Industrial production of lutein in *Scenedesmus almeriensis*

Part II. Upstream and Photobioreactor design

Del Rio, M.; Gres, M.; Gutiérrez, A.; Huguet, M.; López, A.; **Torrellas, M.**

Introduction

The aim of the project is to design an industrial biotechnological production plant of lutein by the culture of the *S. almeriensis* microalgae. The annual production of the microalgae is 50 tons. Taking into account that the 0.55% of the dry weight of the microalgae is lutein and that the final downstream yield is an 80%, the annual purified lutein production is 205Kg.

Given that the total culture volume needed to achieve 205 Kg lutein/year is 200m^3, to do this, the project needs approximately 24 photobioreactors of 8.66m^3 each are used for microalgae's growth. There is a constant input of fresh medium and also a harvest flow during the hours of sun light.

Objectives

The main goal of this part II of the project is to design a large scale production of microalgae. This includes the upstream process and also the bioreaction.

1. Scale up of the production system, photobioreactors
2. Productivity improvement
3. Achievement of optimal culture conditions

Upstream

The medium used is *Mann&Myers* with an extra amount of fertilizers. Given that the volume needed for one day is 68m^3, this two components are mixed in a tank of **100m^3**. The outlet rate of the tank works during 10 hours achieving a final flow of **6.8m^3/h**. To ensure that the medium is not contaminated it is filtrated using a 2μm pore diameter filter.

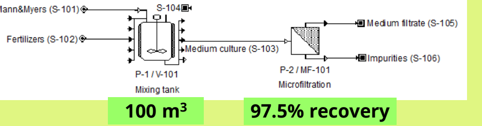


Figure 1: Upstream diagram designed using SuperPro ®

100 m^3 — 97.5% recovery

Airlift

The airlift structure has three important functions, witch are essential for the microalgae growth.

- Circular Mixing → **Homogeneity**
- Air injection → **O_2 removal**
- CO_2 injection → **pH**

Operation conditions

During 10 hours of light the photobioreactors work in continuous mode. Throughout 14 hours of dark the fresh medium and harvest flows are closed.

Parameters	Value
Solar radiation	650-2000 μE/m²·s
Temperature	30ºC (Greenhouse)
pH	8
Liquid velocity	2.05 m/s
Dilution rate	0.34 day-1

Table 1: Culture conditions

Tubular Photobioreactor Dimensions

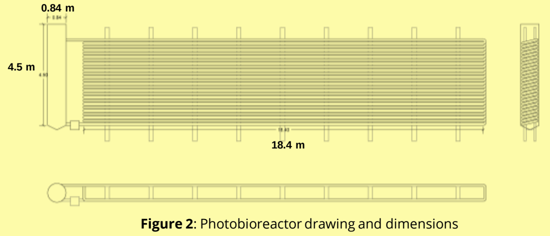


Figure 2: Photobioreactor drawing and dimensions

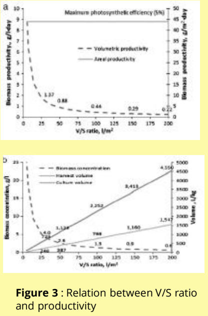


Figure 3 : Relation between V/S ratio and productivity

Parameters	Semi-industrial	Industrial
Length solar collector (m)	400	1025
Diameter solar collector (m)	0.09	0.1
Volume solar collector (m³)	2.5	8.05
Height airlift (m)	3.5	4.5
Diameter airlift (m)	0.4	0.84
Volume airlift (m³)	0.5	0.89
Total volume (m³)	3	8.94
Volume culture reactor (m³)	2.62	8.66
Liquid velocity (m/s)	0.9	2.05
V/S ratio (m³/m²)	0.07	0.05
Productivity (g/L·dia)	0.7	0.88

Table 2: Comparison between pilot plant and industrial plant photobioreactors

Solar collector

The solar collector goal is the photon capture by the microalgae, with the aim of reaching the **maximal photosynthetic efficiency**

To achieve the maximal photosynthetic efficiency the Dark/Light cycle frequency should be about 1-1.5 Hz

Light zones vs Dark zones

Figure 4: Distribution of light and dark zones inside the solar collector

Microeddies

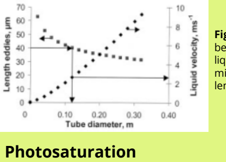
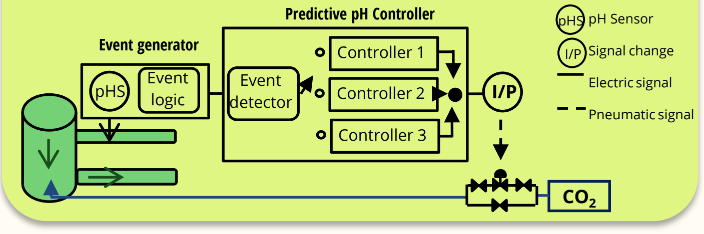


Figure 5: Relation between diameter, liquid velocity and microeddies 's length

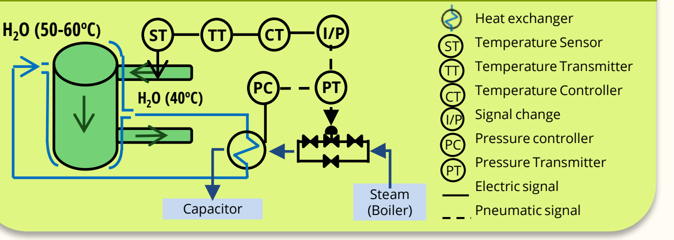
Photosaturation

↑ D + ↑ Liquid velocity } Dark/Light cycle deregulation

Predictive pH Control



Temperature Control



Conclusions and future steps

Throughout the project have been achieved the various sub-objectives that were proposed at the beginning, such as the State of the art, which production strategies exist, tubular photobioreactor operation among others. Once passed the sub-objectives, the two main objectives of the project were faced: increasing the volume and productivity of the photobioreactor system, in order to obtain a competitive industrial process. As it can be seen, at the end of the project those objectives have been achieved. Current research is still working at laboratory scale or pilot plant scale, but considering several improvements in the process it has reached up to 10g/L. Presently there are two main lines of investigation: the use of LEDS during the dark hours or even during all day and the use of GMOs (Genetic Modified Organisms) in order to increase the production.

However, it should be noteiced that the technology used for the production of microalgae still has some points that need to be improved, but for sure in the next years microalgae production systems, will be a reality.

UAB Universitat Autònoma de Barcelona

References:

- Acién, F., Fernández, J., Magán, J. and Molina, E. (2012). Production cost of a real microalgae production plant and strategies to reduce it. *Biotechnology Advances*, 30(6), pp.1344-1353.
- Molina, E., Fernández, J., Acién, F. and Chisti, Y. (2001). Tubular photobioreactor design for algal cultures. *Journal of Biotechnology*, 92(2), pp.113-131.
- Pawlowski, A., Fernández, I., Guzmán, J., Berenguel, M., Acién, F. and Normey-Rico, J. (2014). Event-based predictive control of pH in tubular photobioreactors. *Computers & Chemical Engineering*, 65, pp.28-39.