Modeling microalgae photosynthesis – A new modeling approach

Background:

Microalgae are considered a potentially relevant way to produce quality food and feed, as well as molecules of interest such as pigments[1]. They are, therefore, a relevant tool to address modern society's challenges. To produce microalgae, photosynthesis is the golden path as:
- it uses sunlight, a free and abundant energy substrate,
- it sequestrates carbon dioxide and delivers ecosystemic benefits[2],
- it fixates pollutants such as nitrate, nitrite[3], phosphorous, …

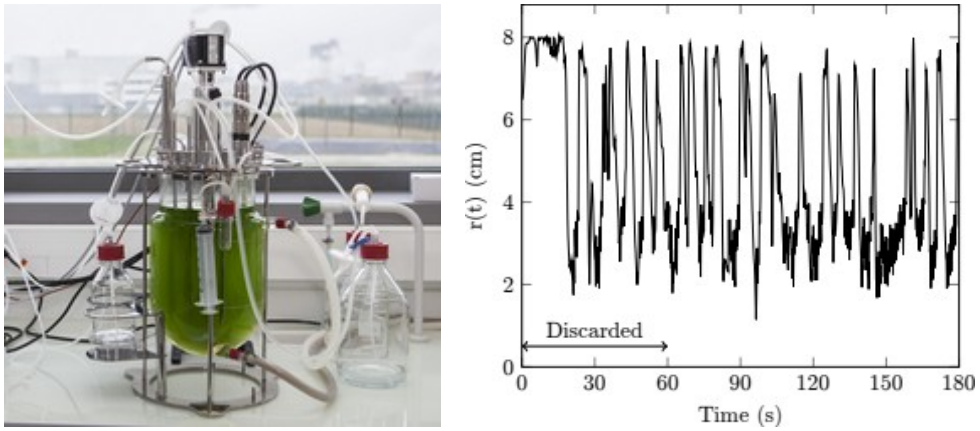

Figure 1: left – actual photobioreactor, right – Position <=> light pattern perceived by the microalgae within the photobioreactor

However, large-scale production is not envisioned in the coming future as light use at the industrial scale is currently suboptimal. Thus, a need to better understand and master microalgae photosynthesis before making photosynthetic microalgae production a reality on a large scale. Among the different avenues to improve the use of light, better modeling of microalgae photosynthesis is required.

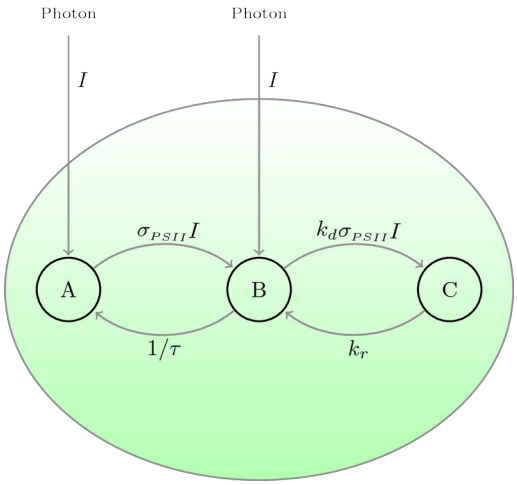

Figure 2: Han's model schematic, among the most advanced model of photosynthetis for microalgae

Indeed, at the photobioreactor scale, microalgal cells are submitted to light in an intermittent manner. First, because of the day/night cycle. Second, because of the fluid motion that brings them close to the lit surface or in the dark core of the culture vessel (Fig. 1). Yet, microalgae are known to react to this everchanging light. There is, therefore, a need to understand how they react and model it. Modeling is an essential step as, in the future, it will allow engineers to design photobioreactors better.

This proposal aims to improve the current photosynthesis model developed for microalgae. They are classically static models[4] or simple dynamic models[5,6] (Fig. 2). In any case, they fail to reproduce microalgae reactions to light in a general way. The of the PhD project is to take advantage of recent advances in photosynthesis[7,8] to develop a new numerical model reproducing microalgae photosynthesis (Fig. 3) and to validate it using state-of-the-art fluorometry methods.

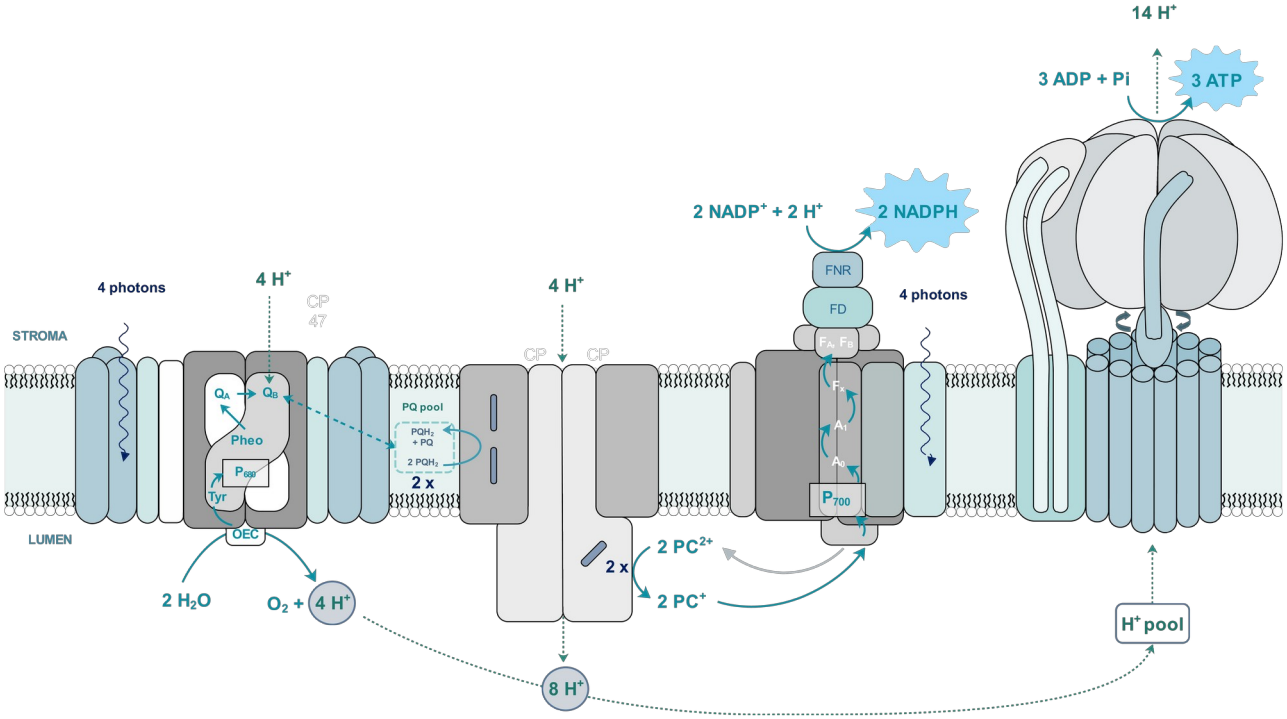

Figure 3: light reactions of the photosynthesis

<u>Description of the work:</u>

This proposal aims to evaluate a new model of microalgal photosynthesis. We will focus on the conceptual level first. Then validation will be undergone. If relevant, in the latest part of the PhD project, we may try to conduct lab-scale bioreactor runs to show the potential applicability of our new model.

The thesis will be articulated around two axes: conceptual developments and fluorometry testings. The bibliography will support the investigations from beginning to end and ease the publication of our results.

Literature survey

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

- photosynthesis,
- microalgae,
- biological modeling,
- numerical implementation of models,
- fluorometry.

Basic model

First, a simple model will be proposed. It will be based on two pillars: the downgrading of the most advanced models for higher-plants photosynthesis and our knowledge of the difference between microalgae and higher plants. The aim is clear: create the first proof-of-concept of our new modeling approach.

Fluorimetry validation
Fluorimetry is a technique that investigates photosystem II's behavior (the core of photosynthesis). We are equipped with an apparatus that also quantifies produced oxygen. On top, we can apply any light pattern we want. Therefore, it will be a very potent tool for examining the microalgal photosynthetic response and the relevance of our model.

Advanced model
Following the first validation of our model, we will iterate and improve it. We may be willing to improve our description of several phenomena such as NPQ, qI, qZ, … In any case, the PhD student will be guided and supported in these tasks. Once updated, another round of fluorometry testing will be conducted to validate the improvement.

Photobioreactor validation run
Finally, we possess very special photobioreactors especially designed for light response investigations. Once confident enough in our model, we shall be able to challenge its predictive capabilities using this device. Here again, the candidate will be trained and supported to operate these photobioreactors.

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., photosynthesis (higher of microalgae), life-science in general, microbiology, … 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:
Dr. Victor Pozzobon, HdR (victor.pozzobon@centralesupelec.fr)

Host team:
The position is open in a dynamic and growing laboratory. It gathers people with a real diversity and complementarity (microbiology, analytical chemistry, numerical methods, …). The person recruited will be surrounded by a rich team (doctors, engineers, other PhD students, all working with microalgae, in numerical and experimental) who will be able to bring their know-how but also benefit from his own. Finally, the Biotechnology Chair is made up of a young, multicultural team that offers many scientific and human opportunities.

Host laboratory:
The Chair of Biotechnology CentraleSupélec Chair, created in 2011 and located at the Bazancourt-Pomacle (51) biorefinery, is structured around three thematic axes: lignocellulosics, bioprocessing and separative techniques, all of which are based on a cross-cutting modeling, instrumentation & visualization foundation. It is one of the four groups hosted by the European Center for Biotechnology and Bioeconomy (CEBB).

References:

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