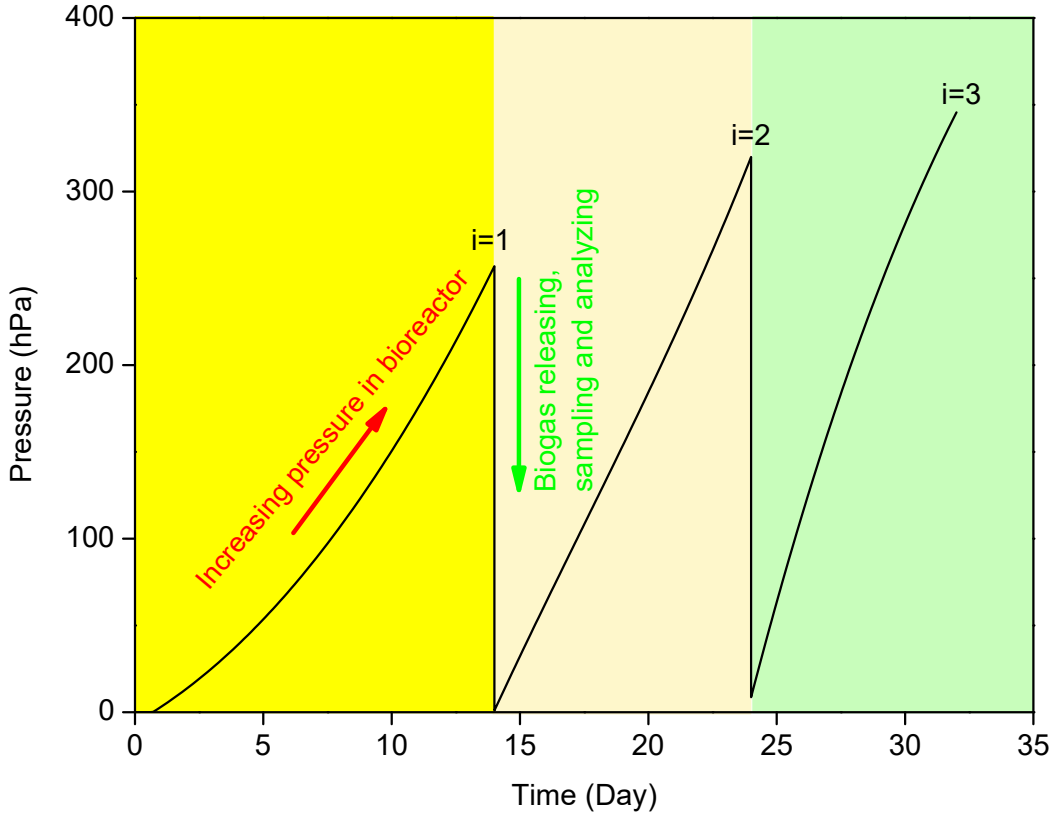
$$V_t = \sum_{i=1}^{N} \frac{P_i \cdot V}{R \cdot T}, \text{ [Nm}^3\text{]}$$

The compound *x* volume production was calculated using below equation:

$$V_{tx} = c_{xi} \sum_{i=1}^{N} \frac{P_i \cdot V}{R \cdot T}, \text{ [Nm}^3\text{]}$$

Where:

V_t – Total biogas volume,
P - Pressure in the OxiTop bioreactor,
V - The volume of space above the liquid phase in the OxiTop bioreactor,
R - Gas constant,



T - Measurement temperature
N – number of biogas release cycles
c_{xi} – concentration of *x* compound in *i* cycle

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Methodology of CH_4, CO_2, N_2, O_2, and H_2 concentration measurements in biogas

- The biogas composition tests were carried out using an AutoSystem XL gas chromatograph equipped with a TCD and FID detector and TurboChrom software (Perkin Elmer) and a Porapak Q 100-120 mesh (6.5 m x 1/8 ”) packed column.

- Each analysis was repeated three times. The tests were carried out using two carrier gases: helium - for H_2, CO_2, N_2, CH_4, nitrogen - for O_2 determination.
- The chromatographic analysis conditions: FID detector temperature 200°C, gas flows in the FID detector - hydrogen 30 cm^3/min, air 300 cm^3/min, TCD detector temperature 100°C, carrier gas pressure (nitrogen and helium) 180 kPa , 15:1 stream split, dispenser temperature 100°C, column temperature 60°C, analysis time 15 min.

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Methodology of feedstock preparation

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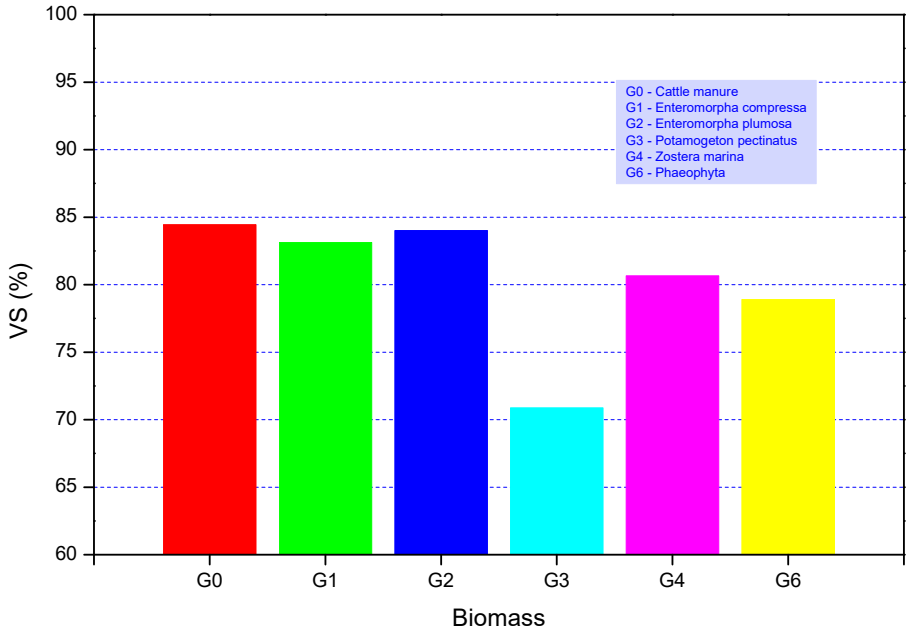
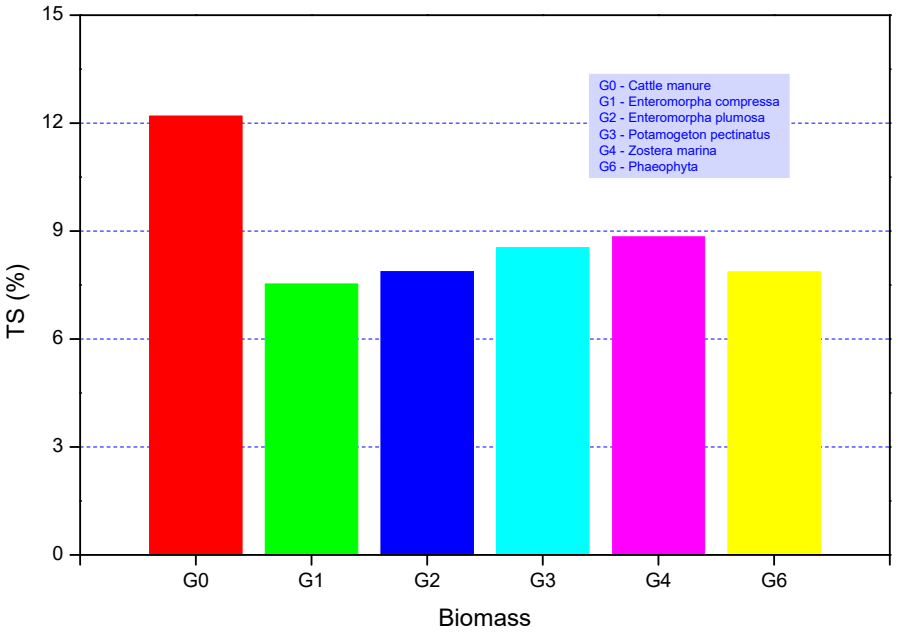
Volatile solids and total solids in feedstock





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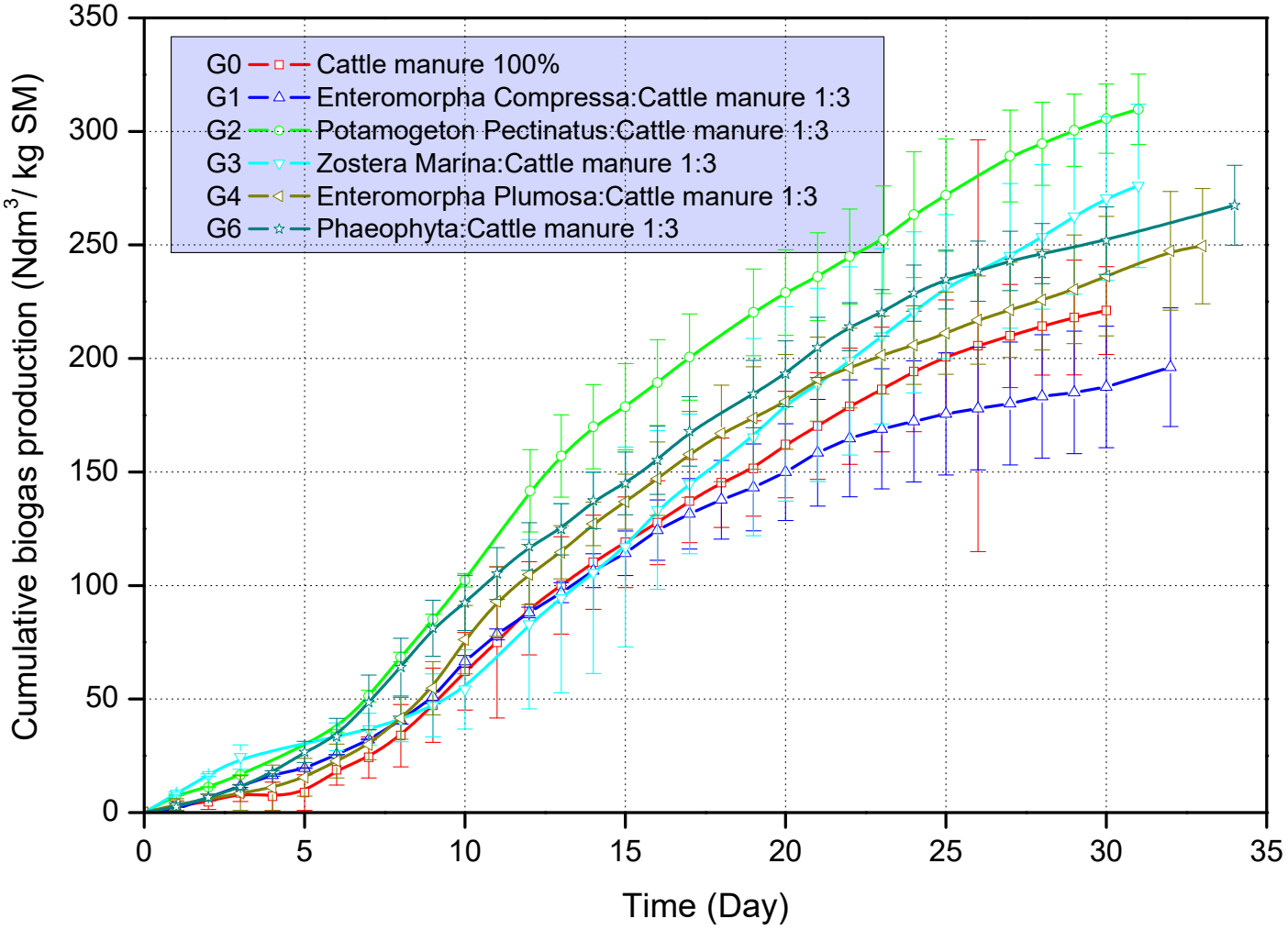
Cumulative biogas production



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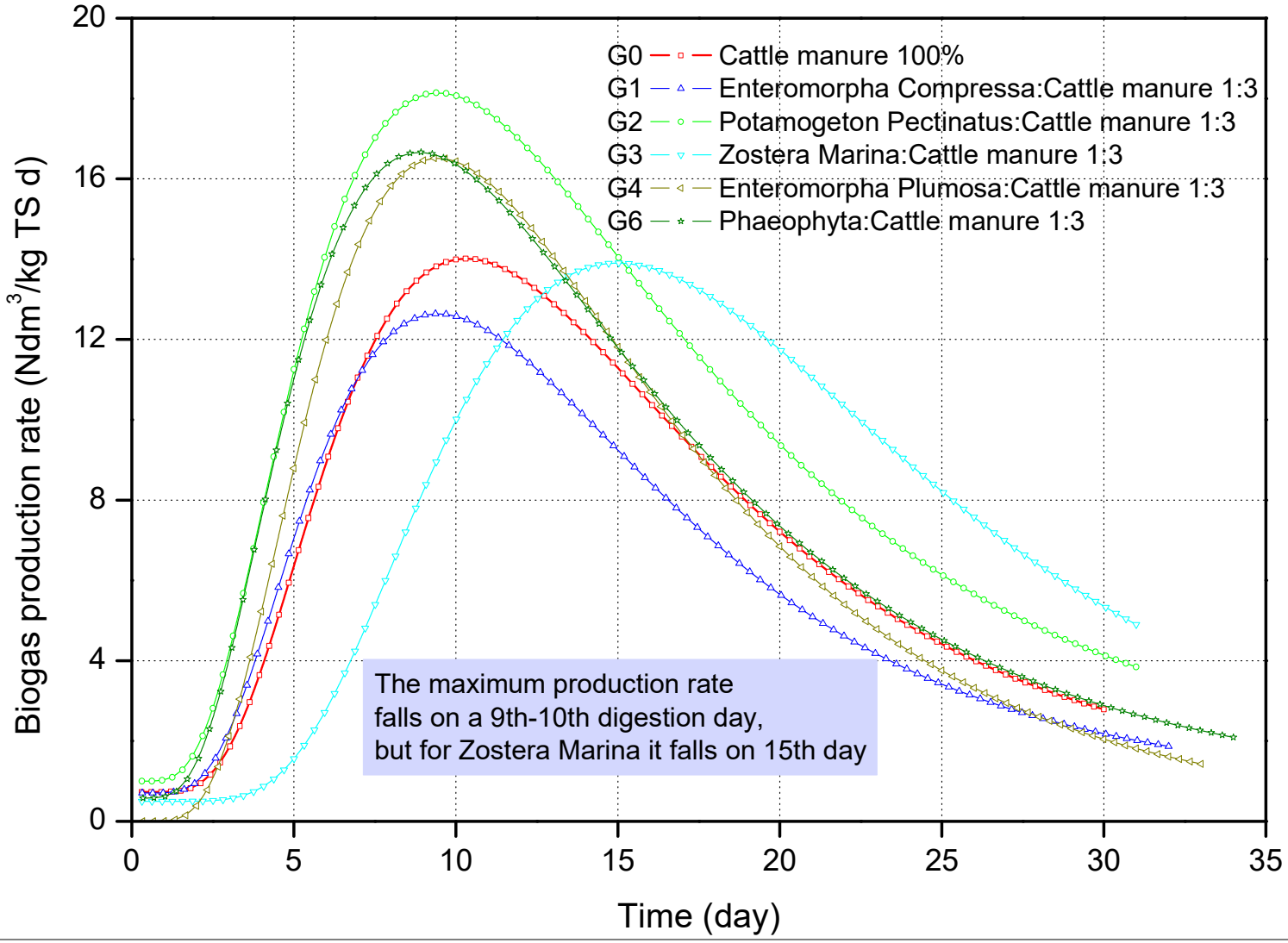
Biogas production rate



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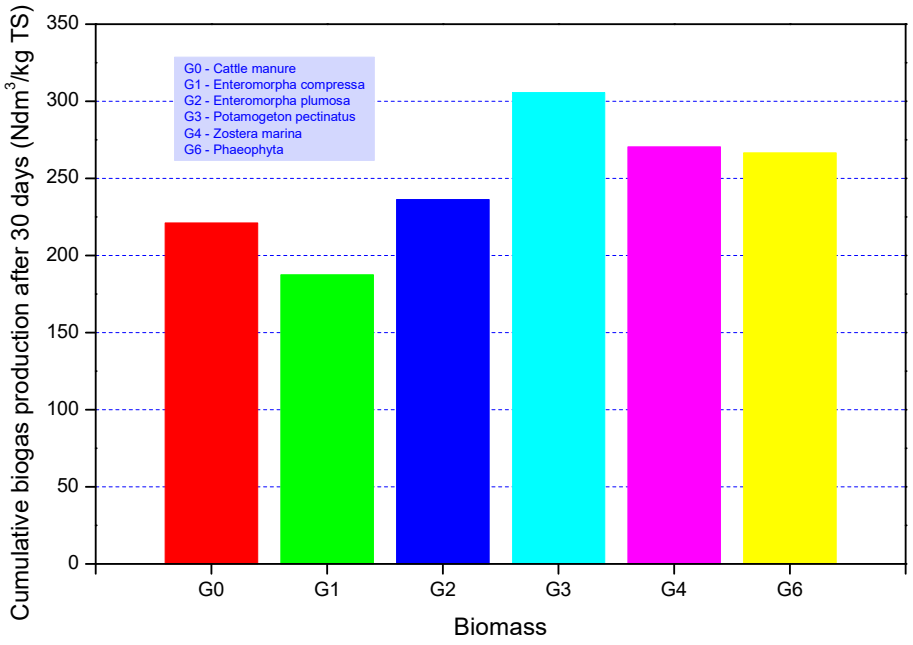
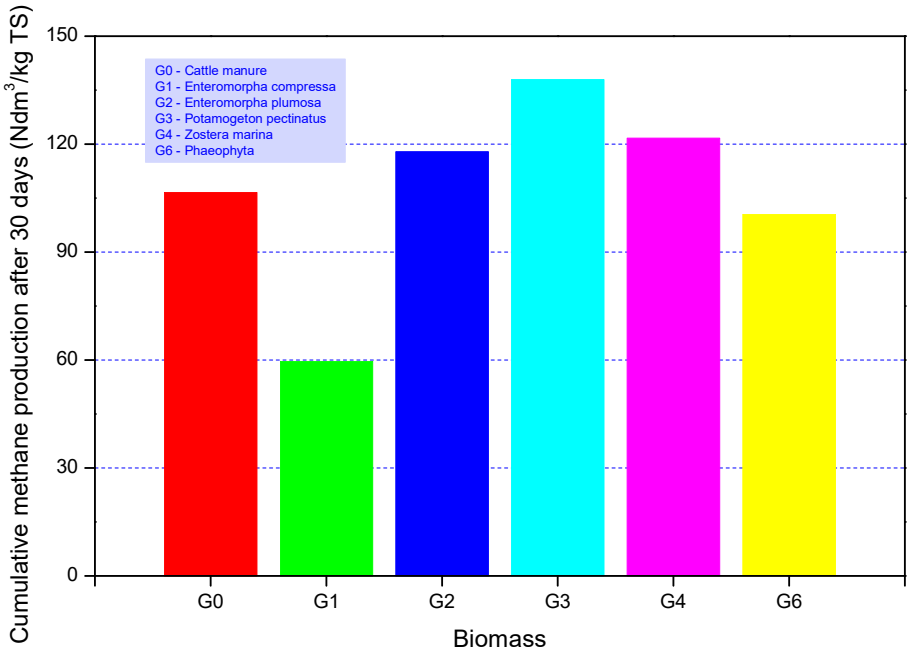
Cumulative biogas and methane production [Ndm^3/kg TS]



Cumulative biogas production [Ndm^3/kg TS]



Cumulative methane production [Ndm^3/kg TS]

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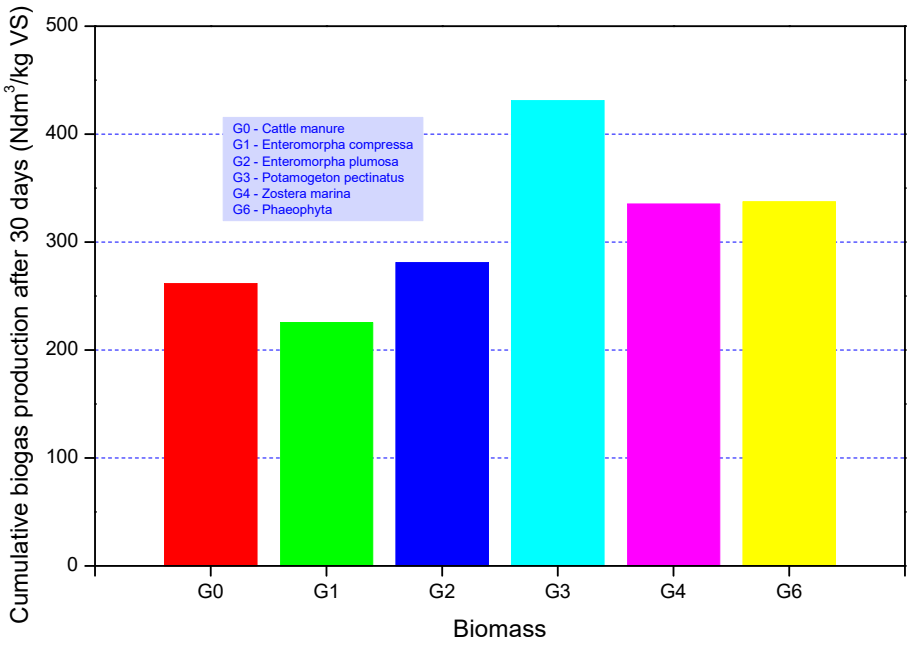
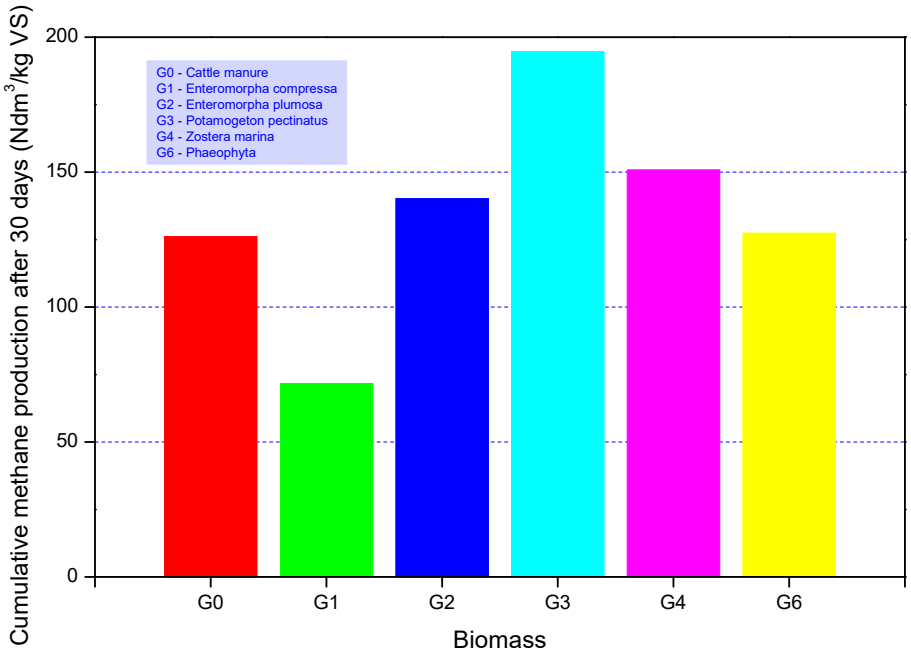
Cumulative biogas and methane production [Ndm^3/kg VS]





The methane largest production was observed for sample G3 (*Potamogeton pectinatus*). The smallest result was obtained for G1 sample, mixture of *Enteromorpha compressa* and cattle manure.

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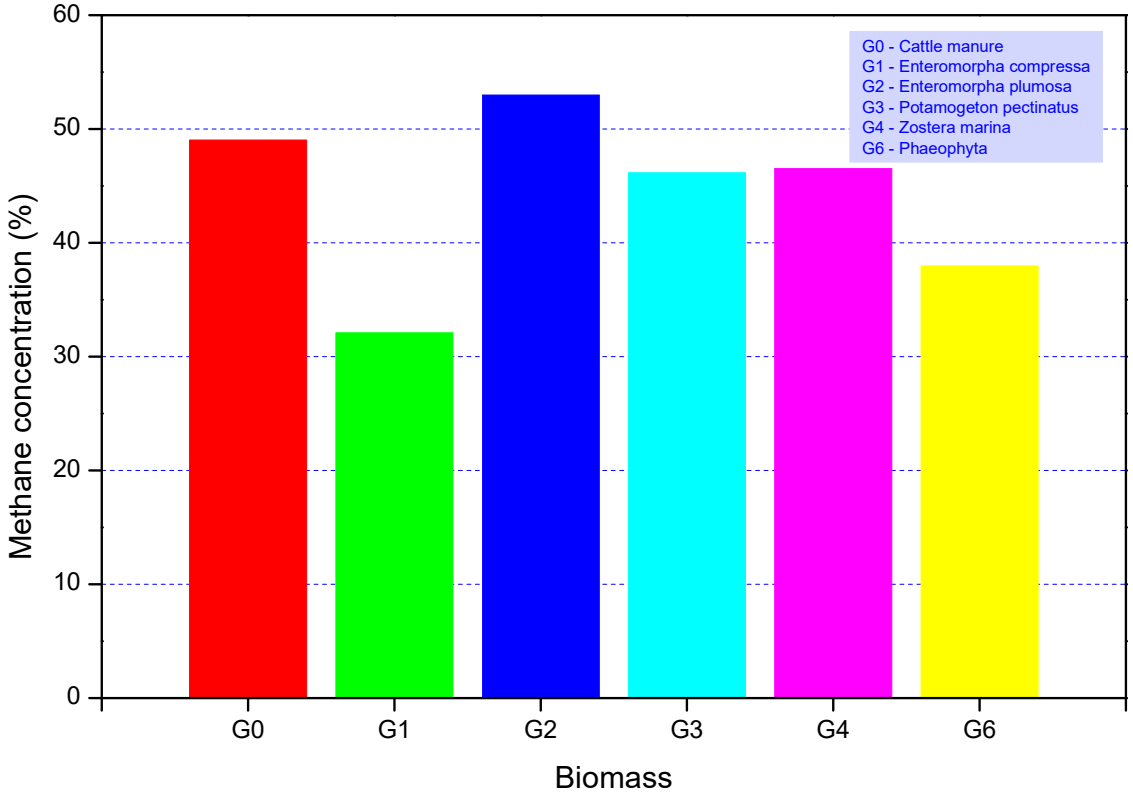
Methane concentration in biogass



The highest methane content in biogas was observed for the mixture of *Enteromorpha plumosa* and cattle manure (G2), while the lowest for the mixture containing *Enteromorpha compressa* (G1)

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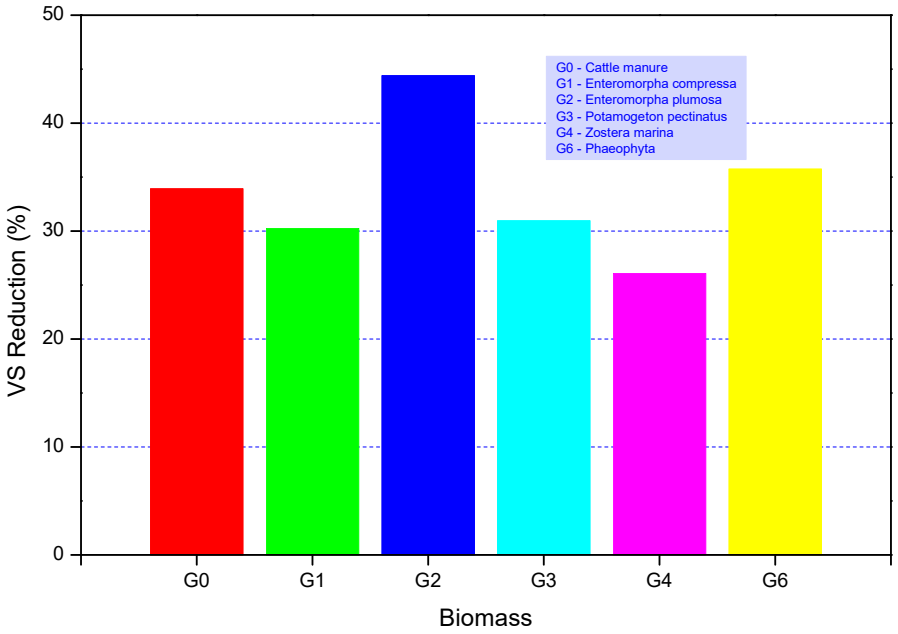
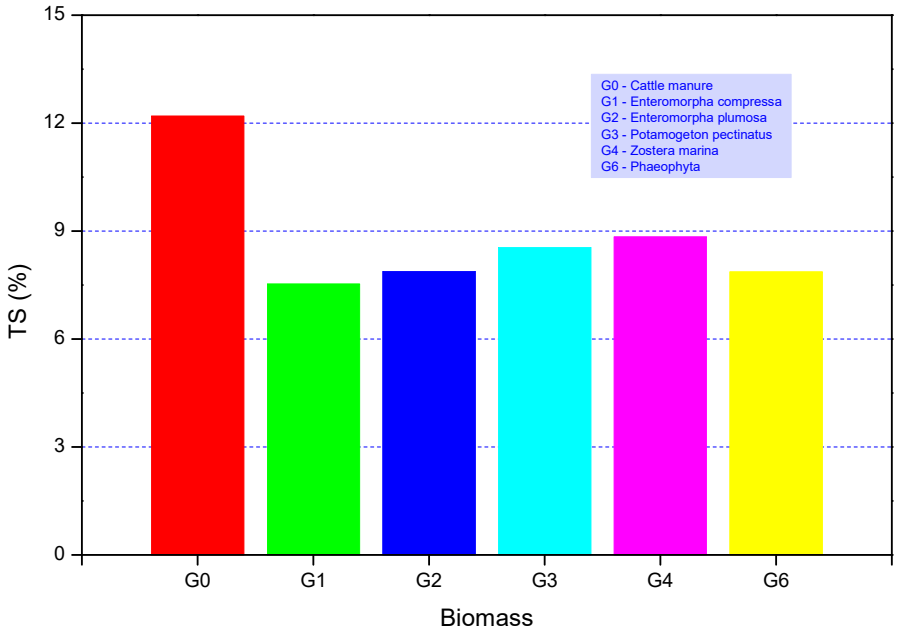
Volatile solids and total solids reduction



Volatile solids reduction during digestion process



Total solids reduction during digestion process

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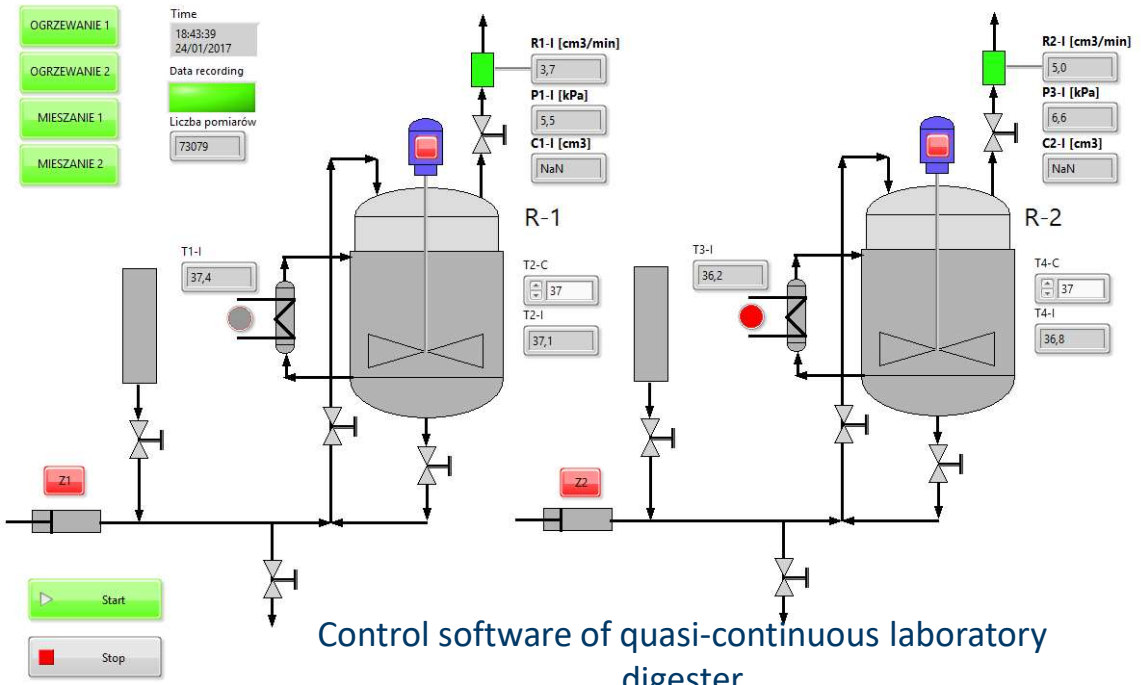
Methodology of quasi-continius digestion of algae biomass



Control software of quasi-continuous laboratory digester

- Digester volume: 10 dm^3
- Active digester volume: 7 dm^3
- Daily biomass load: 333 cm^3/d
- HRT 21 days

- Digester load: 4 kg VS / (m^3·d)
- Temperature: 37±0.1 ° X
- Total solids: 5.0%

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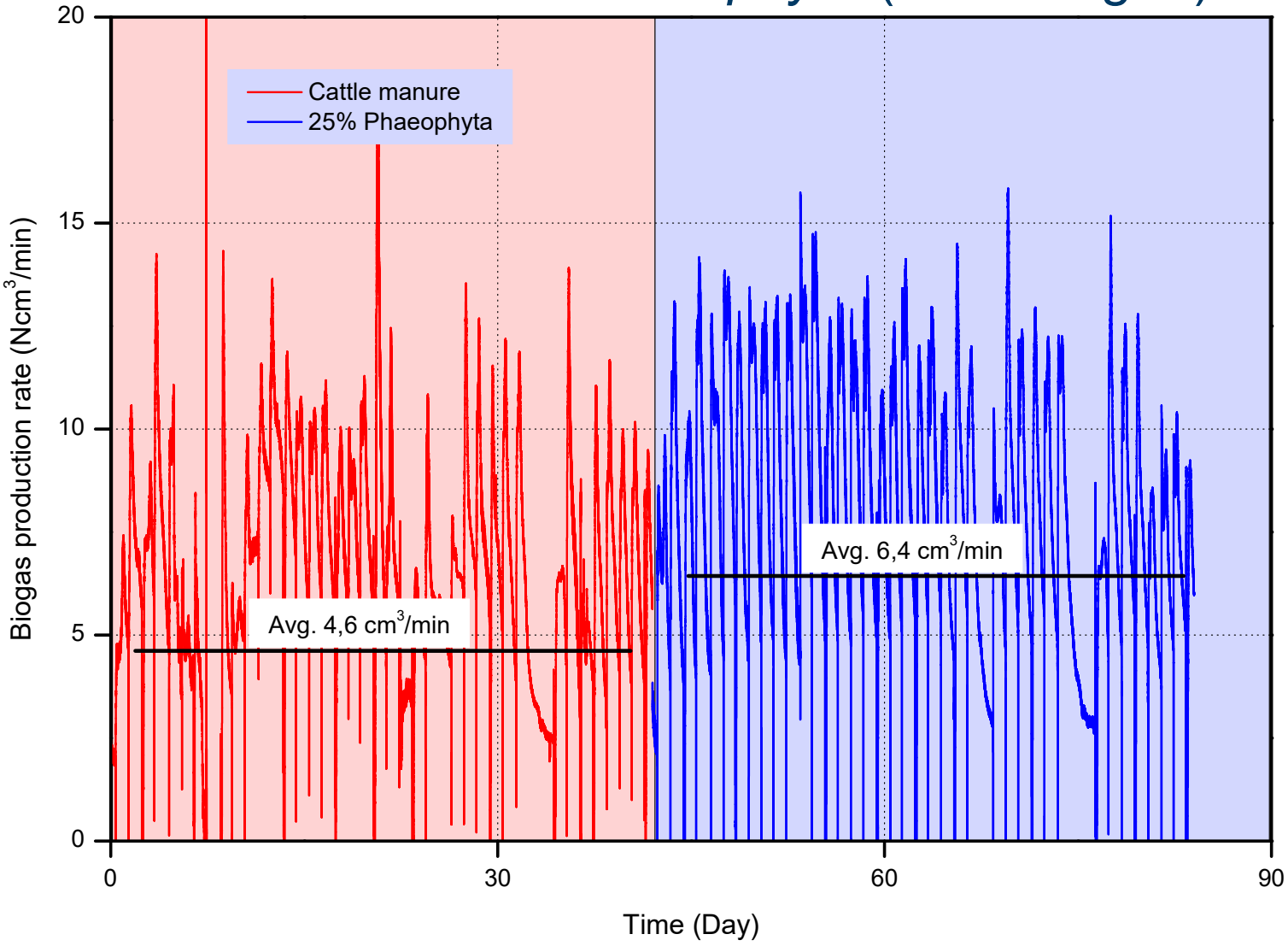
Biogas production in quasi-continuous digestion of cattle manure and *Phaeophyta* (brown algae)



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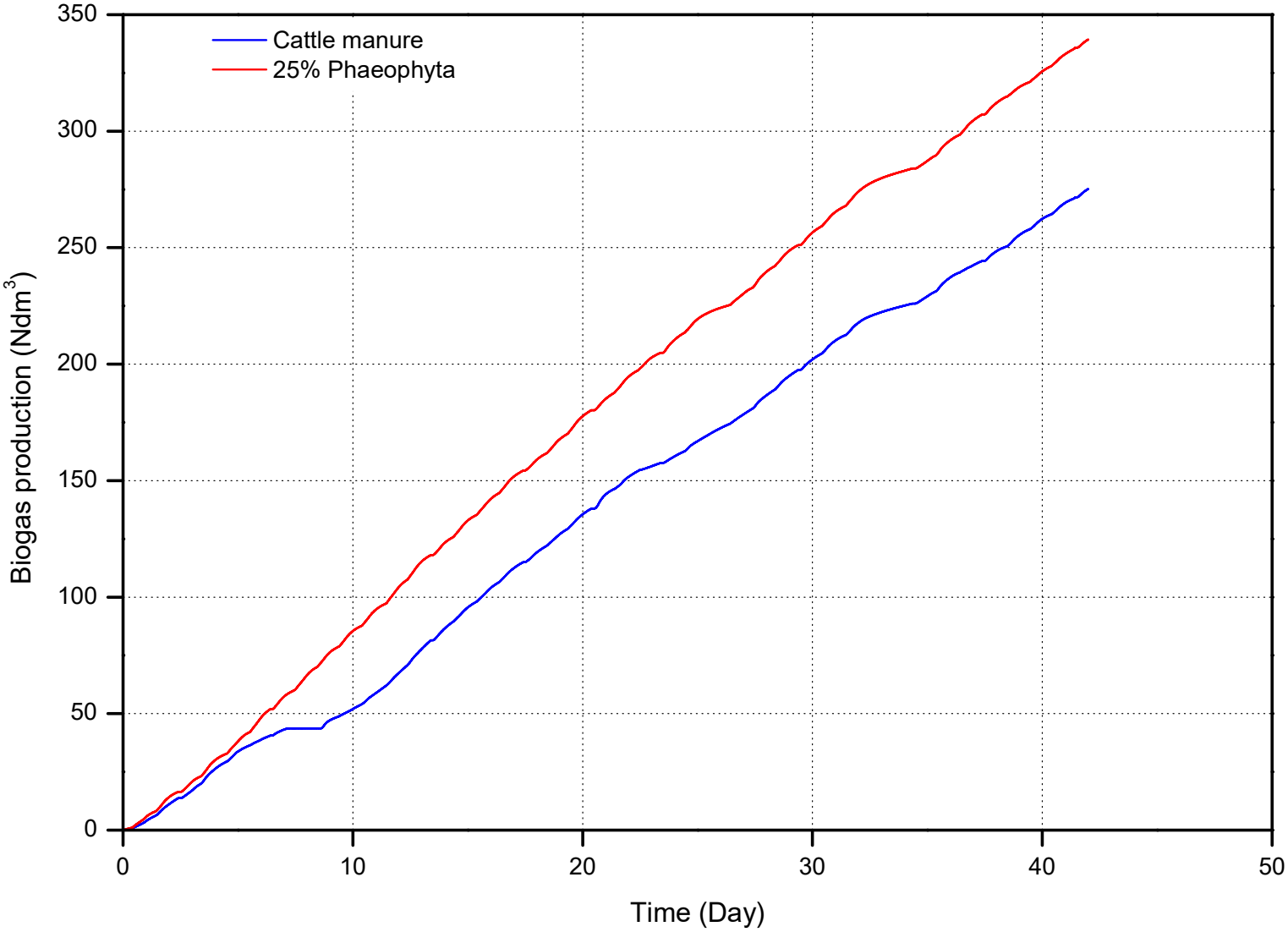
Cumulative production of biogas in quasi-continuous digestion of cattle manure and *Phaeophyta* (brown algae)



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Summary

- Preliminary studies in lab-scale of algae digestion indicate that co-fermentation algae with waste biomass causes increase in biogas production
- Only in the case of *Enteromorpha compressa* (sample G1) a slight decrease in productivity was observed compared to cattle manure
- Preliminary measurements show that the best results synergy in codigestion process can be obtained for *Enteromorpha plumosa*
- The highest methane content in biogas was observed for the mixture of *Enteromorpha plumosa* and cattle manure (sample G2), while the lowest for the mixture of *Enteromorpha compressa* (G1)
- Co digestion can be very good method for utilizing excessive marine biomass when the all technical problems will be solved (sand content, marine biomass storage)

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Thank you!

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