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White and red LEDs as two-phase batch for cyanobacterial pigments production

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ABSTRACT

Carotenoids and phycobiliproteins have a high economic value, due to their wide range of biological and industrial applications. The implementation of strategies to increase their production, such as the application of two-phase light cultivation systems, can stimulate pigments production, increasing economic turnover. In this sense, *Cyanobium* sp. was grown in seven different two-phase white/red cultivation arrangements, varying the time of each light from 0 to 21 days. Biomass, photosynthetic activity, pigments profile and antioxidant capacity were measured along time. Red light increased photosynthetic activity and pigments content (ca. 1.8-fold), and the use of a two-phase cultivation system generally raised bioactivity and production of phytochemicals. Among the studied, the optimal cultivation condition was found with 10 days of white followed by 4 days of red light. The optimized growth led to a productivity of 137.4 ± 0.8 mg L^{-1} d^{-1} of biomass, 17.0 ± 0.2 mg L^{-1} d^{-1} of total phycobiliproteins and 4.5 ± 0.2 mg L^{-1} d^{-1} of carotenoids.

1. Introduction

Light is the main source of energy for photosynthetic organisms such as cyanobacteria. These prokaryotic organisms are ubiquitous and have diverse morphologies and physiologic features, thus being able to produce a wide variety of bioactive secondary compounds with diverse chemical structures (Graham et al., 2016). Some of those compounds had attracted economical interest due to their industrial applicability, biological benefits and high-added value, what led to a massive production of cyanobacterial biomass in the last few years (Belay, 2013).

Phototrophic systems are the most common for cyanobacteria-based bioprocesses, and consist in the use of light as energy source and carbon dioxide as inorganic source of carbon (Guedes et al., 2014; Schulze et al., 2014). In this matter, pigments represent both fundamental components on the cyanobacterial metabolism and one of the most expressive compounds in the market of cyanobacteria-based products (Markets, 2019).

Cyanobacterial pigments are responsible for the most essential processes of photosynthesis – light harvesting and energy transfer to photosystems (Geada et al., 2017; Henry, 2004). In cyanobacteria they are grouped in three classes: chlorophylls, carotenoids and phycobiliproteins (Henry, 2004) – being the latter the major components of antennae pigments. These protein-pigments are organized in the thylakoids membranes in form of phycobilisomes complexes (Pagels et al., 2019). Four types of phycobiliproteins can be found in cyanobacteria: phycocyanin, phycoerythrin, phycoerythrocyanin and allophycocyanin, depending on the species. When it comes to carotenoids (i.e. carotenes and xanthophylls), these compounds are considered essential for the survival of photosynthetic organisms (Cogdell and Frank, 1987; Guedes et al., 2011a), and responsible for a great part of chromatic acclimation and adaptation of cyanobacteria, together with the phycobiliproteins. Moreover, phycobiliproteins and carotenoids can act as protectors against oxidative damage, mantaining the photosystem functional (Guedes et al., 2011a; Pagels et al., 2019). Apart from their role inside the cell, due to their biochemical and bioactive properties, cyanobacterial pigments can be explored in several fields, such as antioxidant, anti-inflammatory and anti-obesity, among others (Pagels et al., 2019), that are highly attractive for industrial areas – e.g. food, feed, nutraceutical and cosmetical (Guedes et al., 2011a; Pandey et al., 2013).

In the last years, the dyes market increased the demand for natural pigments for application in the food and feed industry (Markets, 2019). In this sense, cyanobacteria relevance for the market is still limited by the high cost of production and the constraints on the downstream process (Acién et al., 2012; Venil et al., 2013). To overcome constrains on the cyanobacteria-based bioprocess and optimize production

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by an accumulation phase was also beneficial to *Cyanobium* sp., our findings showed an increase of ca. 1.5-fold in pigments content using red LED, and an increase of 1.2 and 1.3-fold for carotenoids and phycobiliproteins productivity, respectively, using a two-phase system of white and red LEDs. Other kinds of two-phase upstream processing have been proposed to microalgae and cyanobacteria-based systems. Ra et al. (2016) showed that a two-phase light system using blue and green LEDs can be used for lipids accumulation in *Nannochloropsis* spp., increasing the lipid content in 1.5 to 1.8-fold. The same system was proposed by Che et al. (2019), using optimized conditions of the first phase (white LED) and a second phase of green LED, the lipidic content of *Isochrysis galbana* reaching up to 70%$_{DW}$. García-López et al. (2020) suggested that a two-phase system using solar light for the growth phase and blue-light for accumulation phase increased phycocyanin production in *Arthrospira (Spirulina) maxima*. Other kinds of two-phase cultivation have also been proposed for microalgae and cyanobacterial production, such as nutrient starvation (Sui et al., 2019), change on the carbon source (Das et al., 2011) or even an increase on light intensity for β-carotene accumulation (Sui et al., 2019).

4. Conclusions

Cyanobium sp. showed two distinct photosynthetic metabolisms under white and red LEDs, being the red-metabolism more photosynthetic efficient and having a higher content of pigments when compared to white. Although, the use a two-phase system using both LEDs increased the maximum productivity of biomass, pigments and total antioxidant compounds.

The best condition for the studied components was 10 days of white plus 11 days of red led, with highest productivity achieved at day 14. The optimal culture process was set as 10 days of growth under white LED plus 4 days of pigments accumulation under red LED.

CRediT authorship contribution statement

Fernando Pagels: Conceptualization, Investigation, Formal analysis, Writing - original draft. **Graciliana Lopes:** Investigation, Formal analysis, Writing - review & editing. **Vitor Vasconcelos:** Conceptualization, Writing - review & editing, Supervision, Funding acquisition. **A. Catarina Guedes:** Conceptualization, Formal analysis, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

None.

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