

From concept to market: Microalgae cultivation for CO₂ and digestate valorisation



Programme

- Welcome and introduction to the microalgae activities of the SEMPRES-BIO project (Marcella Souza, UGent)
 - Belgian pilot scale results (Merve Konucu, Innolab)
 - Spanish pilot scale results (Georgina del Puerto, UVic)
 - Interactive session: challenges and opportunities for implementing the technology (Marcella Souza, UGent)
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SEMPRE-BIO

Fostering circular economy in Europe

We will demonstrate new cost-effective ways
to produce biomethane

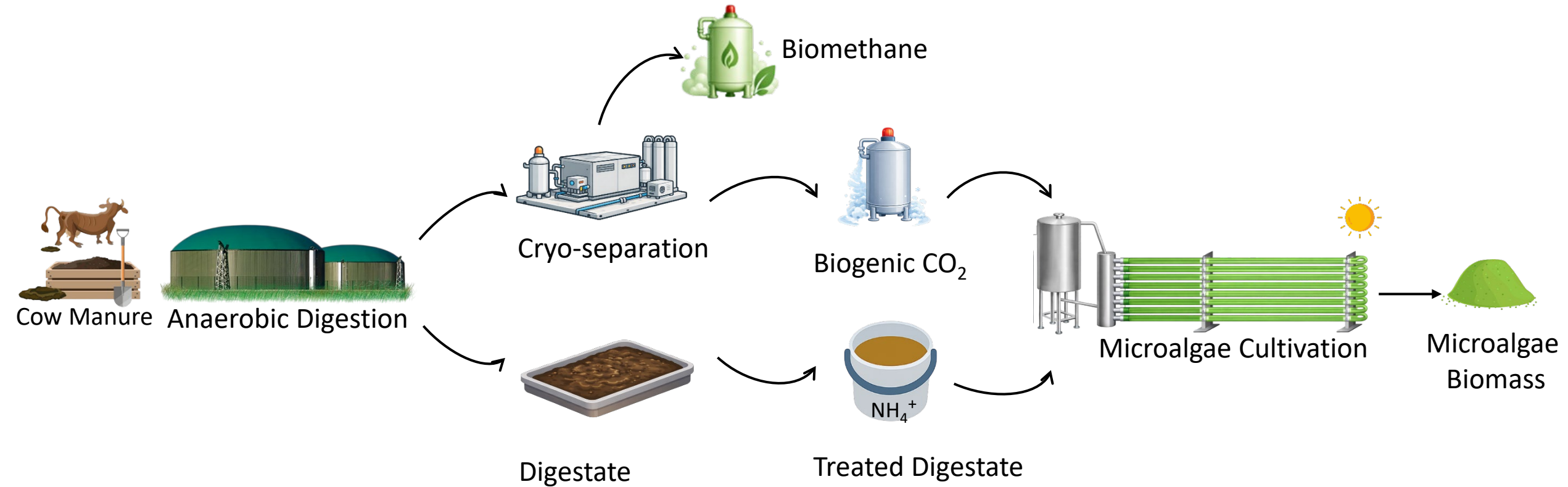
SEcuring doMestic PRoduction of cost-Effective BIOMethane



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SEMPRE-BIO: CS3 - De Zwanebloem Farm

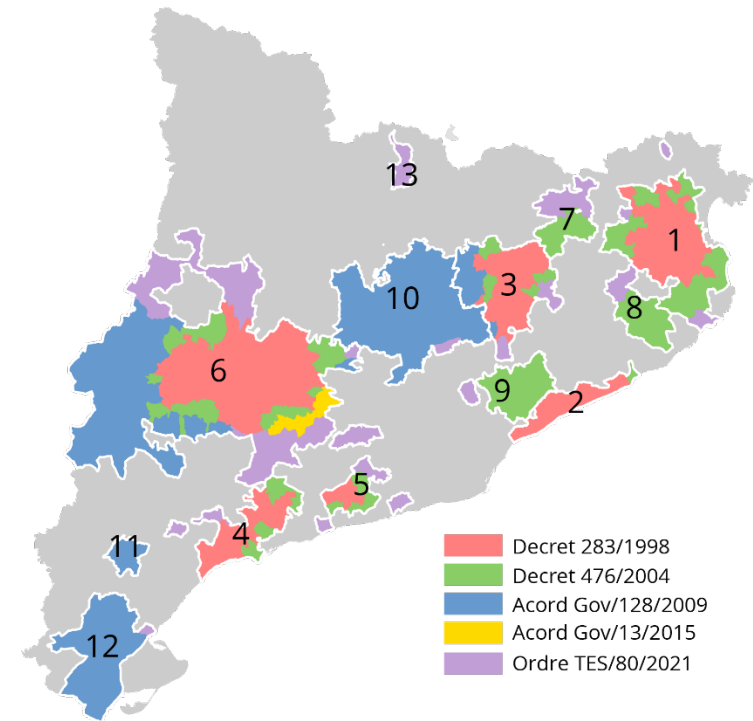


Regional context: Nitrate Vulnerable Zones

Flanders is a nitrate vulnerable zone



Catalunya nitrate vulnerable zones



Regional context: Flemish cattle industry

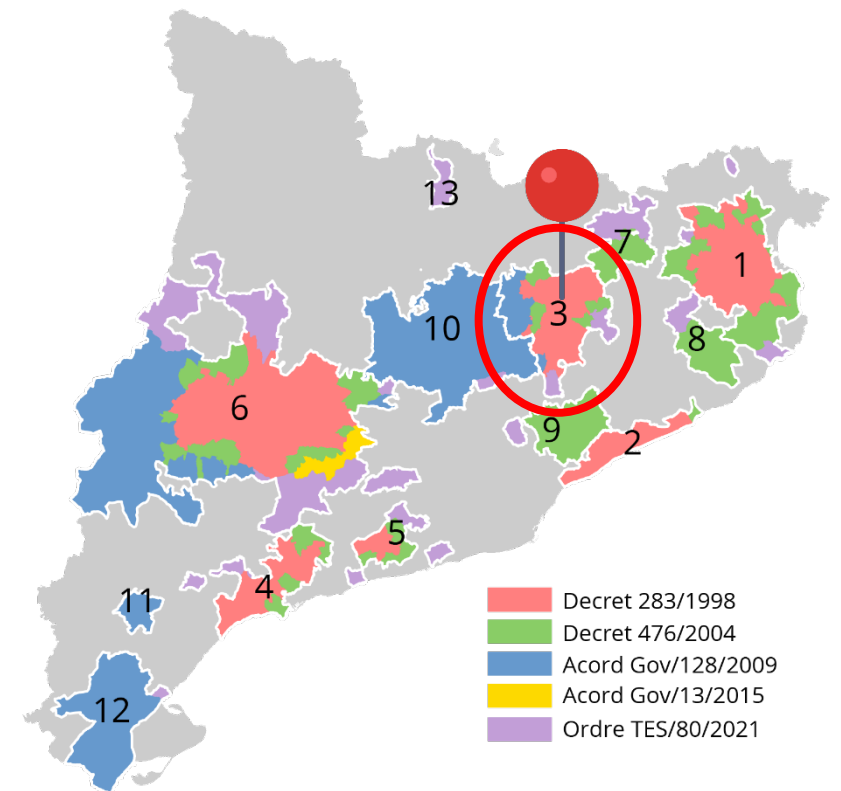
- Around 500,000 dairy cattle
- 1.16 million beef cattle
- Case study 3: 800-900 cows producing 25,000 t manure/year

42,000,000 t manure/year

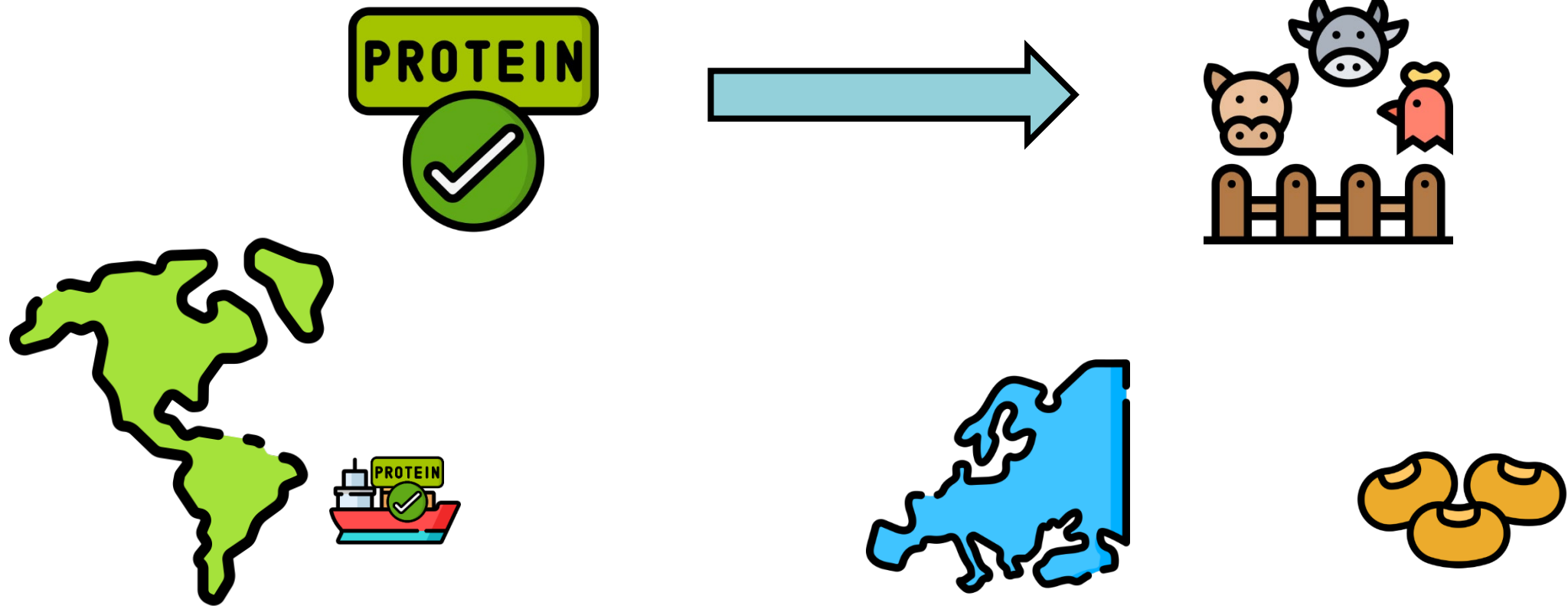


Regional context: Catalan pig industry

- 8.2 million head of pigs
- Central Catalonia region: 600 pig livestock farms – 33-55% regional economic significance



Nutrient imbalance: manure x feed



Growing microalgae on digestate



Reducing excess
digestate



Producing
protein-rich
algae



Closing local
nutrient loops

Belgian Pilot Scale Results

Merve Konucu



Pilot-scale Microalgae Cultivation at Innolab

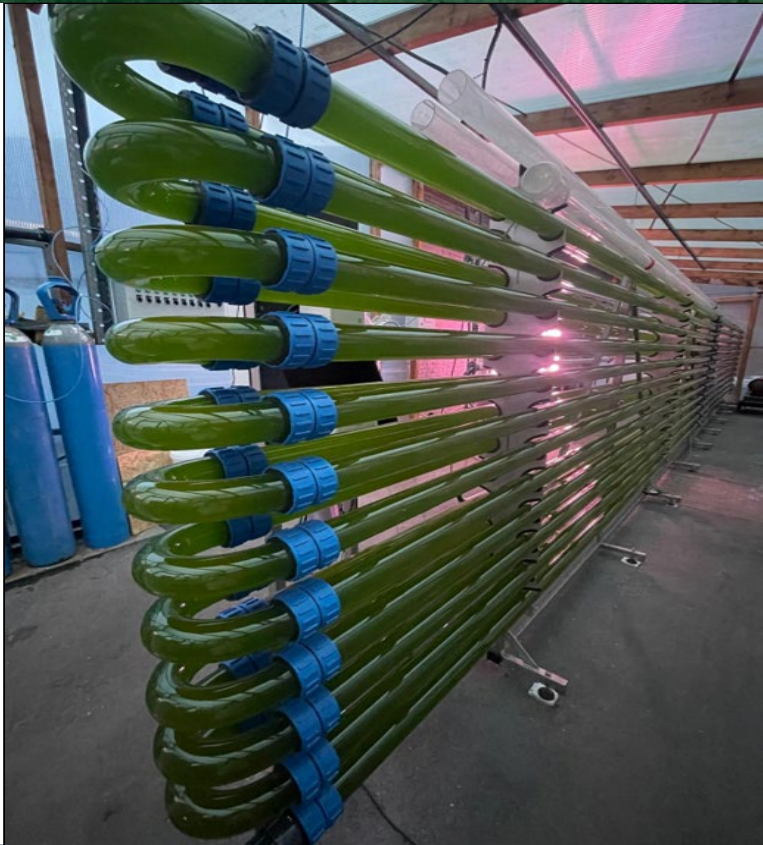


-Operated **1000L** pilot scale reactor

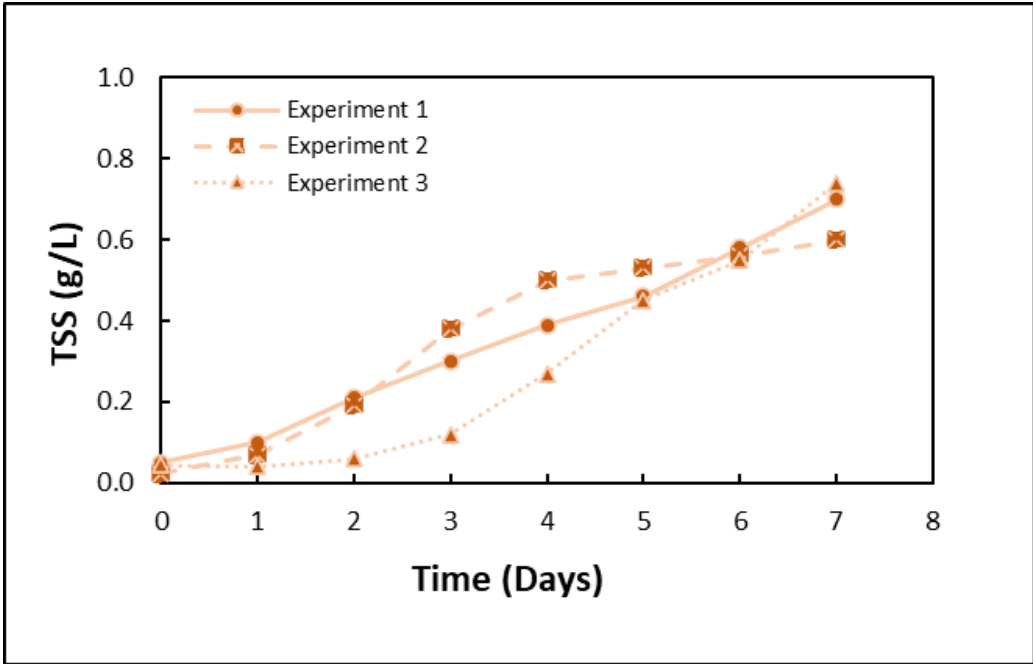
-***Desmodesmus denticulatus*** selected microalgae


-Evaluated **Biogenic CO₂** and **Digestate** as a nitrogen source to produce protein-rich microalgae biomass


Desmodesmus denticulatus Cultivation – Batch Mode





Synthetic Media + Commercial CO₂



- 
7 Days

Microalgae Production
- 
2.36 kg

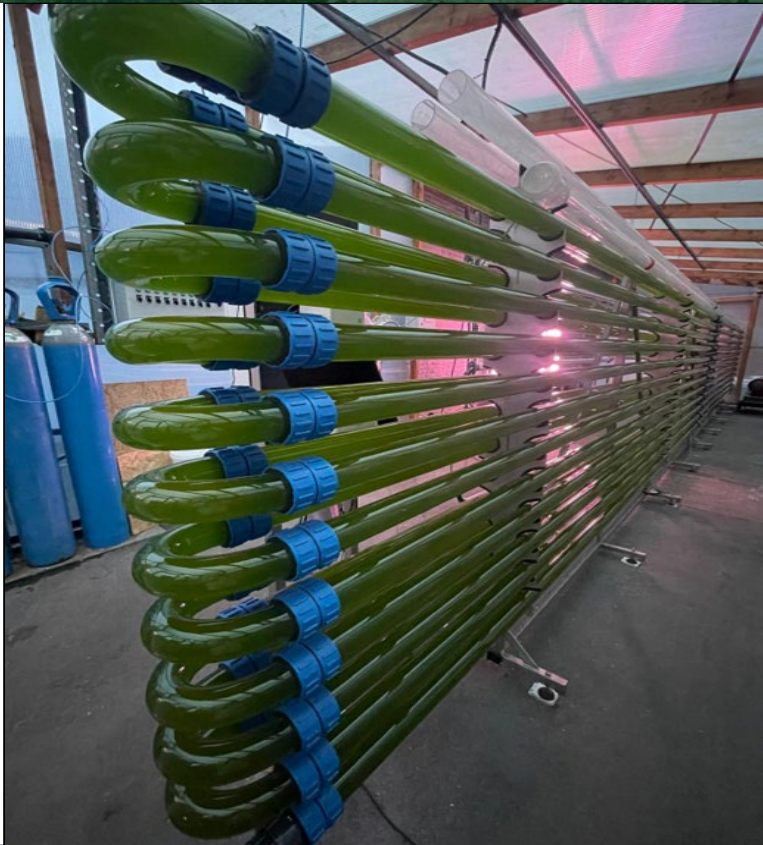
CO₂ input
- 
~ 0.7 kg

Microalgae biomass
- 
33- 37 %

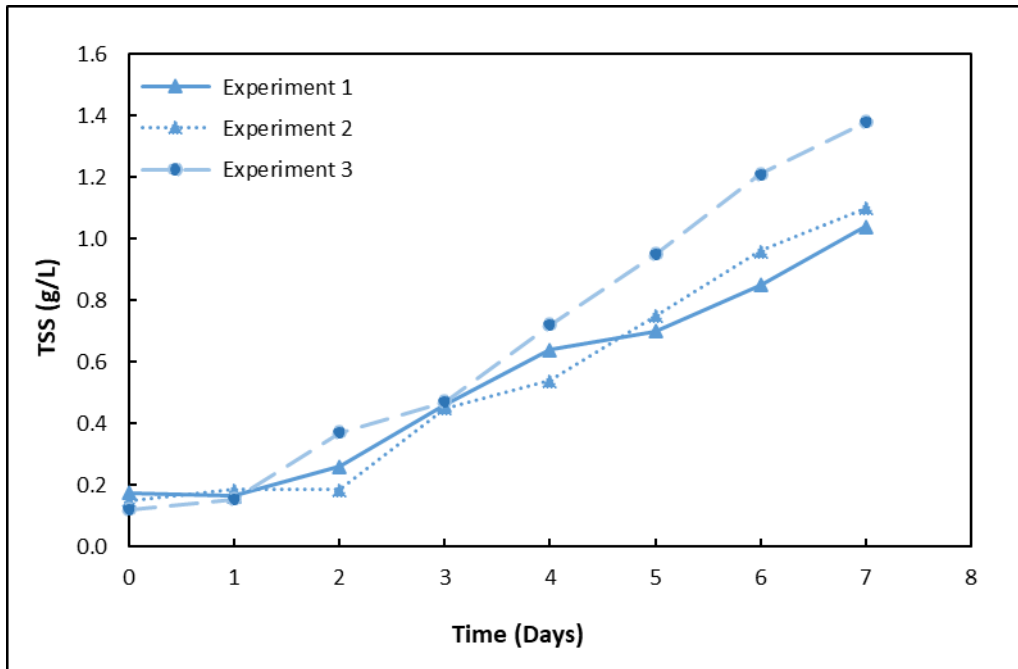
PROTEIN






Working volume : 1000L, temp: 20-23 °C

Desmodesmus denticulatus Cultivation – Batch Mode



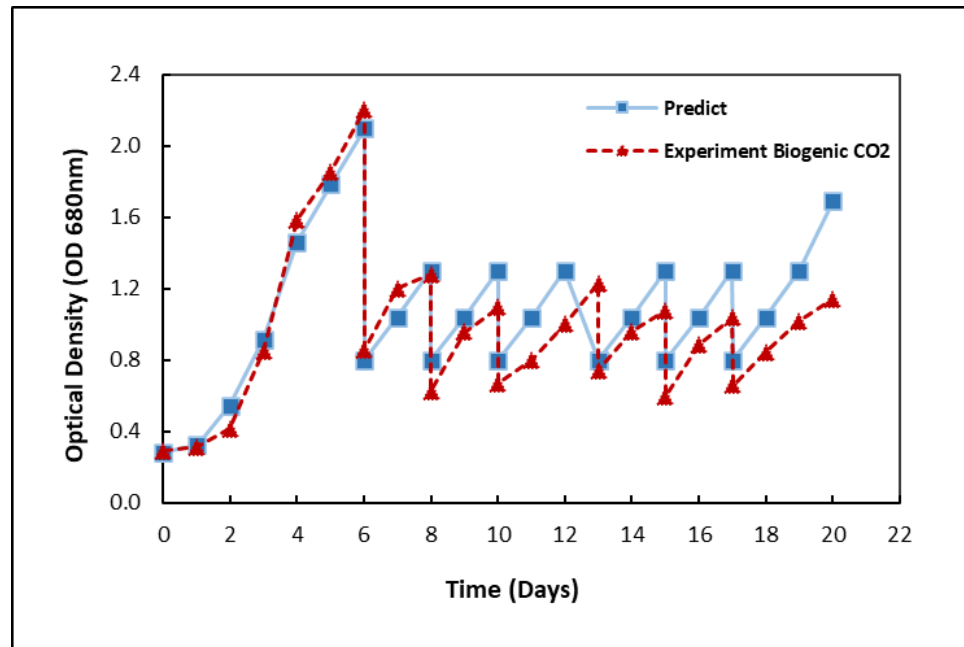
3% Digestate + Biogenic CO₂








	7 Days
Microalgae Production	
	35 L (untreated)
Digestate	
	~1.5 kg
CO₂ input	
	1.0-1.3 kg
Microalgae biomass	
	35-36%

Working volume : 1000L, temp: 20-23 °C

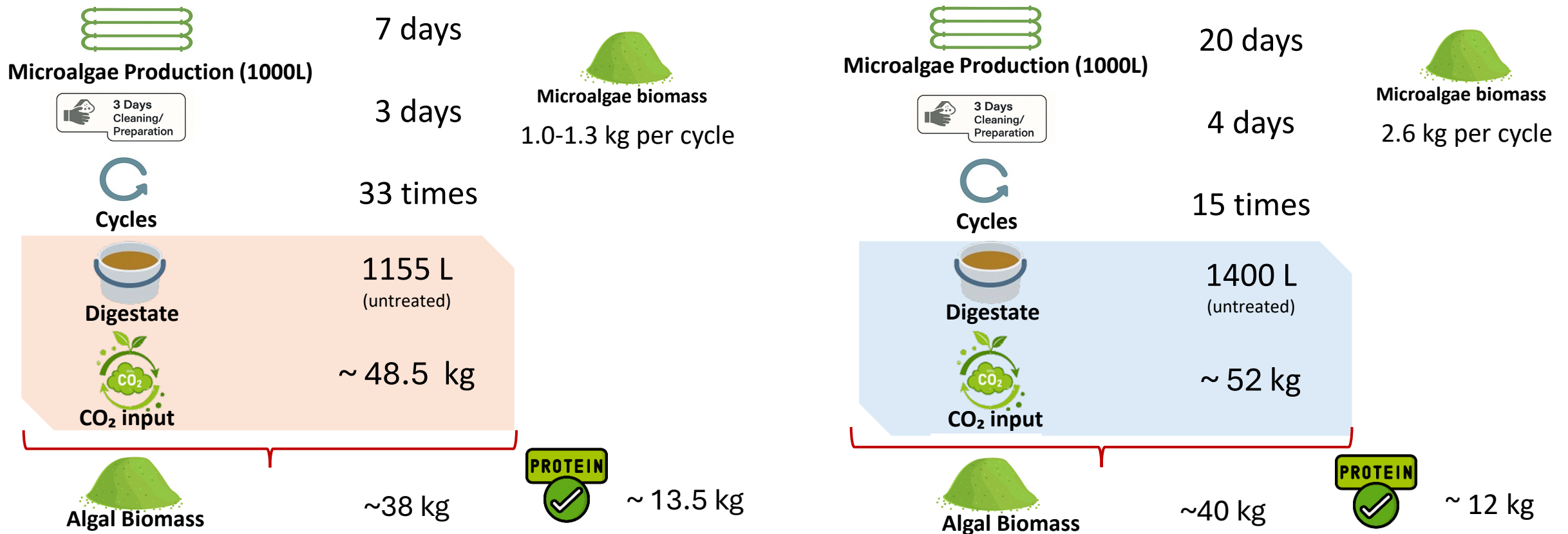
Desmodesmus denticulatus Cultivation- Semi-continuous Mode



- 3% Digestate supplemented with Biogenic CO₂
- 2-day renewal: 50% culture withdrawal based on by OD₆₈₀ values

	20 Days
Microalgae Production	
	92 L
Digestate	(untreated)
	~3.55 kg
	2.6 kg
Microalgae biomass	
	30%

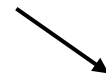
Batch vs. Semi-Continuous – Annual Productivity Comparison



Batch vs. Semi-Continuous – Annual Productivity Comparison



Similar biomass yields between systems are likely due to
👉 **biofilm-induced growth limitation in semi-continuous mode**



reduced light availability and productivity

CONCLUSIONS



- ❖ Digestate and Biogenic CO₂ supported microalgae growth, showing it is suitable for sustainable cultivation
- ❖ Biofilm accumulation reduced light penetration and effective biomass recovery, impacting overall productivity
- ❖ Temporal variability (including seasonal effects) influenced biomass production, highlighting the importance of time-dependent process conditions
- ❖ Further development is required to account for the observed process variations



Innolab Belgium
Marechalstraat 70
8020 Oostkamp



info@innolab.be



[@innolab-labs](https://www.linkedin.com/company/innolab-labs)



Spanish Pilot Scale Results

Georgina del Puerto



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Beta

Biodiversitat, Ecologia,
Tecnologia Ambiental i Alimentària



Pilot-scale microalgae cultivation at BETA TC (Vic, Catalonia, Spain)



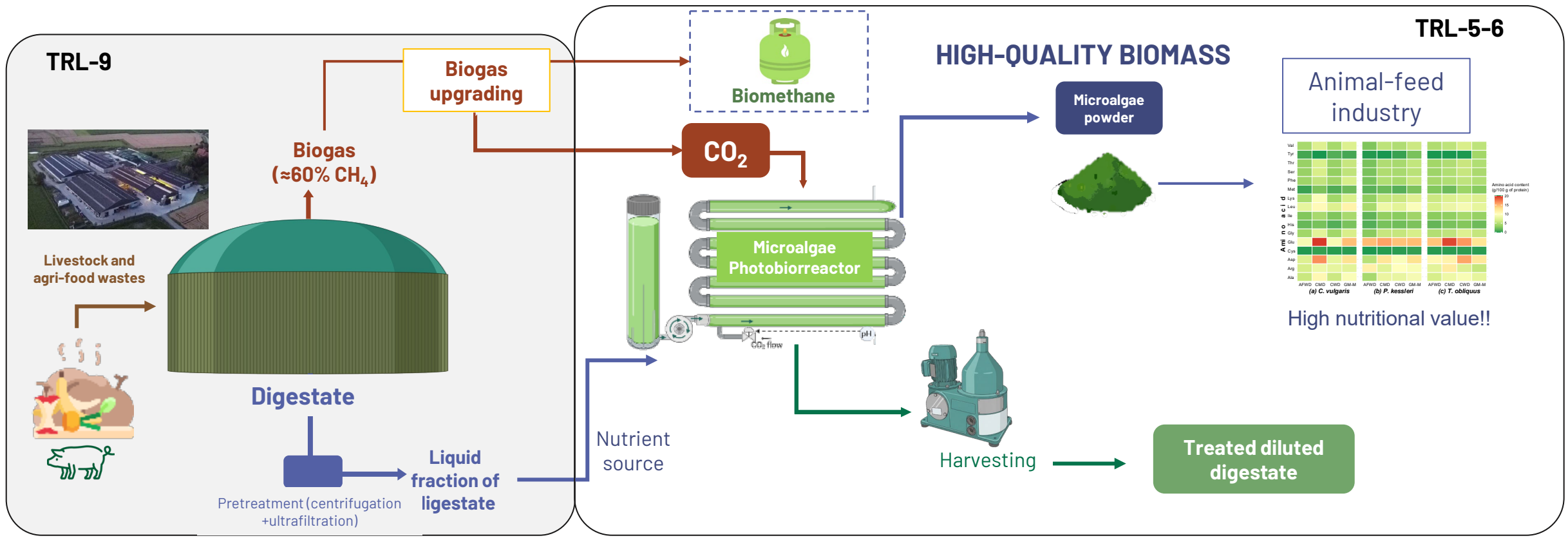
Spanish outdoor Pilot-scale photobioreactor (PBR) (BETA TC facilities)

- Location: BETA TC facilities (41°56'03.4"N, 2°15'55.4"W; Vic, Barcelona, Spain)
- Outdoor pilot-scale photobioreactor
- 600 L (400 illuminated area and 200 L degasification unit). Surface: 18 m²
- **Microalgae species: *Parachlorella kessleri* selected**
- High-protein microalgae biomass was produced with Digestate and compared with synthetic medium
- **Digestate characteristics: Agri-Food Waste Digestate (AFWD) – 10% pig manure and 90 % agri-food waste**





Process scheme





Results: synthetic medium

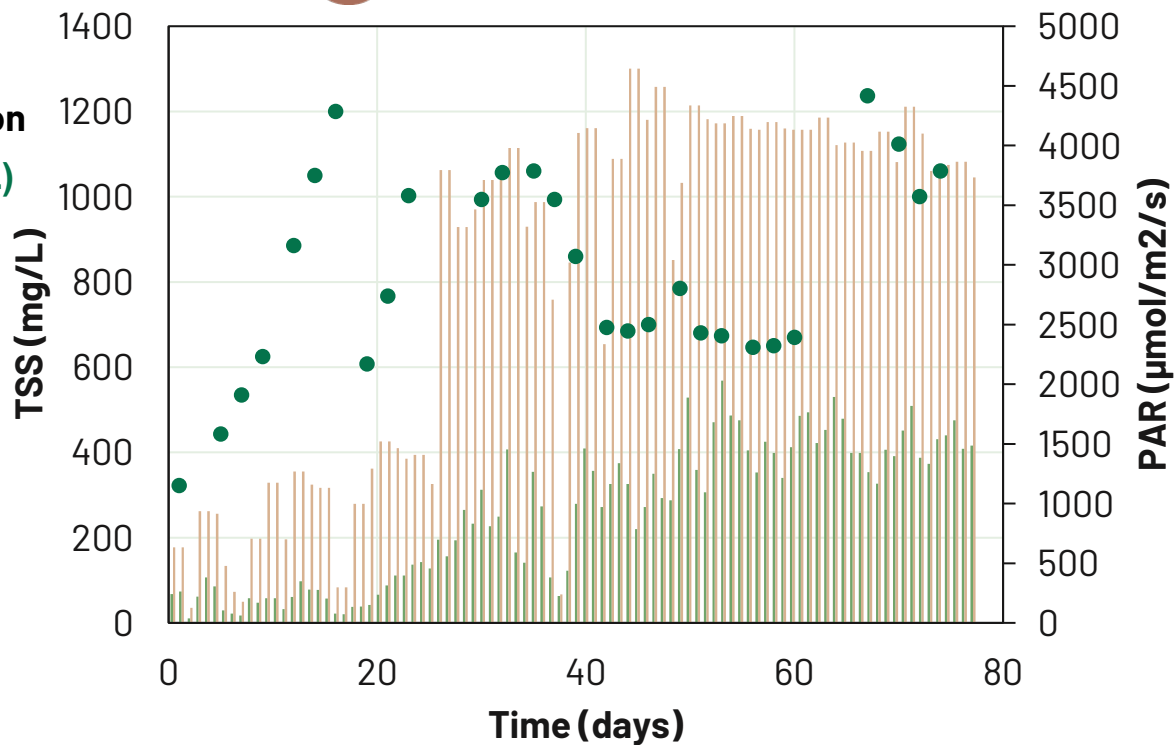


Synthetic medium



Biomass concentration

● TSS (mg/L)



**Light intensity:
Photosynthetically Active
Radiation (PAR)**

Average PAR ($\mu\text{mol}/\text{m}^2/\text{s}$)

Max PAR ($\mu\text{mol}/\text{m}^2/\text{s}$)



Biomass productivity (mg TSS/L/d):

78 ± 35 (Batch)

89 ± 19 (Semi-Continuous)

PROTEIN



Protein content (% DW):

31 ± 7 (Batch)

28 ± 2 (Semi-Continuous)



Results: digestate

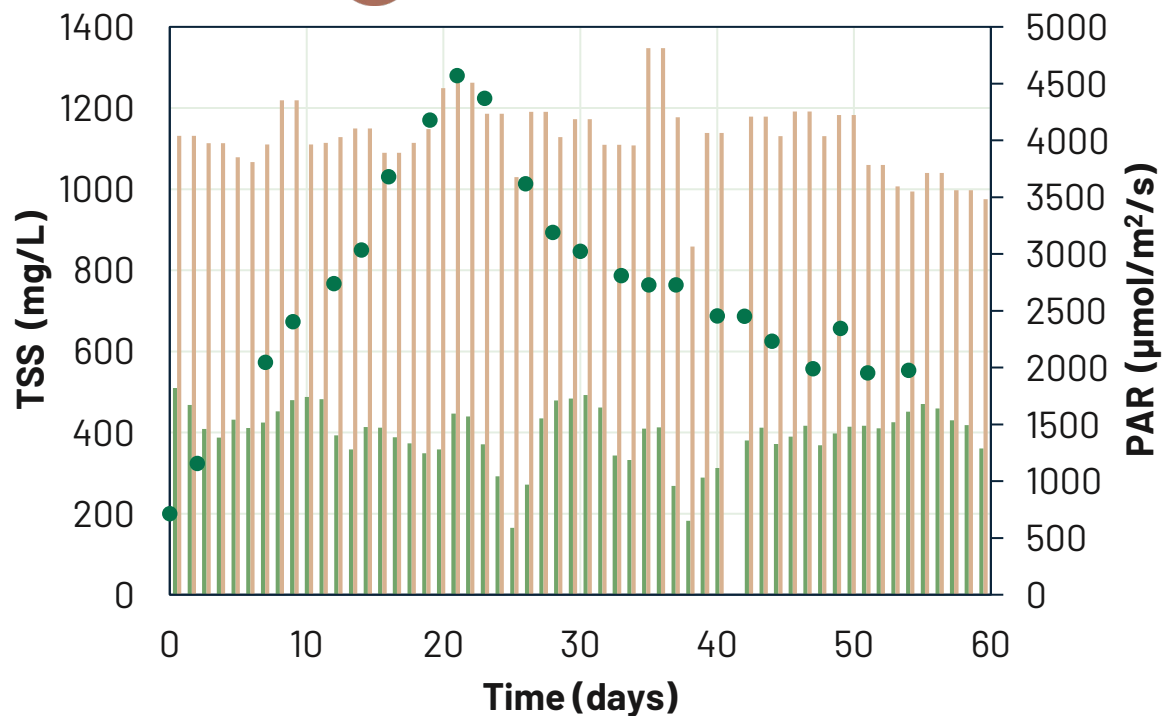


Biomass concentration

● TSS (mg/L)



2% Digestate



Light intensity: Photosynthetically Active Radiation (PAR)

Average PAR ($\mu\text{mol}/\text{m}^2/\text{s}$)

Max PAR ($\mu\text{mol}/\text{m}^2/\text{s}$)



Biomass productivity (mg TSS/L/d):

53 ± 16 (Batch)

74 ± 19 (Semi-Continuous)

PROTEIN



Protein content (% DW):

31 ± 9 (Batch)

35 ± 4 (Semi-Continuous)



Results: synthetic medium and digestate

Table 1. Results summary

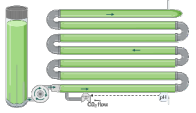
Period	Operation mode	Days	PAR ($\mu\text{mol}/\text{m}^2/\text{s}$)	Volume harvested (L)	Maximum concentration (mg TSS/L)	Biomass productivity (mg TSS/L/d)	Biomass concentration (mg TSS/L)	N-removal (mgN/Ld)	Protein content (% DW)
Synthetic medium (74 days)	Batch	25 days	605	910	1317	78 ± 35		5.4	31 ± 7
	Semi-Continuous	49 days	1399	2760	1237	89 ± 19	865	6.4	28 ± 2
Digestate: 2% AFWD (56 days)	Batch	21 days	1510	120	1280	53 ± 16		3.9	31 ± 9
	Semi-Continuous	34 days	1369	1980	1223	74 ± 19	739	5.8	35 ± 4



Annual productivity: batch



Synthetic medium

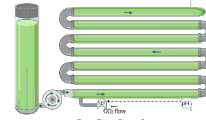


600 L

- Pilot: 600 L
- Batch phase (10 days)
- 2 days cleaning
- 30 cultivation cycles



Digestate: 2% AFWD



600 L

- Pilot: 600 L
- Batch phase (10 days)
- 2 days cleaning
- 30 cultivation cycles



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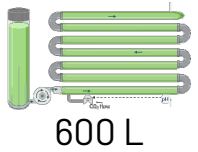
This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101084297



Annual productivity: semi-continuous

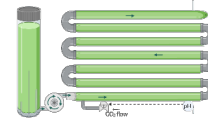


Synthetic medium



600 L

- Pilot: 600 L
- Semi-continuous: TRH 10 (600 L every 10 days)
- Cleaning frequency: 2 days every 30 days
- Cycles: 3 cycles every 32 days



600 L



Digestate: 2% AFWD

- Pilot: 600 L
- Semi-continuous: TRH 10 (600 L every 10 days)
- Cleaning frequency: 2 days every 30 days
- Cycles: 3 cycles every 32 days



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the European Union

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Annual productivity: comparison with conventional protein sources

Conventional Protein

- Soybean: 1.5 to 2.5 - 2.5 to 3.5 ton/ha seed
- Sunflower: 0.8 to 1.5 - 2.5 to 3.5 ton/ha
- Cotton seed: 4 to 5 ton/ha
- Pea: 0.6 to 0.8 ton/ha dry pea

Crop yields (FAO, 2026)



Algae biomass (2% AFWD)

- **Batch:** ~15 kg algal biomass → **8.5 tonnes/ha**
- **Semi-Continuous:** ~12 kg algal biomass → **6.7 tonnes/ha**



Conclusions



- High-protein microalgae biomass (30 - 35% DW) was produced using digestate, achieving productivities comparable to synthetic medium
- Annual productivity requires validation under changing weather conditions
- Overall, microalgae-digestate production can be further optimized, particularly in semi-continuous operations
- Production yields exceeded those of conventional protein sources





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Challenges and opportunities for the technology



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Animal By-Products Regulation

► **B** REGULATION (EC) No 1069/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 21 October 2009

laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation)

(OJ L 300, 14.11.2009, p. 1)

**Microalgae cultivation is not included in the ABPR;
ruled by national authorities**



Animal By-Products Regulation

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**Manure cannot be used for feeding farm animals
(exceptions are made for pets, zoo, and fur animals)**



Heirbaut algriculture





Food-grade CO₂ from manure



IEA Bioenergy
Technology Collaboration Programme

Case Story

IEA Bioenergy: Task 37: 11 2020

**Production of food grade
sustainable CO₂ from a
large biogas facility**
GO'CO₂ at The Korskro Biogas Plant, Denmark.



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Thank you!

marcella.fernandesdesouza@ugent.be

