Bioprocess Design of an Astaxanthin Production Plant - II
Carlos Juliá Figueras, Marc Sánchez Farrando and Carme Pons Royo

Introduction
The aim of this project is the simulation of an industrial plant for the production of astaxanthin (3S,3’s), which is a carotenoid from the family of xanthophylls. Firstly, the project design was developed with the idea of being economically feasible and taking environmental feasibility into account, as much as it was possible. When the first project was completed some solvents used in the downstream of the process were identified and classified as toxic or harmful for workers and environment. Then, an alternative generation of plausible designs was accomplished and an innovative downstream process has consequently been implemented. In this poster, the emphasis will be placed on the improvements achieved in this new industrial plant.

New Block Flow Process Diagram

Improvements and results

**Improvements**
- Replacement of the dodecane extraction for one based on olive oil.
- Removal of the methanol solvent in excess.
- Replacement of the dichloromethane chromatography for a differential extraction.
- Replacement of the settler tank after chromatography for a distillation.
- Changes in crystallization conditions.
- Addition of a tray dryer.
- Formulation of the product.

**Results**
- Main environmentally controversial effluents removed.
- Slight decrease in the total amount of astaxanthin produced.
- Higher product purity: >98.8%.

New Process Flow Diagram

Within this diagram, the complexity of this project can be widely observed. It has been developed by SuperPro Designer® software (Intelligen, Inc.). The production process is divided into five coloured sections: upstream, bioreaction, downstream, polishing and formulation and packaging. The plant works on discontinuous mode (photobioreactor in fed-batch mode). Willing to accomplish an annual production of 200 kg, there was the necessity of introducing three indoor airlift LED-based photobioreactors. As seen in the left image, the light phase of the olive oil extraction is recirculated with its respective purge. The bottleneck of the process is the photobioreactor, lasting for 66.68 hours (0.067 g/l of biomass). The product is obtained with a purity of, at least, 98.8%.

Astaxanthin Production Plant

**Photobioreactor**

- Green stage
  - Haematococcus pluvialis cells are grown in a mixotrophic medium (acetate) at 30°C. Its maximal growth rate is 0.028 h⁻¹.
- Red stage
  - The cells obtained in the first stage are then exposed to environmental stresses (nitrogen deprivation and light intensity increase) to trigger the production of the secondary metabolite astaxanthin.

**Downstream**

- Mixer-settler
  - 48 h in total.
  - 36 h extraction.
  - 93.71% recovery yield.
  - Light phase: olive oil.
- Differential extractor
  - 6.75 h in total.
  - 90% recovery yield.
  - Two-solvent phase.
  - Light phase: ethyl acetate – hexane.
  - Heavy phase: ethanol – water.
- Crystallizer
  - 7.08 h in total.
  - Solvent pre-evaporation at 110°C.
  - 99% crystallization yield.

Gantt chart

An example of time optimization is shown in the upstream section. P1 and P2 (inoculum preparation and photobioreactor) are temporarily connected. Additionally, SIP and CIP are correctly implemented before and after each process.

Conclusions

By gathering information through research articles and patents, this project has been redesigned with success. Under no circumstances, did we have in mind reducing the total annual amount of astaxanthin produced (198.32 kg/yr) compared with the original project. However, reducing the environmentally unfriendly effluents had its consequences. Further details on economic and environmental impact assessments are exposed in the third part of this project.