Bioprocess Design of an Astaxanthin Production Plant - III

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Introduction

The main objective is to create a manufactured product that uses a sustainable process that minimizes negative environmental impacts, conserve energy and natural resources, is safe for employees, community and consumers sustainable manufacturing and is economically sound; to produce natural astaxanthin with 98.8% of purity. To consider a project sustainable is required an evaluation of three different aspects, the economic to determinate the viability, the environmental that points out the changes made in the project to become a sustainable process and the social that describes the labor and management organization, as well as alternatives to innovate the process and the control implemented to assess specifications of astaxanthin.

Economic Analysis

It is required an economic analysis to determine the viability of the project and the costly points

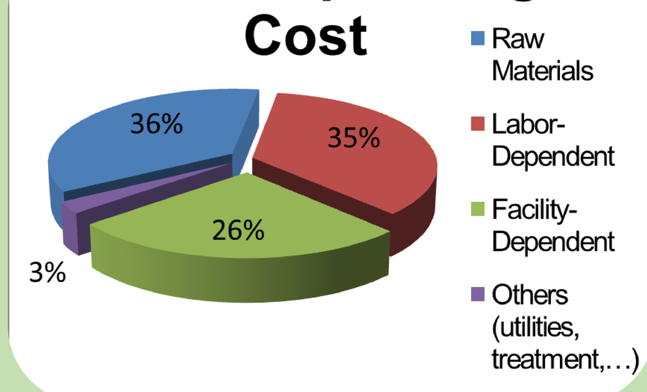
Executive Summary	
Total Capital Investment	26,004,000 $
Operating Cost	16,837,000$/yr
Main Revenue	31,644,000 $/yr
Other Revenues	230,010 $/yr
Total Revenues	31,874,000 $/yr
Unit Production Cost	4.26 $/MP Entity
Unit Production Revenue	8.06 $/MP Entity
Return On Investment	43.35 %
Payback Time after start-up	2.31 years
NPV (at 7.0% Interest)	51,399,000 $

- Viable project with high benefits in the current market
- Production objective achieved (200kg/yr)

Revenues	
Dried Biomass	181,000 $/yr
CO2	1,000 $/yr
Astaxanthin	31,143,000 $/yr

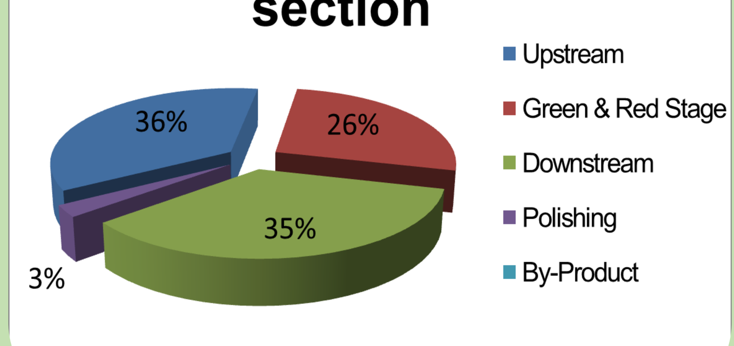
Extra Benefits :
- CO_2 from adjacent industries
- Used algae

Annual Operating Cost

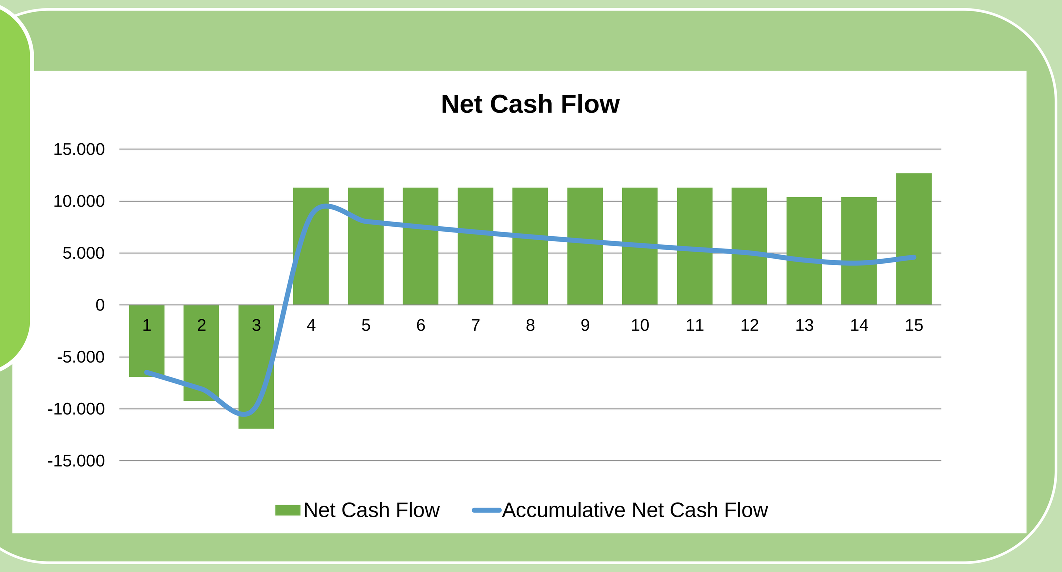


The highest cost : **raw materials,** but **labor** supposes a high cost

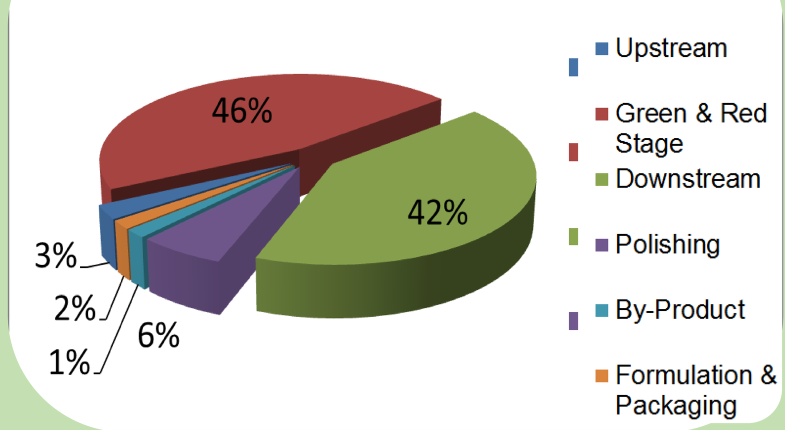
Material cost per section



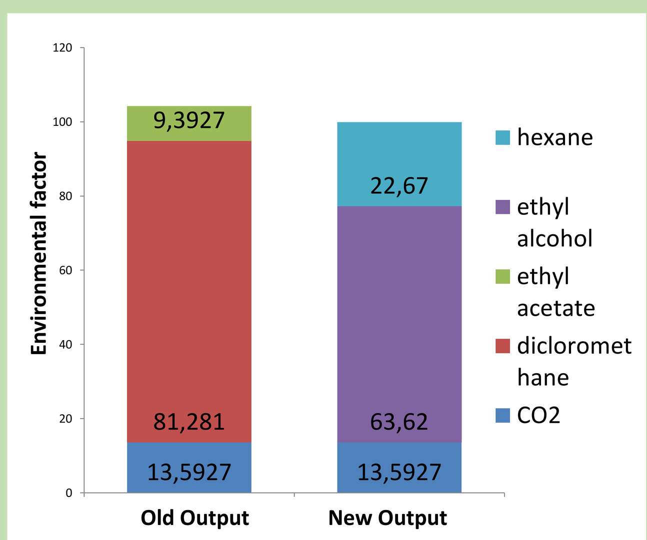
Capacity to produce benefits during the useful life of the plant



Labor cost per section



Environmental Analysis



- Dichloromethane and dodecane streams were removed from the initial process.
- Pollutant streams were reduced.
- EI and GEI values lower in the new process, even, having more A-components.

Environmentally-friendly

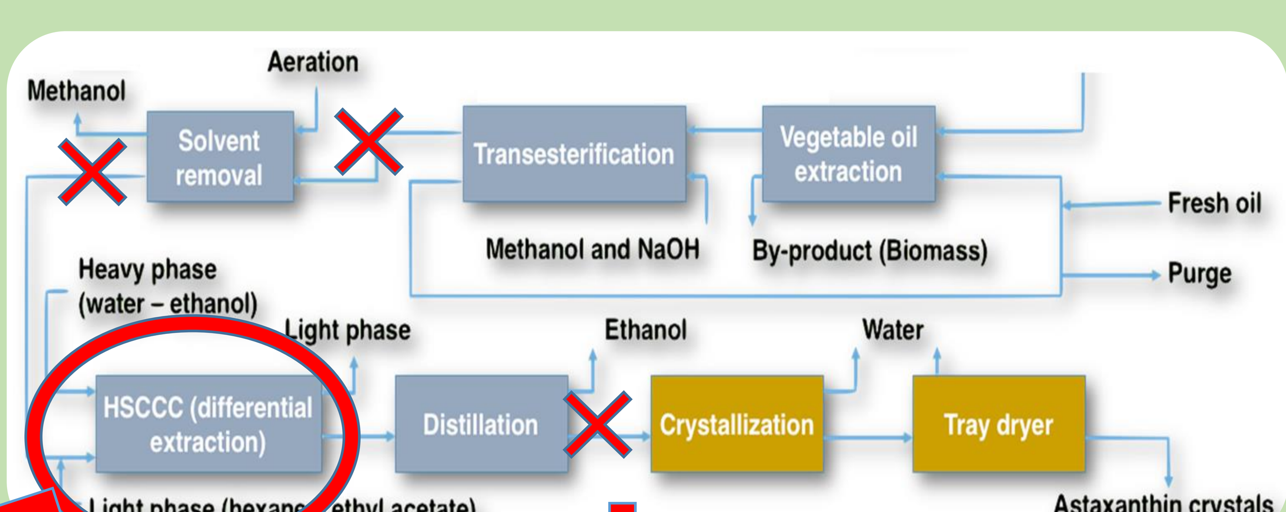
Assesment metric	Old process	New process
Mass Index MI (kg/kg P)	160,045.53	207,047.69
Number of A-components	1	2
EI inputs (index points/kg P)	18,201.54	17,545.87
EI outputs (index points/kg P)	7,222.47	5,471.86
General Effect Index (0-1)	0.16	0.11

Social Analysis

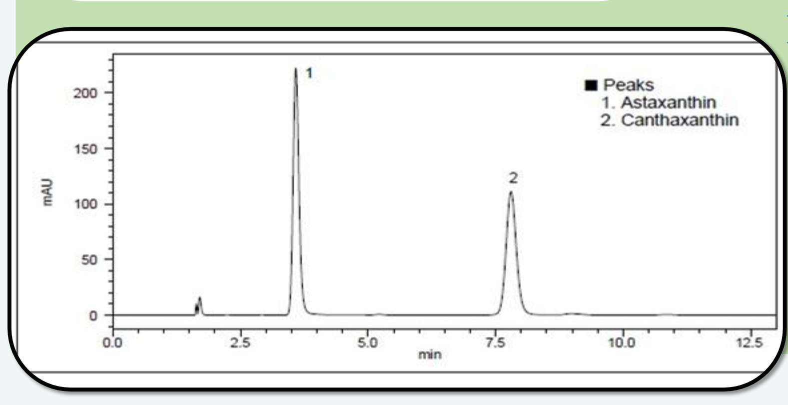
- **Natural product used as nutraceutical**
- **Potential technological innovation**
- **Health insurances for workers and their families and quality of health and security measures**
- **Quality work with time arrangements that make the working and familiar life compatibles**
- **Training programs for students and employees**
- **Job creation**

Control

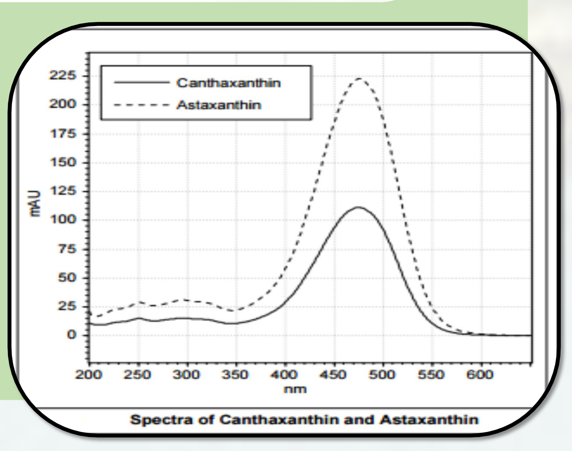
To guarantee the percentage of purity of Astaxanthin, it is required an accurate control. There are two methods to quantify Astaxanthin



The HSCCC is the critical point. Analysis by HPLC provides the most accurate quantification of astaxanthin present in the sample.



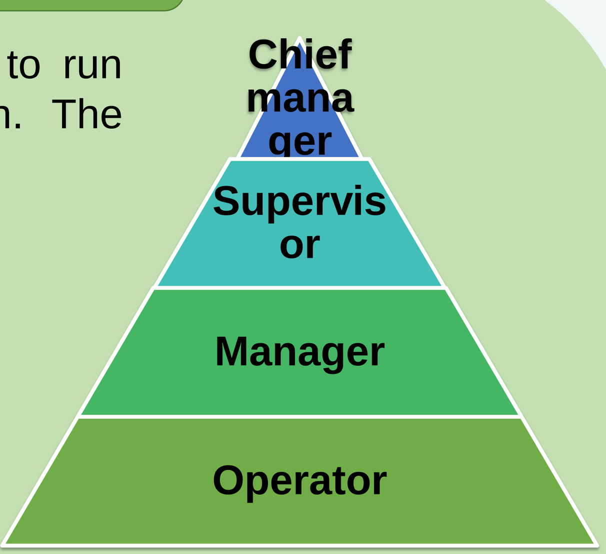
Spectrophotometric analysis, the light absorbance of the extract solvent containing the astaxanthin is measured at a wavelength (478 nm)

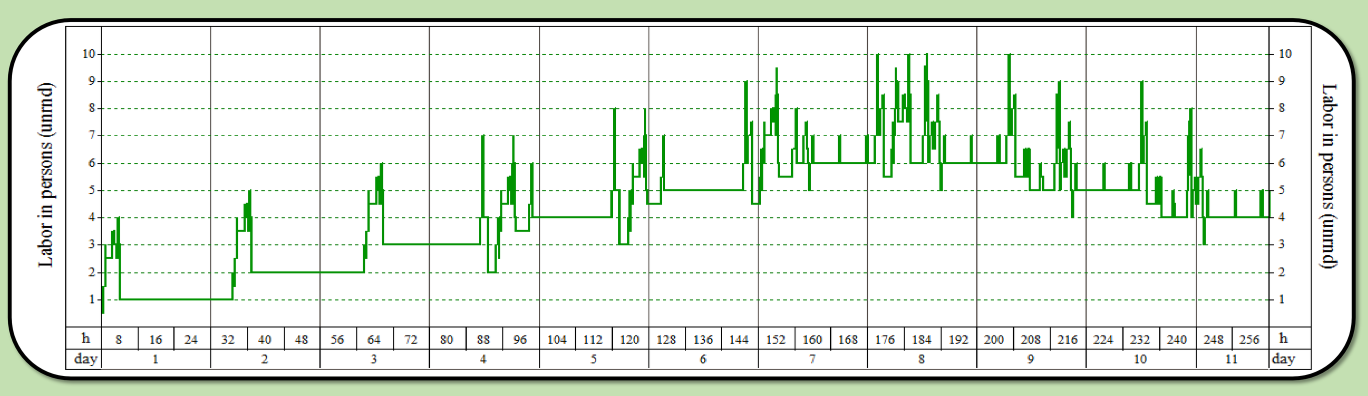


Labor diagram

It is required qualified staff in order to run efficiently the astaxanthin production. The staff is composed by:

Reactor Operator
QC analyst
Filter operator
Dryer Operator
Others





Operators: Due to the quantity of batches produced at the same time, it is required between 5-10 operators to work efficiently. The plant is working 24h/day, 3 work-shifts of 8h

Alternatives

Biosynthesis of Astaxanthin in non-carotenogenic microorganism like E.Coli

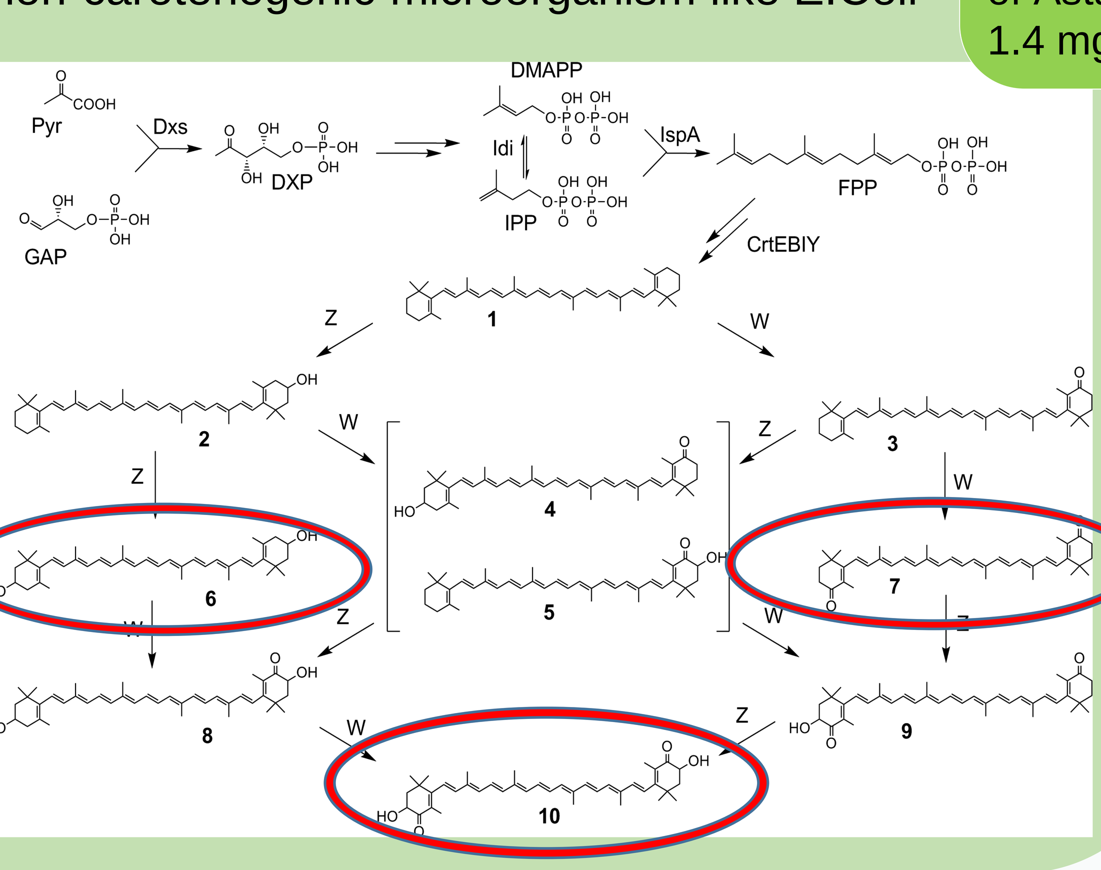
Concentration of Astaxanthin: 1.4 mg/g cdw

Plasmid-free E. Coli strain with *crtE,B,I,Y,Z,W* as individual expression.

Encoding for:
- **β-carotene ketolase (W)**
- **β-carotene hydroxylase (Z)**

Recombination using λ-Red technique.

Limitation step:
Zeaxanthin to Astaxanthin.
(high concentration obtained)



Conclusions

Economically viable project in an emerging market

Sustainable process

- Production objective is achieved
- Product with scope in the future
- Good opportunity for investors

Environmentally-friendly process
Social acceptance of the plant
A control system is required to control the critical parameters for not altering the quality of the final product.
H.pluvialis needs high levels of irradiance and the cell culture and its growth are slow and inefficient. It could be solved using other microorganism, but the system needs to be improved.

UAB

Chromatogram of astaxanthin– *Picture edited and extracted from: : Shimadzu Apllication News, High performance liquid cromatography. Shimadzu Corporation, International Marketing Division. 3.Kanda-Noschikicho 1-chome, Chiyoda-ku, Tokyo, 101-8448, Japan.*
Spectra of astaxanthin– *Picture edited and extracted from: Shimadzu Apllication News, High performance liquid cromatography. Shimadzu Corporation, International Marketing Division. 3.Kanda-Noschikicho 1-chome, Chiyoda-ku, Tokyo, 101-8448, Japan.*
Scheme of the putative astaxanthin biosynthesis pathway in recombinant E. coli – *Figure edited and exctracted from: Lemuth et al.: Engineering of a plasmid-free Escherichia coli strain for improved in vivo biosynthesis of astaxanthin.Microbial Cell Factories 2011 10:29.*
Symbol of sustainable process -*Picture edited and extracted from: US Department of Commerce (2011), Sustainable Manufacturing Initiative website. http://trade.gov/competitiveness/sustainablemanufacturing/index.asp, accessed 27 April 2011.*
Picture in the background *Picture edited and extracted from: Proyecto Agua, flickr.com/microagua, Llicència Creative Commons*
All data used for economic and environmental analysis, were obtained from SuperPro Designer