Improving light absorption and energy conversion in Photobioreactors for microalgae production

University of Padova

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Elena Barbera, Eleonora Sforza, Barbara Gris, Alberto Bertucco,
Department of Industrial Engineering (DII) via Marzolo 9, University of Padova, 35121 Padova (Italy)

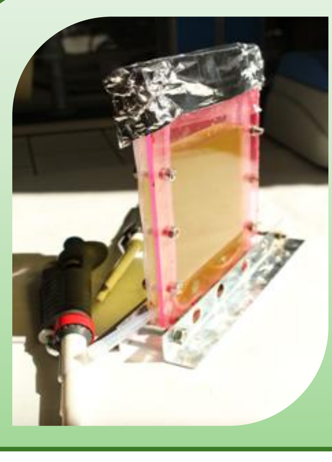
ALGAE BIOMASS ORGANIZATION

INTRODUCTION

Biofuels from microalgae represent a highly attractive energy source, that could potentially replace traditional fossil fuels. Nonetheless, the feasibility of a competitive large-scale cultivation system is still limited by a low energy conversion and efficiency: of the entire solar radiation spectrum, only the visible range is a photosynthetic active radiation (PAR) and, moreover, algae absorb preferentially blue and red wavelengths, leading to a loss of part of the energy in green and yellow ranges. In addition, when exposed to high light intensities, microalgae are subjected to photosaturation and photoinhibition phenomena, which greatly reduce their productivity.

This work is focused on improving the energy conversion in PBRs, following two strategies: increase the portion of spectrum available for photosynthesis employing spectral-converter filters, or integrate microalgae reactor with a photovoltaic (PV) cell to produce directly available energy together with biomass, and reduce photoinhibition.

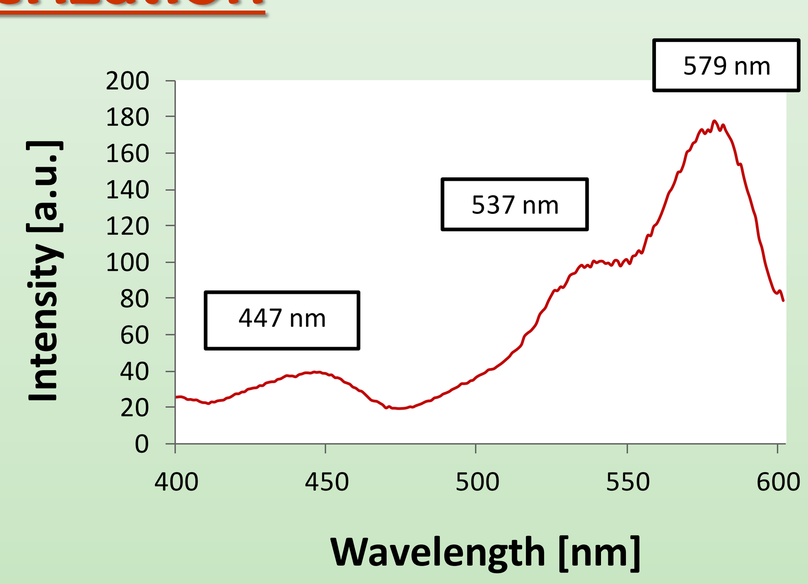
Use of spectral-converter filters



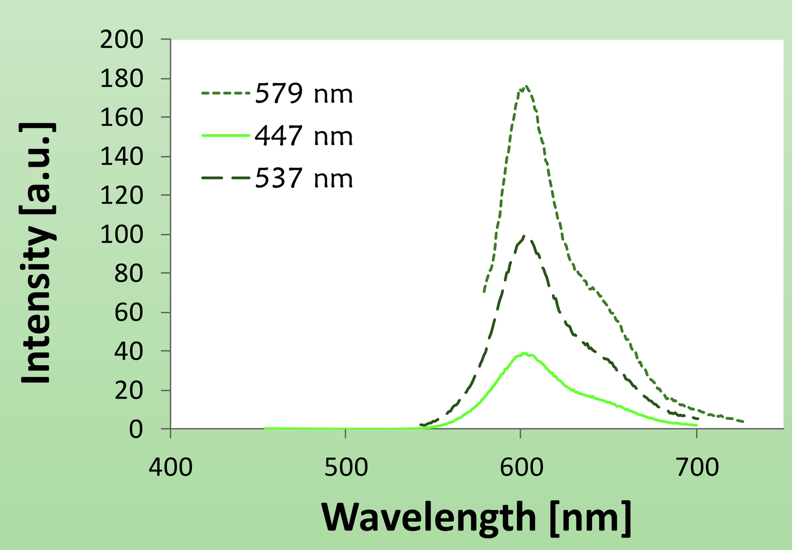
Experimental set-up:
Batch experiments were carried out with *Nannochloropsis salina* in flat-panel PBRs using a red spectral-converter filter

Characterization

Absorption spectrum of the red filter (400-600 nm) shows three peaks at **447nm**, **537 nm** and **579 nm**.

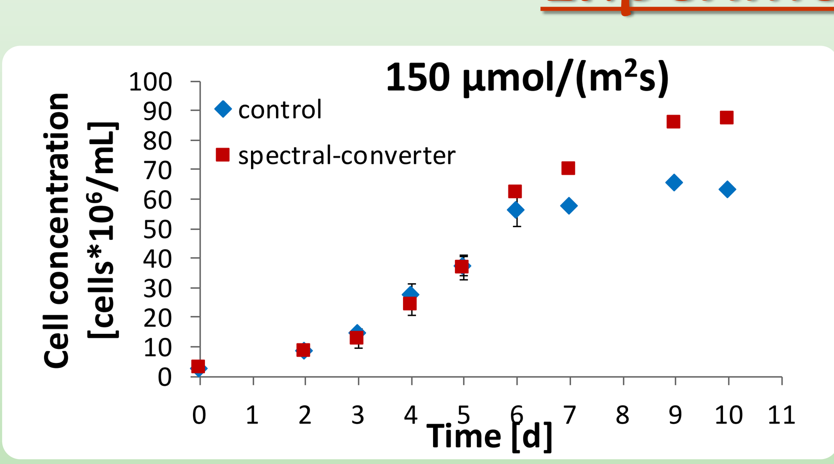


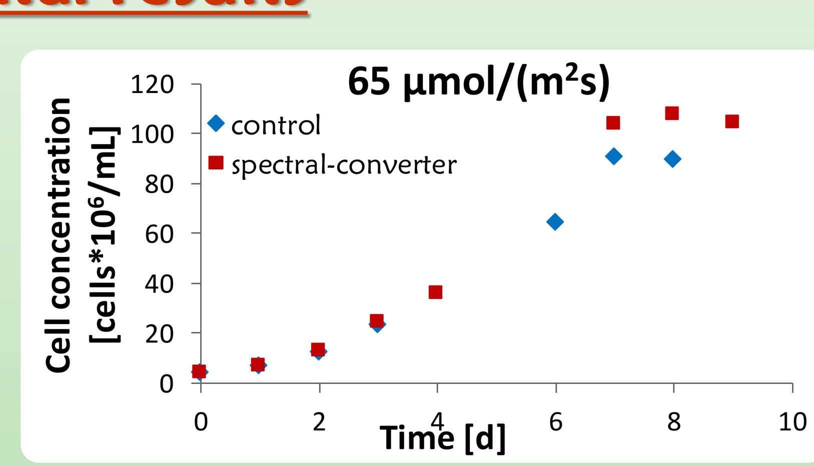
The spectral-converter filter was excited at each of the three wavelengths. Emission spectra obtained by fluorimetry show a peak at ~600 nm.
The intensity of each peak corresponds to that of the respective wavelength absorption, suggesting a good efficiency of energy shifting.



The spectral-converter filter thus absorbs the **green** and **yellow** wavelengths and shifts the radiation to **red** range, potentially enhancing the total amount of photons utilized by algae.

Experimental results



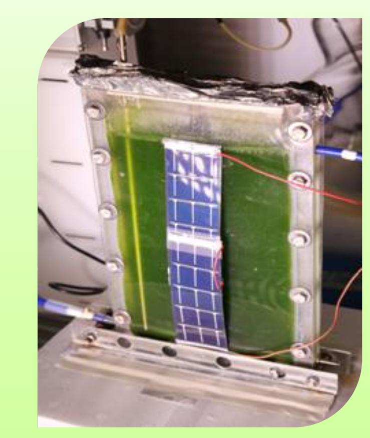


Results of batch experiments at **150 μmol/(m²s)** and **65 μmol/(m²s)** show no significant difference in growth between control and PBRs covered with spectral-converter.

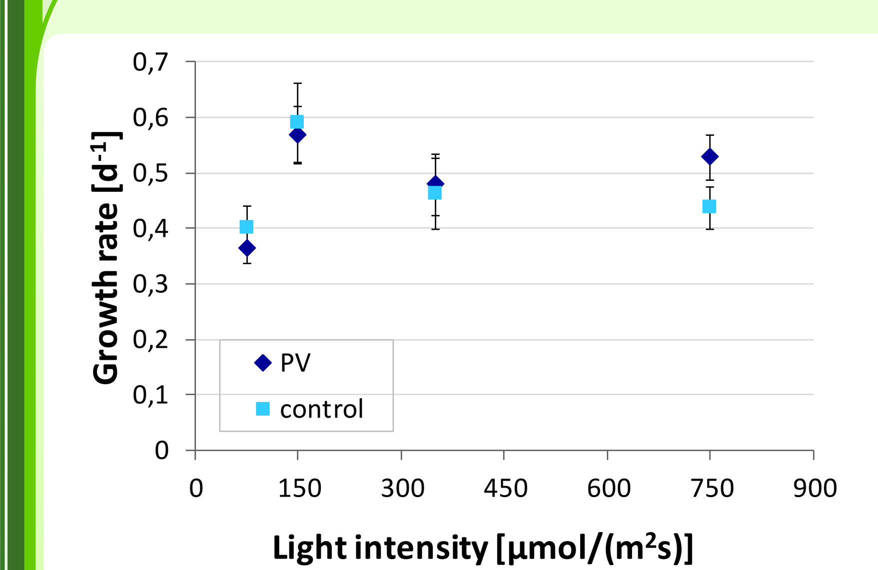
Growth rate [d⁻¹]		
	Control	Spectral converter
150	0.5206 ± 0.02875	0.5096 ± 0.01075
65	0.4607 ± 0.03943	0.4575 ± 0.03167

Integration with photovoltaic

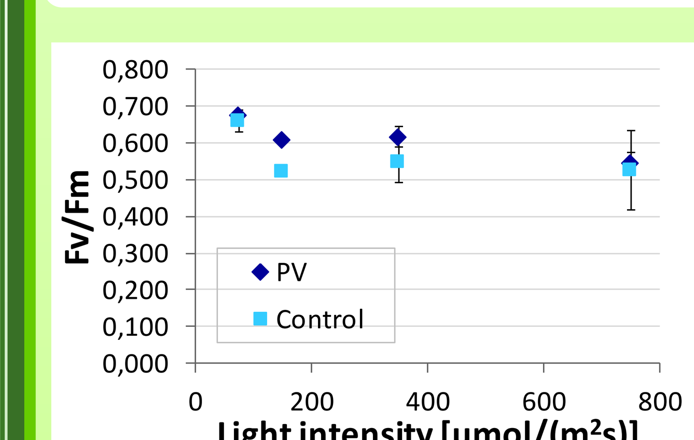
Experimental set-up:
Batch and continuous experiments with *Nannocholropsis salina* in flat-panel PBRs. 30% surface covered with a standard silicon PV panel.

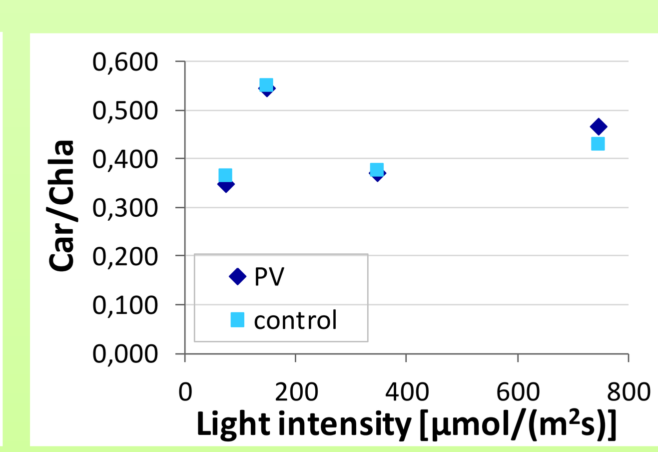


Batch experiments



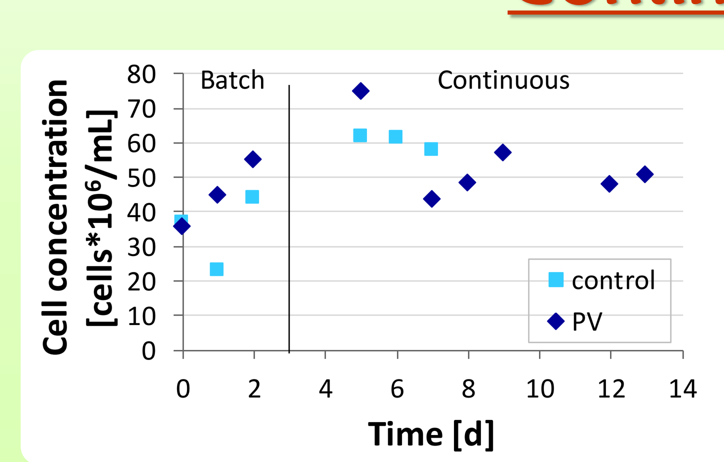
Specific growth rates are not significantly different at low light intensities.
At higher intensities (750 μmol/(m²s)) the specific growth rate is greater when covering 30% of the irradiated surface with a PV panel: this may be due to a reduction of **photosaturation** and **photoinhibition.**

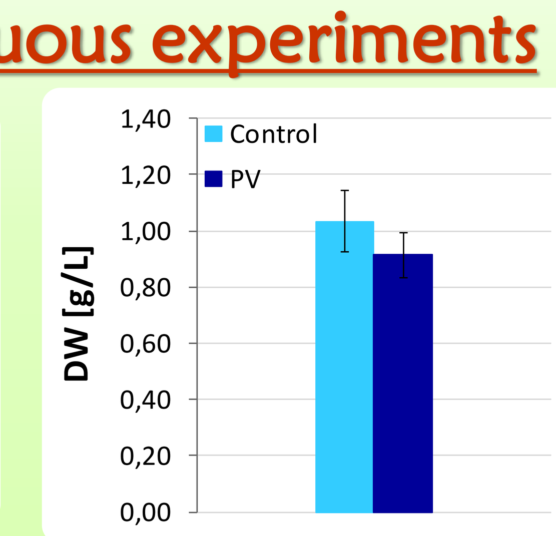




Also the value of **Fv/Fm** and the **Car/Chla** ratio are not significantly affected by the presence of the PV panel.

Continuous experiments





I = 150 μmol/(m²s)
τ = 1.69 d

At low intensities biomass concentration [g/L] at steady state is not significantly lower when 30% of the irradiated surface is covered.

Energy conversion, on the other hand, is greater when integrating the PBR with a PV panel:

3.15% of total radiation for control PBR

6.74% of total radiation for PV-PBR
(considering a typical efficiency of 13% for a standard Si PV panel)

CONCLUSIONS

- The spectral converters considered, despite shifting the green radiation towards the red range, do not substantially increase the growth rate
- Batch experiments with PV show that the growth rate is not negatively affected by 30% coverage of irradiated surface
- At high intensities the growth rate is even greater, due to a beneficial effect in terms of photosaturation and photoinhibition
- Continuous experiments confirm previous results at low intensities, and show an improvement in terms of overall energy efficiency
- Further experiments in continuous are to be carried out at higher intensities to verify the beneficial effect in terms of photosaturation and photoinhibition

Mail to: elena.barbera@studenti.unipd.it