BIOPROCESS DESIGN FOR GREEN ETHYL LACTATE IV: ENZYMATIC ESTERIFICATION AND OVERALL PLANT ASSESSMENT

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OBJECTIVE

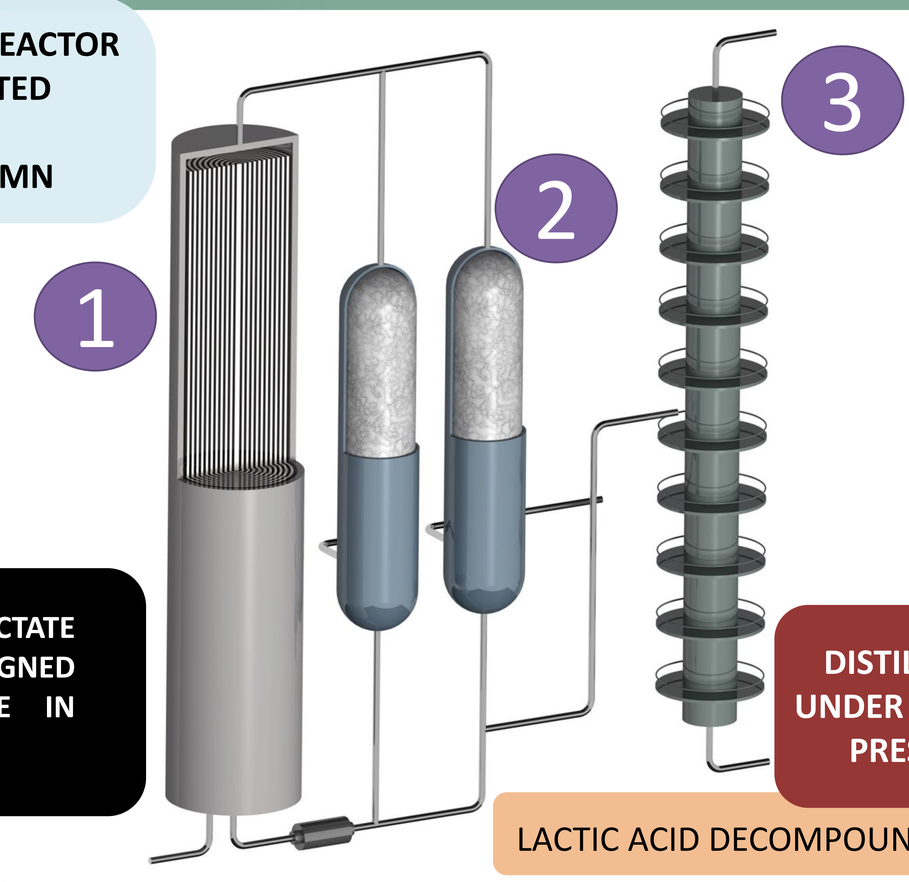
In this specific project, the esterification part of the plant has been improved and an economic analysis of the whole plant with all changes done so far has been studied in order to determine the modification effect.

REACTIVE DISTILLATION

HIGH MOLAR RELATION → **ENZYMATIC ESTERIFICATION**

LOW YIELD

1- FIBROUS BED BIOREACTOR
2- GRANULAR ACTIVATED CARBON COLUMN
3-DESTILLATION COLUMN

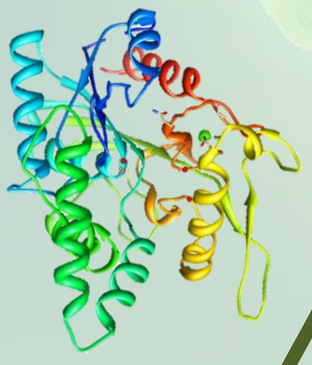


DISTILLATION UNDER REDUCED PRESSURE

LACTIC ACID DECOMPOUNDS TºC >110ºC

A SYSTEM FOR ETHYL LACTATE SYNTHESIS HAS BEEN DESIGNED BY USING AN ENZYME IN ORGANIC MEDIA

Sub-class of enzymes within the esterase family whose natural function is to hydrolyse long chain triacylglycerol.



INDUSTRIAL APPLICATION

INDUSTRIAL IMPROVEMENTS

-Increase thermo-stability
-Increase reaction rate
-Increase stability over time
-Increase the adaptability to different feedstock

OPERATION IN ORGANIC MEDIA

ADVANTAGES

- New reactions can be carried out
- Unwanted reactions because of water are reduced
- Equilibrium in hydrolytic reactions can be shifted towards synthesis

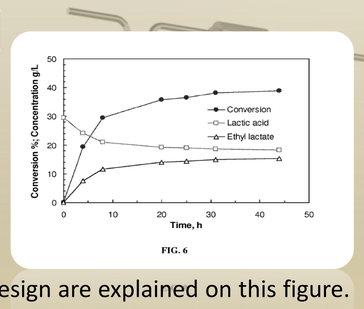
SOLVENT CHOICE

HIDROPHILIC SOLVENT Strip the enzyme from the essential water
HIDROPHOBIC SOLVENT Molecular toxicity and different phases

ENZYMATIC ESTERIFICATION

DESIGN BASIS

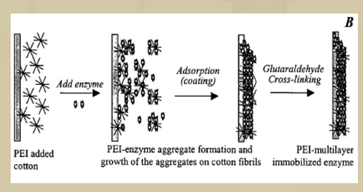
YIELD 78%
CONVERSION 39%



Results of the initial design are explained on this figure. However, a conversion and a yield over 90% can be achieved if a system to remove water continuously is designed.

ENZYME IMMOBILIZATION

Enzyme will be immobilized in a packed-bed bioreactor by using cotton that surrounds a metallic structure and Polyethyleimine (PEI).



IMMOBILIZATION PROCEDURE

FINAL SYSTEM DESIGN

To allow a continuous water extraction, it has been considered that a differential part of the fluid will remain in the system by doing 10 turns around the system before it continuous the process.

1. WATER CONTINUOUSLY REMOVED: Conversion 90%

2. UNIFORM REACTION SYSTEM (Recirculation)

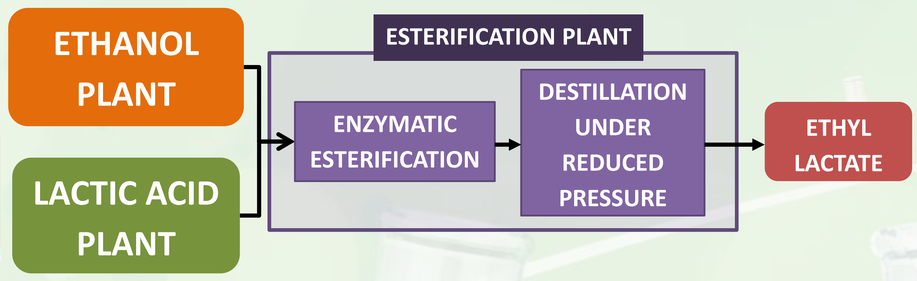
Plug Flow Reactor → Stirred Tank

EASIER TO CONTROL

THIS SYSTEM WILL BE CHEAPER AND SAFER

PLANT DIAGRAM

After all the improvements done, the plant has now a more linear evolution. Using two different feedstock enabled us to optimize each plant separately. This and the efficiency esterification improvement presents us a more operationally simple plant that can be economically attractive



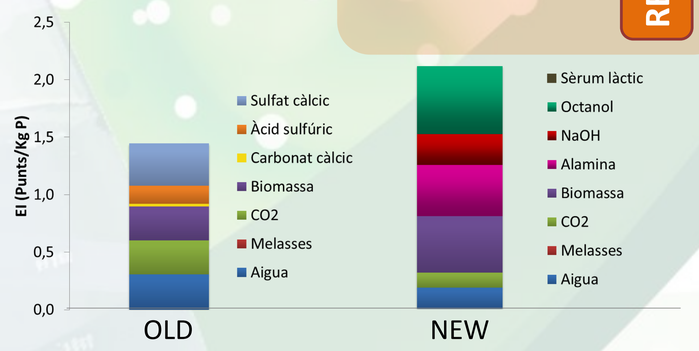
ENVIRONMENTAL ANALYSIS

THE TOTAL ENVIRONMENTAL INDEX OF THE PLANT IS NEARLY THE SAME AND IS **FAR AWAY FROM THE ONES OBTAINED BY THE CHEMICAL INDUSTRY (>10).**

OLD
~~CALCIUM CARBONATE (X)~~
~~GYPSUM (B)~~

NEW
ALAMINE (A)
OCTANOL (A)
+ RECYCLING!

OBJECTIVE ACHIEVED

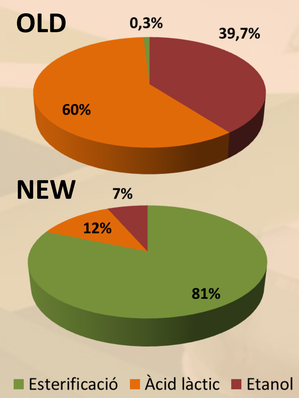


Products with high environmental index (calcic sulphate and calcic carbonate) have been removed in the lactic acid plant. However, new more dangerous products (Alamine and Octanol) have been introduced. The clue to success is the recirculation of these organic solvents, which allow us to have almost the same total environmental index.

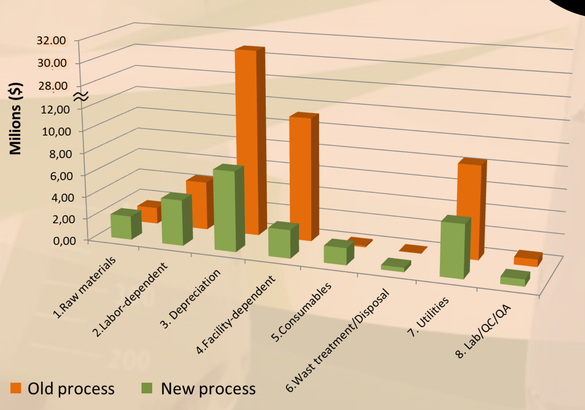
ECONOMIC ANALYSIS

	OLD	NEW	
Income	64	**44**	M$/year
Net profit (30% tax)	4	**14**	M$/year
ROI	0,64	**9,67**	%
Pay Back Return	18,16	**6,88**	Years
VAN	-254	**50**	M$
Unitary Cost	5,84	**2,34**	€/Kg

OBJECTIVE ACHIEVED



DIRECT FIX CAPITAL



ANNUAL PLANT COST

- **Direct fix cost and initial inversion reduction**. Now esterification has the main role when it comes to the DFC cost. However, despite the increase, the process efficiency compensates the increment.
- **Increase in the raw material and consumable cost**. The plant is now more variable cost dependent.

CONCLUSION

After all the improvements done in the whole plant, a project that initially was not economically attractive is now a good opportunity for investors while at the same time the plant design is environmentally friendly.

REFERENCES

- Yang, S-T.(2013), Patent US 8.357.519. United States
- Yang, S-T., Albayrak, N. (2007). Patent US 7.166.451. United States
- Tufvesson, P., "Lipase Catalysed Synthesis of Speciality Chemicals. Technical, economical and environmental aspects", Department of Biotechnology, Lund University, December 2008.