LED light tailoring in a planar photobioreactor for optimization of microalgae growth.

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Abstract
Microalgae are well known for their potential in producing valuable substances for nutraceutical and pharmaceutical industries, as well as a source of biofuel. The use of the photosynthetic capacity of microalgae is a new alternative for carbon dioxide bio-fixation. Therefore, the purpose of this work is to identify the best microalgae growth conditions, using an experimental planar photobioreactor (PBR) and LEDs with variable intensities as light source. Two different illumination intensity levels were used during the experiment: 33 and 57 μE of PPFD (Photosynthetic Photon Flux Density). A series of growth parameters such as temperature, pH, dissolved CO_2 and oxygen concentrations, were real-time monitored. Optical density (OD) and dry weight were periodically evaluated in order to measure the concentration of biomass in the culture. Overall, the innovative approach of this work allowed to 1) successfully cultivate *Scenedesmus obliquus* in a closed photobioreactor under low photon flow; 2) establish a correlation between biomass concentration and LED intensity for this specific microalga strain which can be used in future experiments in order to finely tune light intensity to the desired biomass density.
Keywords: *Scenedesmus obliquus*, LED light source, planar photobioreactor, PPFD, microalgae.

1. Introduction

Microalgae are photoautotrophic organisms, meaning that they use photons as an energy source to sustain cell growth. Light source can be natural (i.e. solar radiation) or artificial. Artificial light can provide a better regulation of the Photosynthetic Photon Flux Density (PPFD), photoperiod and light spectra in microalga cultivation. In this study, illumination based on LEDs was selected for two reasons: 1) it is possible to use selected spectral region instead of the entire emission spectrum such as fluorescence tubes to fit the photosynthetic algal needs, 2) fine regulates the dimming state of light source. In the past, peer reviewed scientific information about applications of LEDs in microalgae cultivation was scarce. For the realization of this research our own photobioreactor was completely designed and realized. The main purpose of this work is to demonstrate that a photobioreactor with a high light efficiency can allow microalgae biomass growth, using a lower photon flux when compared to similar technologies.

2. Material and Methods

2.1. Microalgae culture

The strain used for this study is *Scenedesmus obliquus* (SAG 276-3a): a freshwater green microalgae species of the genus Scenedesmus, known for the genetic coding of its mitochondria. This strain was selected on basis of previous studies (Franchino et al., 2013). The experiments were carried out using a BG-11 growth medium.

2.2. Photobioreactor

The experimental apparatus used for microalgae cultivation is made of two main parts: a planar photobioreactor and a mixing tank. The light-dependent phase of photosynthesis occurs in the first one; the tank is necessary for mixing microalgal volume with nutrients and to wash dissolved oxygen produced during microalgae photosynthesis as well as for monitoring of the process parameters (temperature, pH, O_2 and CO_2 concentrations). The photo-phase loop consists of a transparent plastic honeycomb panel and sealing systems. Microalgae follow the path obtained with the use of the sealing and connection systems between an alveolar element and the following one. In the photo-phase loop they are irradiated by the light coming from the LED panel interposed between the two-parallel flat-panels. The movement of liquid is necessary to ensure for the entire population of microalgae the same exposure to light, a constant availability of nutrients and a good mixing of liquids. Also, the correct choice of the liquid handling device allows to reduce the overall system's energy consumption. The retention tank is mainly used to ensure optimal culture mixing and oxygen removal. This step is necessary because high concentrations of oxygen has an inhibiting effect on microalgae growth. Also, the growth medium can be added directly to the tank and get properly mixed. A gas cylinder containing food grade CO_2 was connected to the retention reservoir by means of

an electric valve; the gas flow was regulated by a flow-meter.

2.3. Experiment setup

The photobioreactor was inoculated to an optical density (OD_{680}) of 0.250 Abs as determined. The total system capacity in this experiment is of 80 L. The illumination system consists of six LED arrays, three in the upper part, and three in the lower part of the photobioreactor. On every array there are several types of LEDs. All these LEDs are governed by a controller. During this experiment, only channel 5 and 10 had a non-zero value, meaning that only white LEDs were used. The photon flux supplied in the first phase of the experiment had a photon flux of 33 $\mu E/m^2s$, while this value increased to 57 $\mu E/m^2s$ in the growth second stage. The photobioreactor consumes 64 W when illumination system has a value of 33 $\mu E/m^2s$ and only white LEDs are in use; it requires 106 W when intensity has a value of 57 $\mu E/m^2s$. The electronics circuit consumes about 44 W in both configurations.

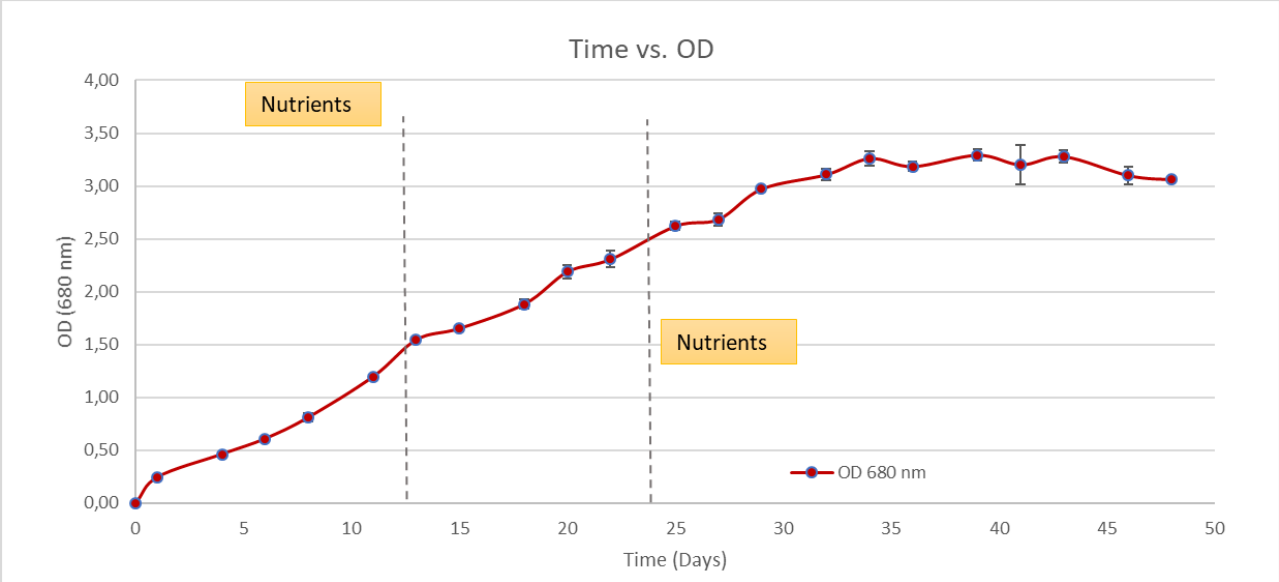

***Figure 1**. Microalgae growth curve determined spectrophotometrically at 680 and 800 nm.*

3. Results and Conclusions

Figure 1 shows the microalgae growth rate curve obtained in the test. The graph shows that a lag phase did not occur. The experiment was carried out in fed-bath mode, BG11 nutrients were periodically added in the FBR to prevent depletion of nutrients. The addition of BG11 prevents the growth inhibition caused by limited availability of nutrients since the hope of present work was to reach the inhibition of growth due to light depletion. Growth medium was then added on the 18th day of the experiment. This did not result in any substantial change in the growth trend, which remained approximately unchanged. At the 36th day of the experiment, the curve suffered a decrease for the first time. Therefore, another portion of growth medium was added which, however, did not cause a significant increase in the culture growth. For this reason, illumination conditions were changed, setting the photon flux to 57 $\mu E/m^2s$. This however did not produce the desired effect since no significant increment in biomass concentration could be observed. Auto-shading effect can be related to the limitation of further increase of biomass growth, although accumulation of inhibiting secondary metabolites in the growth medium is under evaluation. Exponential phase lasted for about 13 days. Afterwards, the OD_{680} values continued to rise following a linear trend. The highest absorption value reached during the exponential period was equal to 1.547, while the highest value reached during the entire experiment period was of 3.293 (day 39). A second important result is related to the light intensity used during this test. It was hypothesized that a high microalgae concentration could be reached by increasing the light intensity from 33 to 57 $\mu E/m^2s$. Instead, increasing light did not cause a significant effect since the optical densities remained roughly constant, around 3,200 (at 680 nm). However, the overall outcome of the experiment is positive: the expected biomass concentration has been reached using a lower light intensity. This is an important consideration since the power consumption and, thus, energy costs were lower. In conclusion, the expected biomass concentration has been achieved in conditions of energy efficiency.

References

Franchino M., Comino E., Bona F. and Riggio V.A. (2013), Growth of three microalgae strains and nutrient removal from agrozootechnical digestate, *Chemosphere*, 6, 738-744.