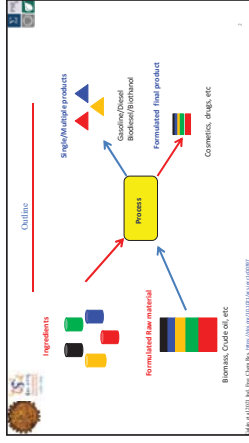


VALORIZACION DE RESIDUOS BIODEGRADABLES Y ECONOMIA CIRCULAR

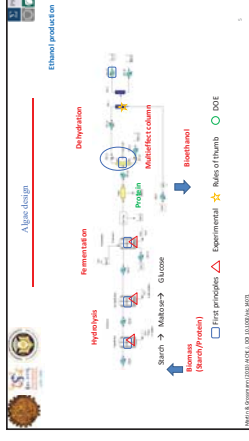
## Ingeniería de producto en biorrefinerías integradas.

Mariño Marín  
Departamento de Biotecnología  
Universidad de Chile  
28 October 2021

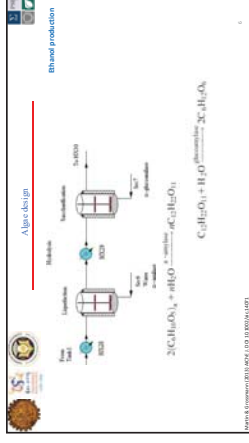
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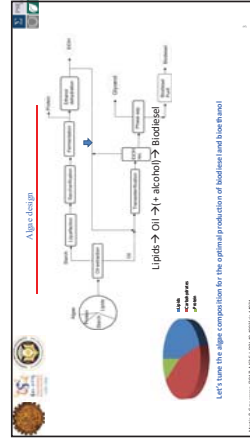
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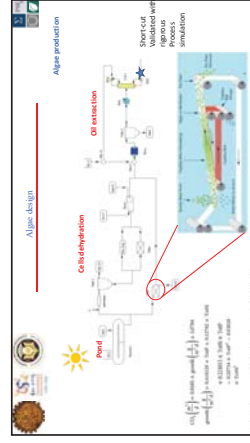
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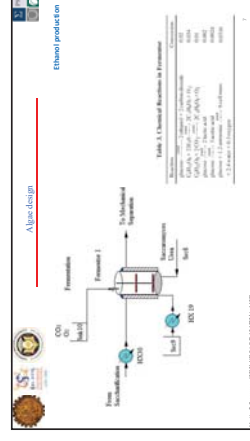
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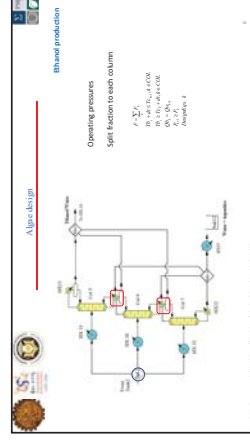
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8

Algae design

Biorefinery production

2. Operating conditions in the reactor - 9 Literature review

Simulation optimization and fast mapping

First principles  $\Delta$  Experimental  $\star$  Rules of thumb  $\circ$  DOE

Alvin, M. A. (2019). Algal Biorefineries: A Review of the Current Status and Future Prospects. *Algal Biorefineries*, 1-15. doi:10.1007/978-94-007-5444-4\_1

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Algae design

Biorefinery production

Table 3. Range of literature of the variables

Variable	Range
Temperature (°C)	15-30
pH	7-10
Light intensity (µmol photons m <sup>-2</sup> s <sup>-1</sup> )	100-1000
CO <sub>2</sub> concentration (ppm)	100-1000
Salinity (g/L)	0-35
Medium composition	Various

Alvin, M. A. (2019). Algal Biorefineries: A Review of the Current Status and Future Prospects. *Algal Biorefineries*, 1-15. doi:10.1007/978-94-007-5444-4\_1

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Algae design

Biorefinery production

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Algae design

Biorefinery production

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Waste to power and chemicals

The Biogas is not only a good fuel, 60-70% CH<sub>4</sub>, but a perfect source of C for synthesis

Alvin, M. A. (2019). Algal Biorefineries: A Review of the Current Status and Future Prospects. *Algal Biorefineries*, 1-15. doi:10.1007/978-94-007-5444-4\_1

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Waste to power and chemicals

As a Fuel  
CH<sub>4</sub>(CO) → 70% 30%

To Syngas  
CH<sub>4</sub>(CO) → H<sub>2</sub> (CO)  
Methanol  
Methanol  
DMF

Waste to Biogas  
Sludge  
Urban Food  
Urban Waste  
Cattle M.  
Pig M.  
Pig S.

Alvin, M. A. (2019). Algal Biorefineries: A Review of the Current Status and Future Prospects. *Algal Biorefineries*, 1-15. doi:10.1007/978-94-007-5444-4\_1

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Waste to power and chemicals

FOR FUEL PRODUCTION  
M: H: C composition  
FOR CHEMICALS PRODUCTION  
TWO STEP ANALYSIS

1. Determine the Biogas composition for the proper H<sub>2</sub> to CO ratio
2. Determine the waste to be used to obtain the biogas composition

Alvin, M. A. (2019). Algal Biorefineries: A Review of the Current Status and Future Prospects. *Algal Biorefineries*, 1-15. doi:10.1007/978-94-007-5444-4\_1

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Waste to power and chemicals

AD  
Gas Clean up  
Gas Tubing  
Steam Turbine

Alvin, M. A. (2019). Algal Biorefineries: A Review of the Current Status and Future Prospects. *Algal Biorefineries*, 1-15. doi:10.1007/978-94-007-5444-4\_1

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Waste to power and chemicals

We maximize CH<sub>4</sub> production → determine the mixture of waste

Endo: 0.077, Exo: 0.06

Waste	CH <sub>4</sub> (kg)	CO <sub>2</sub> (kg)	CH <sub>4</sub> (kg)	CO <sub>2</sub> (kg)
Food	1.0	0.5	0.5	0.25
Manure	1.0	0.5	0.5	0.25
Energy	1.0	0.5	0.5	0.25
Other	1.0	0.5	0.5	0.25

The credit from the digester is 0.111!

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Waste to power and chemicals

What is the biogas composition to produce chemicals?

We react to CO ratio and optimize the biogas composition to get to it

Dry/Steam reforming

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Waste to power and chemicals

What is the biogas composition to produce chemicals?

We fix the H<sub>2</sub> to CO ratio and optimize the biogas composition to get to it

Waste	CH <sub>4</sub> (kg)	CO <sub>2</sub> (kg)	CH <sub>4</sub> (kg)	CO <sub>2</sub> (kg)
Food	1.0	0.5	0.5	0.25
Manure	1.0	0.5	0.5	0.25
Energy	1.0	0.5	0.5	0.25
Other	1.0	0.5	0.5	0.25

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Waste based bioline!

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Waste to power and chemicals

Anaerobic digestion: previous work

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Waste to power and chemicals

Syngas Preparation: Purification and Composition adjustment

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Waste based bioline!

Biogas digester production

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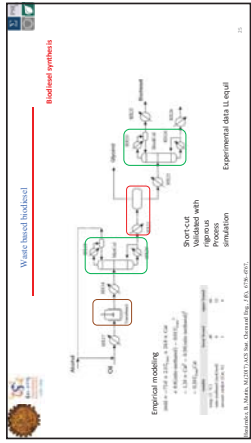
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Waste based bioline!

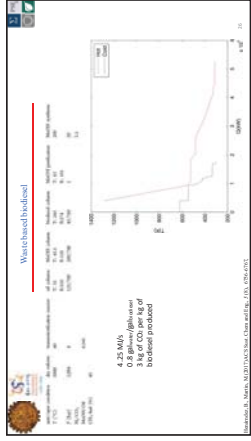
Methanol synthesis

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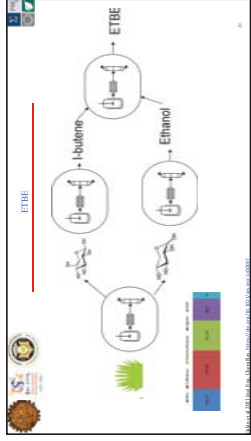
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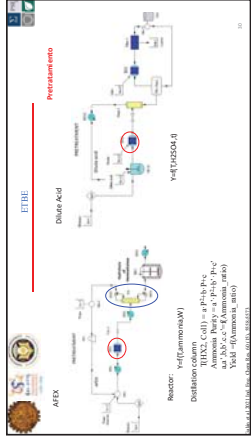
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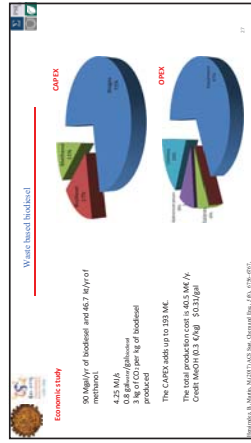
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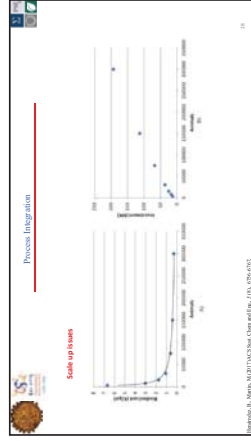
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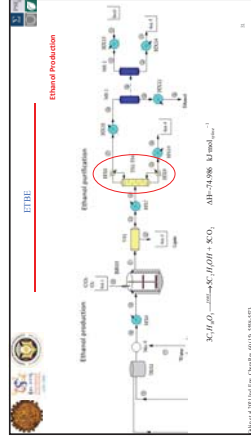
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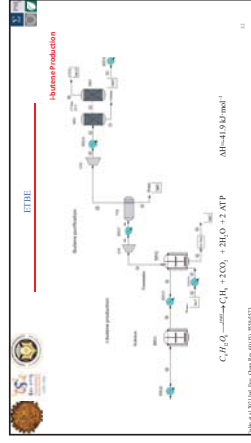
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**ETBE**

**ETBE Synthesis**

$$C_2H_5 + C_2H_5OH = (C_2H_5)_2OC_2H_5$$

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**ETBE**

**Economics**

For a facility that processes 500 ktpy of biomass produces 90 ktpy of ETBE, the investment adds up to 180 MC, with a production cost of 0.53\$/kg

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**Xylool & Sorbitol simultaneous production**

**Sugar fermentation**

$$10C_6H_{12}O_6 + 32C_6H_{12}O_5 + 78H_2O \rightarrow 10C_6H_{12}O_4 + 32C_6H_{14}O_6 + 180CO_2$$

37

**Xylool & Sorbitol simultaneous production**

**Sugar fermentation**

$$10C_6H_{12}O_6 + 32C_6H_{12}O_5 + 78H_2O \rightarrow 10C_6H_{12}O_4 + 32C_6H_{14}O_6 + 180CO_2$$

Specific concentration range of fractions:  
100-300 g/L  
X (fructose) above 90%

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**ETBE**

**Product design**

A biomass with 40% in cellulose and 23.0% hemicellulose is better for this facility.  
A facility that use this biomass requires 165846 investment and a production cost of 0.546\$/kg. In the production of 1234 ktpy, it reaches a cost of 0.53\$ with respect to the use of switchgrass is achieved

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**Xylool & Sorbitol simultaneous production**

**Alcohols Production**

**PRE-TREATMENT**  
 - HPLC  
 - Sulfuric Acid  
 - Ethanol  
 - Water

**FERMENTATION**  
 - Fermenter  
 - Distillation

**PURIFICATION**  
 - Evaporation  
 - Extraction  
 - Distillation

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**Xylool & Sorbitol simultaneous production**

**Sugar analysis**

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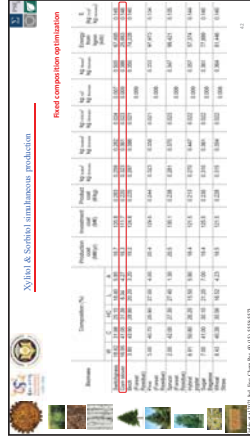
**Xylool & Sorbitol simultaneous production**

**Purification**

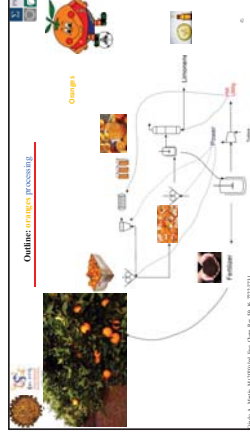
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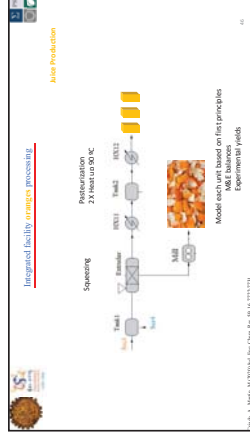
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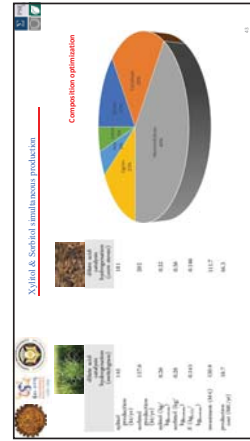
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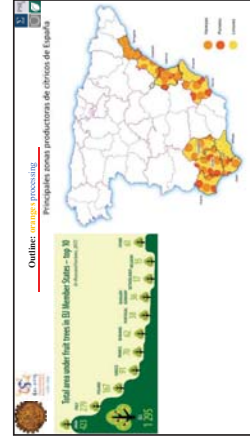
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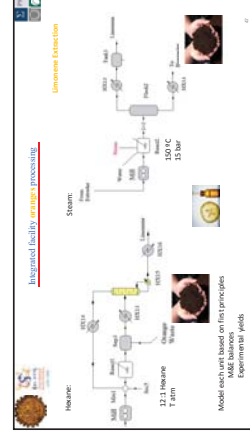
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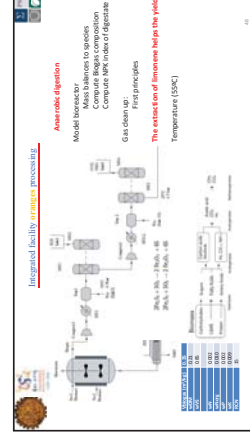
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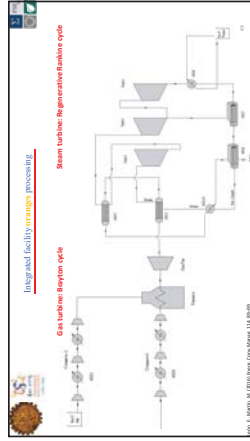
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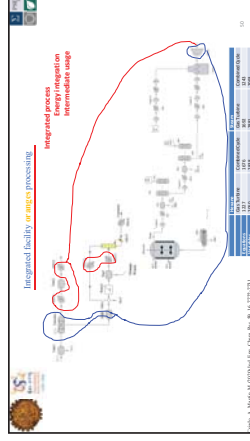
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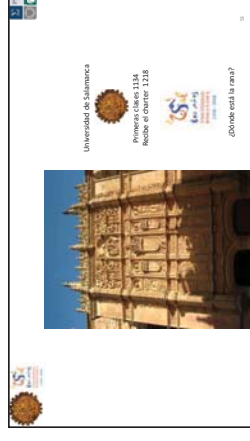
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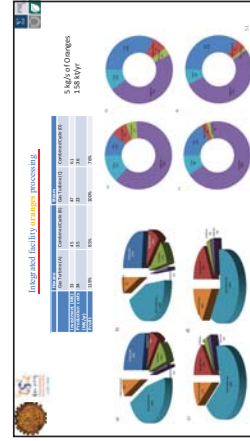
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Year	University	Location	Current
1808 1809 1810	University of Bologna	Region of Emilia-Romagna	Italy
1808-1817 1818 1819	University of Oxford	Region of England	China, United Kingdom
1812-1819 1820 1821	University of Salamanca	Region of Castile and León	Spain
1820 1821	University of Salamanca	Region of England	United Kingdom

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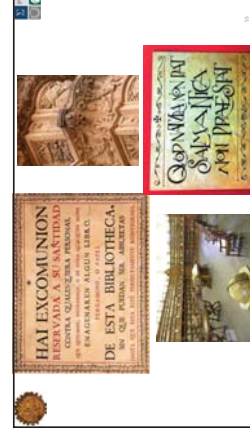


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**Conclusions**

- Development of circular economy for production design
- Superstructure modelling has been carried for technology selection
- Strategic models are developed using different approaches (MABE, Rules of thumb, DOE, Comsol, ...)
- Raw materials are an additional variable
- Agent specific business. Competition in terms of major ingredients
- Integrated business models are an opportunity for circular economy
- Screening of existing raw materials

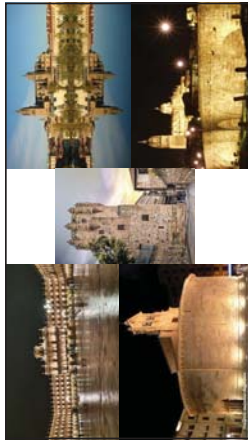
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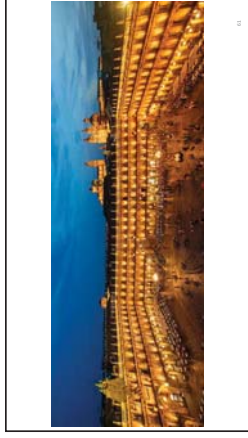
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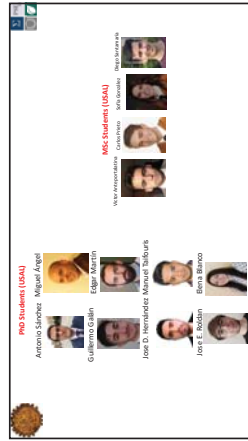
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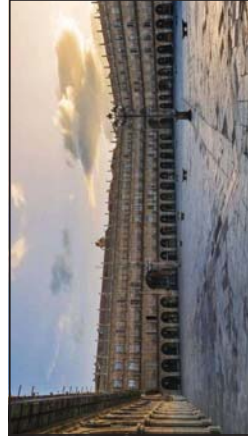
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