A Novel Biorefinery Approach

Sustainable Production of Biofuels, Pharmaceuticals and Functional Food

PART I. OVERALL VIEW OF AN INTEGRATED PROCESS

Corbera F., **Jiménez M.** & López A.

Biorefinery's Fundamentals

Novel features

Multiproduct facility with a renewable and sustainable feedstock

Production of **bulk chemicals**, **biofuels**, **food** and **specialties**

Market competitive products

Hypothesis statements

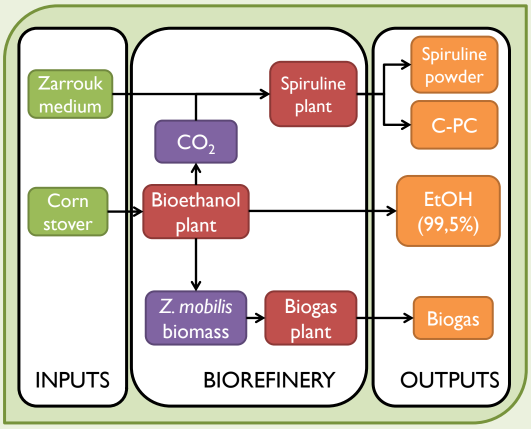
- The by-products produced by a core process can be effectively used as feedstock for secondary processes.
- The integration of independent processes can significantly improve the economic perspective of a non-profitable process.

Objectives

Design an green ethanol production process fed by a lignocellulosic feedstock	Transform the biomass produced into energy by performing an anaerobic digestion
Use the CO_2 towards an algae plant to produce functional food and pharmaceuticals	Improve ethanol's plant economic feasibility with the products of the coupled processes

Products	Production
Ethanol	180,000 MT
Spirulina	1000 MT
Biogas	20,000 m³
Phycocyanine	100 kg

Overall Scheme



Processes

1) Bioethanol plant: fed with corn stover, which is treated with a **physical and biological pre-treatment** to obtain the sugars within its structure. These sugars will feed a ***Zymomonas mobilis*** culture that will produce the ethanol. Using distillation columns and molecular sieves ethanol will be extensively purified.

$$\text{Corn stover} \xrightarrow[\text{mobilis}]{\text{Zymomonas}} \text{Ethanol (99,95 \%)}$$

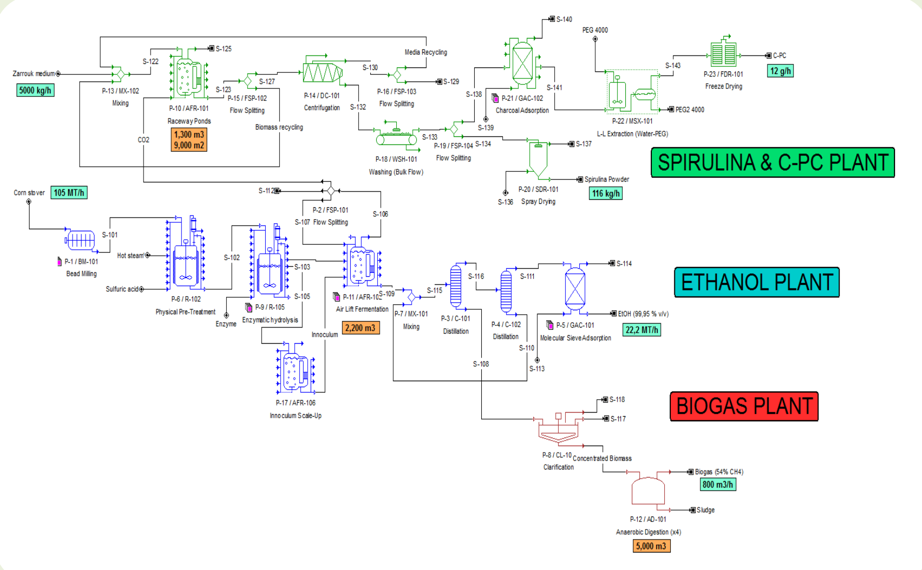
2) Spirulina/C-PC plant: it is fed on Zarrouk medium and CO_2 produced in the ethanol plant. It produces Spirulina in **raceway ponds** and C-Phycocyanine (C-PC) is obtained by homogenizing and purifying a fraction of the algae produced.

$$CO_2 \xrightarrow[\text{platensis}]{\text{Arthrospira}} \text{Spirulina + C-PC}$$

3) Biogas plant: it uses the biomass coming from the bottoms of the distillation columns. Upon this biomass an anaerobic digestion will be performed so as to transform this **useless biomass** into a **valuable energetic resource**.

$$\text{Biomass} \xrightarrow[\text{consortia}]{\text{Anaerobic}} \text{Methane (biogas)}$$

Flow Process Dyagram

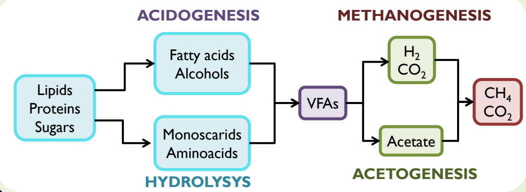


Biocatalysts

Zymomonas mobilis *Arthrospira platensis*

Anaerobic consortia

Hydrolytic/Acidogenic	Acetogenic	Methanogenic
Main genus	**Main genus**	**Main species**
Streptococcus, Pseudomonas, Bacillus, Clostridium, Micrococcus or Flavobacterium	*Syntrophomonas and Syntrobacter*	*Methanobacterium suboxydans and M. propionicum*
Substrates	**Substrates**	**Substrates**
Complex organic components	Short volatile acids (VFAs)	H_2, CO_2, acetic acid
Products	**Products**	**Products**
Volatile fatty acids (VFAs): formic, acetic, propionic, butyric and pentanoic acid.	Acetates and H_2	CH_4 and CO_2

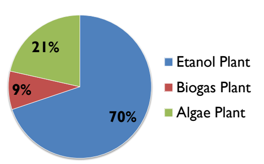


Economic analysis

Economic summary			
Total Capital Investment ($)	139,000,000		
Annual Operating Cost ($)	235,600,000		
Unit production Cost ($/kg)	Spirulina	EtOH	C-PC
	52.14	0.58	544,000
Unit Product Revenue ($/kg)	Spirulina	EtOH	C-PC
	115	0.7	800,000
Gross Margin (%)	24.3		
Return on Investment (%)	32.6		
Payback Time (years)	3.4		
NPV (4 % interest) ($)	41,300,000		

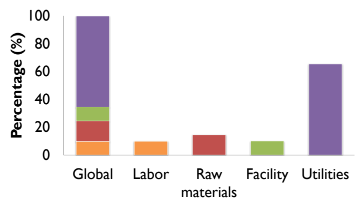
Operational cost distribution

The core process, the ethanol plant, represents the main annual cost for the biorefinery, due to the high necessity of utilities it requires.



Annual cost composition

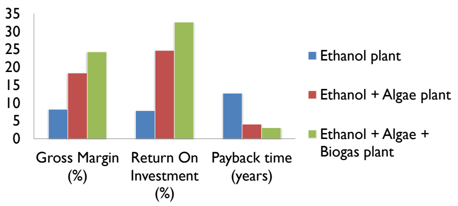
Utilities, specifically standard power, implies the major annual cost for the biorefinery. Nevertheless, the biogas used and cremated in the CPH engines mitigates this percentage, saving part of the utilities cost.



Results – Comparison between processes

Three scenarios where studied: an single ethanol plant, a coupled algae an ethanol plant and a biorefinery of ethanol, algae and biogas. As a result, the following statements where formulated:

- The economic feasibility of each plant improves as more processes are integrated.
- The more integrated are the processes the less cost is reported annually.
- The algae plant has the greatest impact upon ethanol's price.
- The biogas plant saves a considerable amount of energy, enough for significantly improve the economy's plant



Conclusions

- The economic feasibility of the plant is subjected to the number of the integrated processes.
- A higher number of coupled processes implies an increase of the initial investment.
- Utilities and transport prices are the bottleneck of this project.
- The algae and the biogas processes are significantly sensible towards the environment and substrate conditions, respectively, which may cause them to fluctuate.

References

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