Exploring the effect of intermittent light on microalgae growth and pigment profile: experiments and modeling

Key words: Microalgae, light, pigments, experiments, modeling

General context:

Microalgae are considered as a potentially relevant way to produce quality food and feed as well as molecules of interest such as pigments [1]. Yet, currently large-scale production is not envisioned in a coming future. Indeed, better understanding of microalgal behavior is still required at a fundamental level.

For example, the reaction of microalgal cells to different stresses has to be investigated. Indeed, these stresses can either be accidental or triggered intentionally as they may induce a culture adaption strategy. Among the well-established stress procedures, nitrogen limitation and excessive light are of the most common. Still, while light modulation (induction of fine-tuned light/dark cycles, called L/D cycles) has been reported as a potentially approach to promote growth [3], its impact of cell secondary metabolite profile has almost never been investigated, nor the dynamic of this adaptation. Indeed, from a biotechnological point of view, two aspects are important to achieve economically viable production: the amount of pigment produced and the time associated to this production. This project aims at proposing a first biotechnological exploration of these aspect by focusing on the cell pigment profile alteration and the timescales associated.

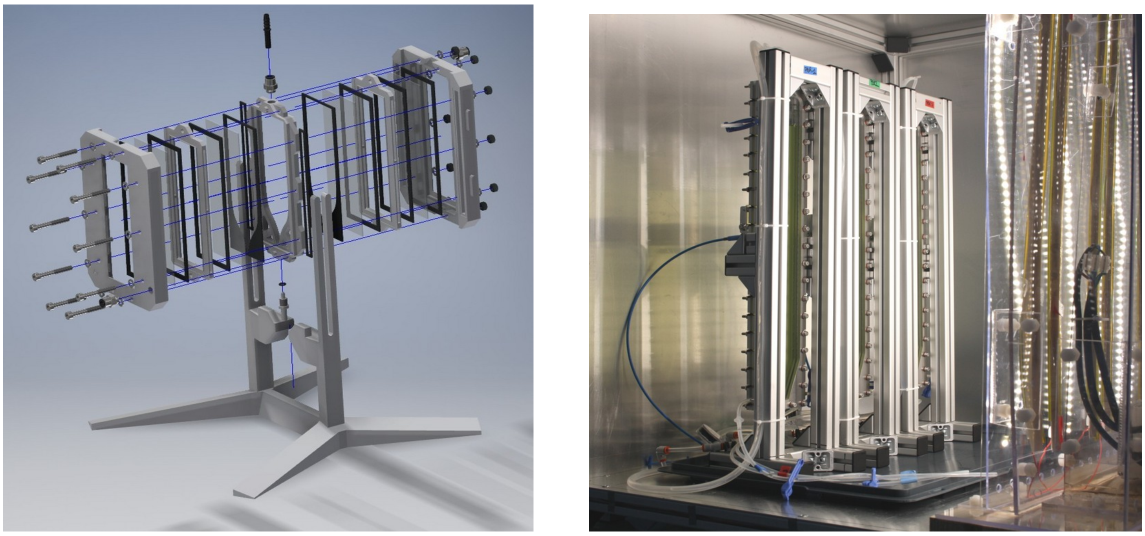

Fig. 1: 3D model of the photobioreactor (left), steel machined version and lighting device (right)

In this context, our lab developed new flat panel photobioreactors that allow cultures to be exposed to controlled and uniform light patterns (Fig. 1) [3,4]. Furthermore, classical high light stressing procedure has been successfully used to alter pigments profile [5]. We would like to go further and explore the possibility of altering pigment profile with intermittent light and understand the metabolic mechanisms behind. In addition, physiological understanding, we would like to develop and/or adapt new biological models [6-9]. Two goals are associated with this part of the work: capitalizing knowledge and create new tools for engineers to design photobioreactors numerically [10].

Description of the work:

The thesis will be articulated around different axes. They could be carried out in parallel, for example, the get familiar with the experimental device could be done at the same time as the bibliography on the conditions of growth of microalgae or develop the numerical model.

Litterature survey

The objective of this study is to bring the student up to date on the following areas:

- culture of microalgae in photobioreactors,
- influence of growth conditions on secondary metabolites profile,
- effect of L/D cycles on microalgae (growth rate, chlorophyll production, lipid production, induced stress, photodamage, ...),
- analytical procedures to quantify pigments
- modeling techniques applied to biological systems (especially photosynthetic units)

Introduction to cell cultivation

The student will become familiar with the experimental set-up (Fig. 1), the culture protocols, as well as the laboratory itself (interactions with other team members, training on analytical equipment, etc.). Thanks to this experience, she/he will be able to make suggestions to improve the experimental set-up. She/he will be able, for example, to propose new culture methods. This period will also allow the PhD student to learn how to use modern data processing tools (Python, R ...).

Experiments

In the light of the bibliography, experimental campaigns will be carried out with the aim of identifying the impact of the L/D cycles on the behavior of microalgae. The monitored outcomes will be: growth rate and pigments concentration and their evolution in time. Additional measurements could be deployed such as photosynthetic apparatus qualification, ROS content analysis, … (those techniques are already implemented in the host laboratory).

Modeling

In addition to experiments, the candidate will develop a numerical model predicting microalgae adaptation to different L/D cycles. The model should be able to reproduce the evolution of cell growth and pigmentation, including the L/D cycles characteristics (frequency, duty cycle and light intensity) but also the still very open question of acclimation regarding these parameters. Complementary analysis (e.g. ROS content) could also be used to help in better understanding, formulating and predicting these values.

Depending on the complexity of the system considered and the data available, different (non-exclusive from one another) approaches could be envisioned, namely: mechanistic modeling, statistical modeling and machine learning modeling. Hybrids approaches could also be considered.

Cultures in a larger volume & model scale-up

As a perspective to this work, a larger scale culture could be conducted to validate that the observed behavior is not a lab-scale artefact. Indeed, it is well-known that small scale results may not be transferable to larger scale. Evaluating this effect could be led if the remaining time allows it. To do so, the student will operate a large volume (5 liters, Fig. 2 left) bioreactor and try to reproduce the small-scale performances.

The developed biological model would be tested by its coupling with a full scale CFD model predicting cell trajectories and light patterns within the photobioreactor (Fig. 2 right). This way we could validate the proposed models will be suitable to design new photobioreactors.

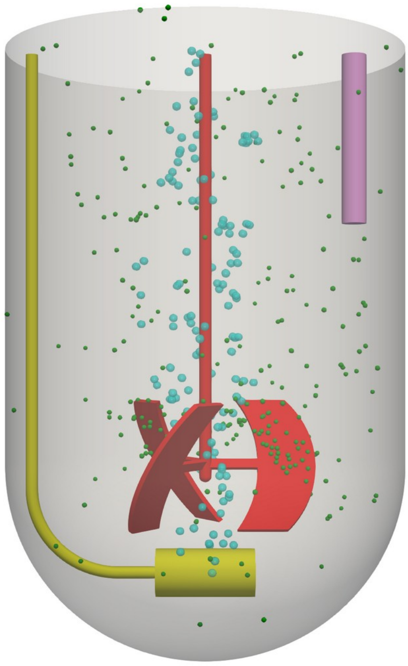

Fig. 2: 5-liter stirred tank photobioreactor (left), numerical simulation (right)

During the thesis

Regular reporting, in the form of written reports and oral presentations, will be expected from the doctoral student. This will enable her/him to accumulate material already written and thus ease the writing of her/his manuscript.

At least one publication in an international peer-reviewed journal will be a prerequisite for the defense of the thesis work.

Desired profile:

The candidate must have a background in line with the proposed topic, *i.e.*, demonstrate knowledge and skills in microbiology and/or biotechnology, numerical modeling, ... This can be exemplified by the following skills:

- microorganisms growth
- model formulation
- numerical analysis

Ease with computer tools is required (at least Windows, MS Office Suite or Libre/OpenOffice). In addition, the following skills will facilitate the work of the future doctoral student: Linux, Latex, Python, Matlab, R. Fluent English (read/written or even spoken) would be a big plus.

On a human level, we are looking for a candidate who is dynamic, curious, autonomous and able to work in a team.

Supervision:

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Host laboratory:

The Chair of Biotechnology of CentraleSupélec, launched in 2010 and located in the Centre Européen de Biotechnologie et de Bioéconomie (CEBB) in Reims, is a dynamic and young group of 30+ people with three areas of expertise:

- Characterization & conversion of lignocellulosics,
- Biotransformation,
- Downstream processing.

Backed by the Process Engineering and Materials Laboratory, this chair is a strong link between its head institution – CentraleSupélec – and economic and academic actors; most of the R&D activities are led in regional, national and international collaborative projects. With its training of high-level general engineers, CentraleSupélec has a strong expertise in modeling applied to (bio)process and (bio)materials. In addition to the experimental approach, the three areas of expertise of the Chair significantly rely on a set of core skills in Modeling, Simulation & Visualization, more particularly oriented towards the modeling of life mechanisms and the up-scaling of processes for the industry. This transverse modelling team is currently reinforced, as the Chair, renewed in 2020 with an increased budget, is structured by the concept of digital twin applied to bio-processes.

The doctoral student will be integrated in the Biotransformation team. She/he will benefit from very recent facilities or new equipment that will be purchased through the renewal of the chair. The group has also good skills in the design and realization of in-house experimental set-up, including CNC, 3D printing and control/command.

References:

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