Universitat Autònoma de Barcelona

Part 4: Sustainability analysis

Doménech D., Nadal G., Sellés S. and **Santo Domingo M.**

INTRODUCTION: The benefits of resveratrol and its growing demand make interesting the development of a biotechnological process to produce this substance. After searching for the best catalyst, and reject some less functional alternatives, the final process is shown in figure 1 as a flow diagram. The design has been carried out with the help of the software SuperPro Designer v8.5.
To end up with the design of the process, it is necessary to analyze it in three ways: economically, environmentally and socially. Thereby, it can be determined the sustainability of the bioprocess, and some changes can be defined to improve it.

ECONOMIC ANALYSIS

Investment

Table 1. Summary of the initial investment for the process plant and the start-up.

Direct Fixed Capital	19 333 938 $
Equipment Purchase Cost	3 188 750 $
Working Capital	288 425 $
Start-up	966 697 $
TOTAL CAPITAL INVESTMENT	20 589 060 $

Cash Flow Analysis

Annual incomes: 50 M pills. Price = 0.3 $/pill.

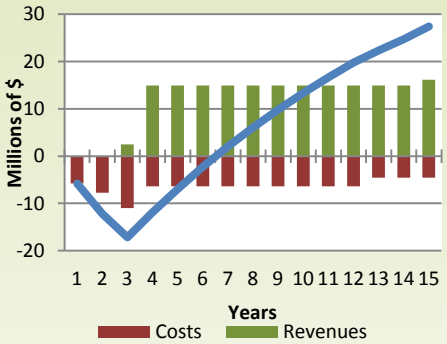

Figure 4. Cash Flow Diagram of the plant in 15 years.

Table 2. Profitability indices of the plant.

Payback Time (years)	2.97
IRR	25.86%
NPV (7%)	29 356 800 $

Annual Operating Cost

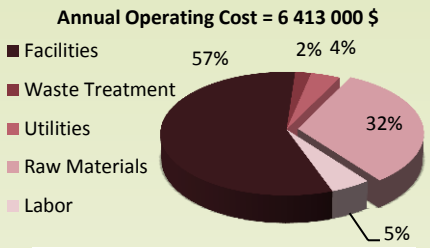

Figure 2. Distribution of annual operating costs.

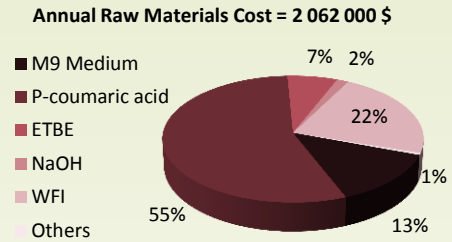

Figure 3. Distribution of annual raw materials costs.

As seen in figures 2 and 3, the process depends strongly on the p-coumaric acid and its price. A sensitivity analysis has shown that the process has benefits till a price of p-coumaric acid of **550 $/kg.**

ENVIRONMENTAL ANALYSIS

The carried out analysis is an approximation of MIPS, developed by the Wuppertal Institute. This analysis consists on studying the environmental impact of the inputs and outputs to see the relative impact.

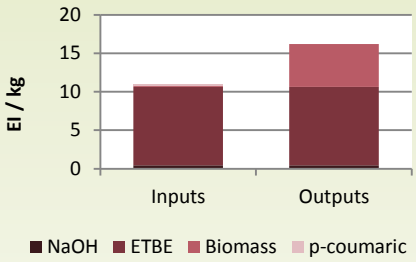

Figure 5. Environmental indices of inputs and outputs of the designed process. Harmless substances not shown.

SOCIAL ANALYSIS

Resveratrol:
-Natural product
-Improvement of life quality

Production plant:
-Job security measures
-Safe and comfortable facilities
-High salaries = 9 $/hr
-Health insurance for workers and their families

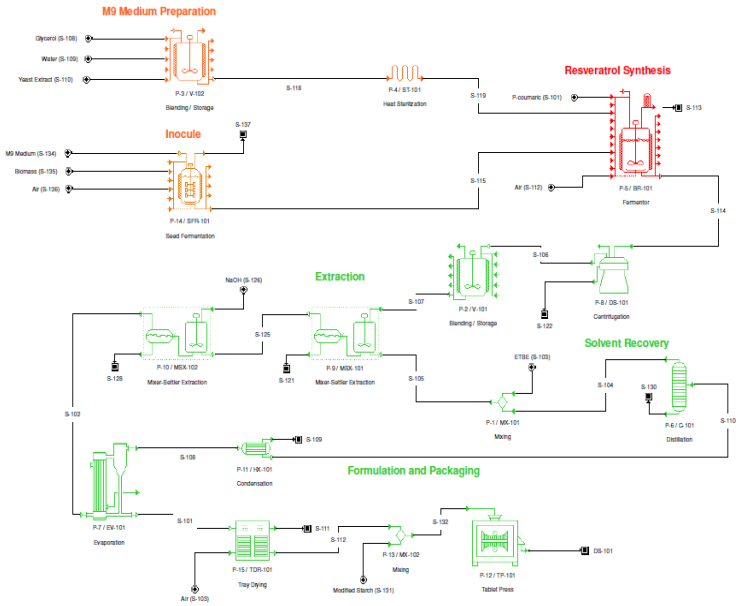

Figure 1. Flow diagram of the developed process to produce resveratrol. Upstream section is shown in orange, reaction section in red, and downstream section in green. All data of equipment and streams are available in the SuperPro Designer file.

IMPROVEMENTS

-Incorporation of p-coumaric acid synthesis pathway in *Escherichia coli*

Through the enzyme tyrosine ammonia lyase (TAL), p-coumaric acid (or PHCA) can be synthesized from tyrosine [1], as seen in figure 6.

The chosen alternative is inserting the gene in the pUC18 plasmid under a constitutive promoter. Thereby, it is only a plasmid in the strain (no compatibility problems), and it is no necessary to perform two consecutive batches, resveratrol is synthesized since the beginning from the main substrate.

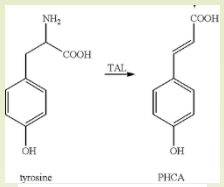

Figure 6. Reaction catalyzed by TAL.

It would be interesting also deregulating the tyrosine synthesis pathway, in order to accumulate this amino acid so the reaction would displace to resveratrol.

-Search for a less pollutant extractor

-Optimization of the process

In case the reaction could be done in one step, it would be interesting the study of a continuous process, to end up with process dead times.

REFERENCES

1-Ferrer, J.-L., Austin, M. B., Stewart, C. & Noel, J. P. Structure and function of enzymes involved in the biosynthesis of phenylpropanoids.Plant *Physiol. Biochem.* **46,** 356–70 (2008).