

Continuous operation of interconnected packed-bed nitrifying bioreactor and an external loop air-lift photobioreactor at pilot scale

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INTRODUCTION

The MELISSA Pilot Plant, as part of the MELISSA Consortium, is a European facility that provides the conditions for the progressive integration and ground demonstration of the MELISSA loop. The integration step described in this work includes the connection between nitrifying (C3) and photosynthetic (C4a) compartments.

OBJECTIVE: Demonstrate the production of oxygen by C4a for future integration with the mock crew (C5), when C4a is fed by the liquid phase of C3, avoiding nitrite/ammonium accumulation.

- ✓ Study the feasibility of continuous long term operation (up to 7 months)
- ✓ Analyse the O₂ production of C4a under different conditions while it is being fed by the C3 liquid outlet
- ✓ Obtain a solid knowledge of C3 and C4a operation under different NH₄⁺ loads and illumination intensities to prepare future integration work packages (WP4 and WP6)

TEST STRATEGY

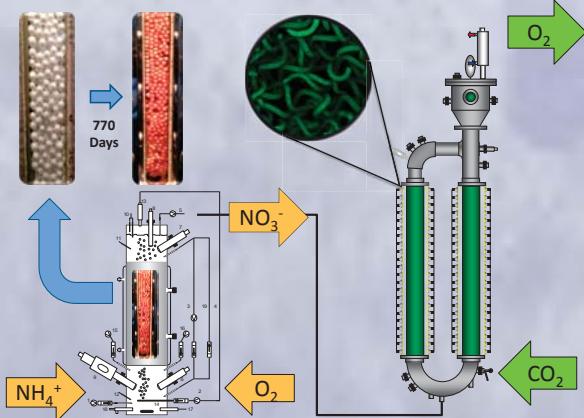
The test campaign takes place during **273 days**. Nitrifying, C3, and photosynthetic, C4a, compartments are connected in the liquid phase under a **continuous operation mode**. Different dilution rates and light intensities are tested. Previous to the connection both bioreactors have been operated in continuous mode in order to reach complete nitrification activity in C3 and stable cell concentration and O₂ production in C4a.

Nitrifying bioreactor conditions

- Packed-bed bioreactor
- Volume: 7L
- Inlet [N-NH₄⁺]: 300 ppm
- Microorganism: *Nitrosomonas europaea*, *Nitrobacter winogradskyi* forming a biofilm around BIOSTYR™ beads.
- Temperature: 30°C
- pH: 8.1
- pO₂: 80% (Closed gas loop with O₂ addition)

Photobioreactor conditions

- Air-lift bioreactor
- Volume: 83L
- Inlet [N-NO₃⁻]: 300 ppm
- Medium: Modified Zarrouk (Cogne, 2007)
- Microorganism: *Arthrospira platensis*
- Temperature: 36°C
- pH: 8.5
- Aeration: 2.8 L·min⁻¹
- CO₂ inlet: 30 ml·min⁻¹ → 1%



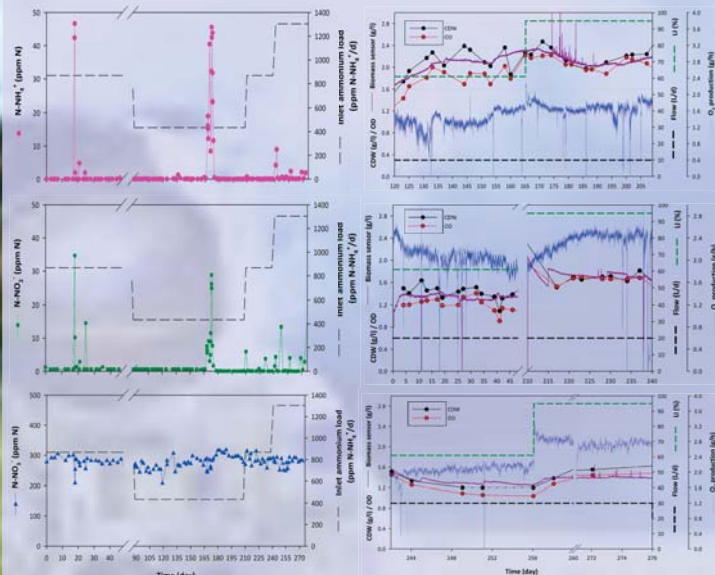
C3 bioreactor is fed with media containing different nitrogen loads: **434, 869 and 1304 N-NH₄⁺ ppm·d⁻¹**

Arthrospira platensis culture is illuminated at two different light intensities: **120 W·m⁻² and 285 W·m⁻²**

Different inlet flows are used (10L·d⁻¹, 20L·d⁻¹ and 30 L·d⁻¹) in order to modify the ammonium load and obtaining different *A.platensis* cell concentrations in C4a

RESULTS

The main focus of the process is the nitrification activity of compartment C3 and oxygen production rates of C4a.



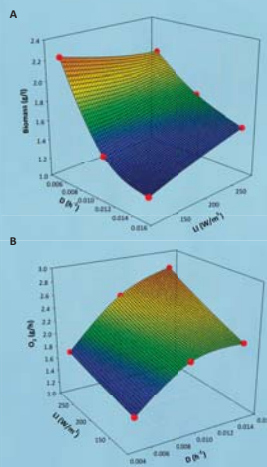
C3 CONTINUOUS OPERATION

1. **99.9% NH₄⁺ elimination**
2. **Complete nitrification**
3. **Robustness** is demonstrated by nitrification recovery after occasional NH₄⁺/NO₂⁻ peaks caused by operational changes.
4. **N balance fits** → no N losses

C4a CONTINUOUS OPERATION

1. **Steady-state** (3 residence times (t) in stable conditions) is achieved for each experimental condition
2. **Cell concentration** between 1.2-2.2 g·l⁻¹
3. **O₂ production rates** between 1.4-2.8 g·h⁻¹

ANALYSIS OF RESULTS



What are the main conclusions about C4a behaviour?

- Cell concentration is mainly affected by dilution rate, rather than light intensity
- O₂ production is more dependent on D than on light intensity → shadow effect of *A.platensis* at low D
- qO₂ is directly affected by D → higher D to improve O₂ productivity

D (h ⁻¹)	Q (L·h ⁻¹)	Light (W/m ²)	O ₂ Production (g O ₂ /h)	Biomass (g/l)	qO ₂ (mmol/g·h)
0.005	10	120	1.43±0.18	2.24±0.15	0.18
	285	285	1.68±0.14	2.05±0.31	0.24
0.010	20	120	2.03±0.15	1.41±0.12	0.44
	285	285	2.44±0.13	1.70±0.07	0.46
0.015	30	120	2.11±0.08	1.20±0.00	0.55
	285	285	2.76±0.10	1.50±0.08	0.60

CONCLUSIONS AND FURTHER STEPS

After a continuous long-term operation of interconnected C3 and C4a compartments, the following conclusions are obtained:

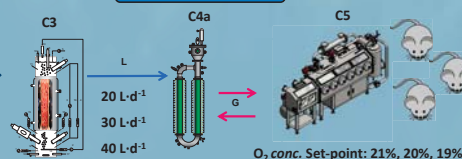
- Successful liquid phase integration between C3 and C4a
- Complete nitrification in C3 during continuous long-term operation
- C4a proves to produce O₂ for C5 (crew compartment) when it is fed by C3

OXYGEN NEEDS FOR 3 RATS

Min (day period): 1.44 g O₂·h⁻¹·rat⁻¹
 Max (night period): 2.07 g O₂·h⁻¹·rat⁻¹

O₂ requirements fulfilled when D is 0.01 or higher → [X] ≤ 1.7 g·l⁻¹

INTEGRATION WP4



O₂ conc. Set-point: 21%, 20%, 19%