BIOREFINERY: A solution for a sustainable future

Part IV. Design of a continuous production plant: analysis and comparison

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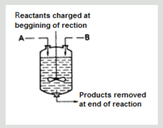
INTRODUCTION

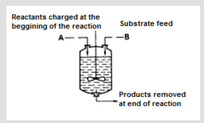
The operation of the bioreactor is usually a key point in the feasibility and functionality of a process when designing an industrial production plant:

BATCH REACTOR



- Small scale preparative reactions
- High product concentration
- Low productivity
- Substrate inhibition

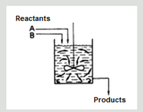
FED-BATCH REACTOR



- Allows maintaining low substrate concentration
- The volume increases continuously

Previously checked

CONTINUOUS REACTOR

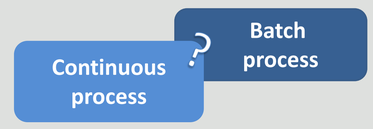


- Large-scale operation
- Low product concentration
- High productivity
- Need to recycle or immobilize cells

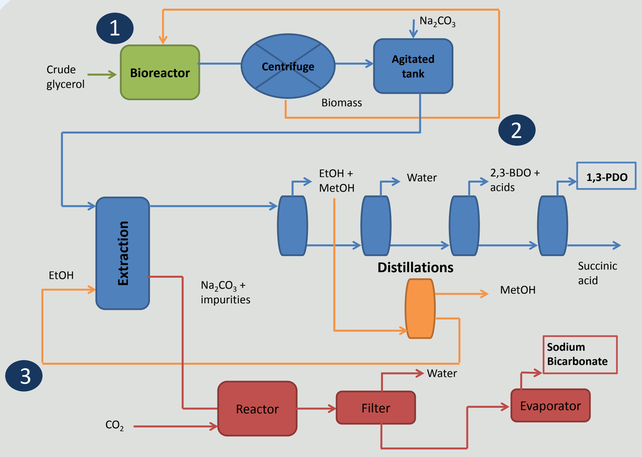
Although the plant was economically feasible, the dimensions of all equipment required was huge and, for this reason, an important percentage of the investment and the annual operating cost corresponded to the equipment use.

OBJECTIVES

The main objective of the present project is to develop a continuous process using the SuperPro designing tool. Compare and discuss advantages and disadvantages of a continuous process and a batch process will enable to enhance the knowledge of both kinds of processes. The control and instrumentation of the process will be also developed, task that involves specific learning in this area.



PROCESS DESCRIPTION



430 kg/h 1,3-PDO Productivity: 7,85 g/Lh

1860 kg/h Bicarbonate Productivity: 9,38 g/Lh

1 BIOREACTOR

- **Glycerol concentration:** if the concentration is low, the reaction is limited by the substrate but if the glycerol concentration is too high, residual glycerol can cause inhibitions.

  Optimal concentration → 60 g/L

- **Residence time:** the average amount of time that a particle spends in a particular system and varies with the volume of the system and the flow. The dilution rate is the inverse of residence time.

  Optimal dilution rate → 0.3 h^{-1}

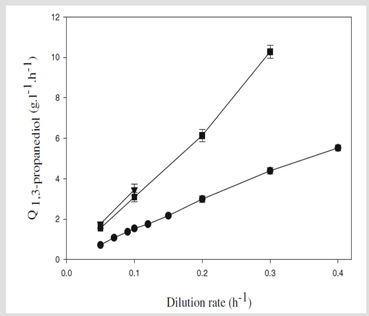


Figure 1: Influence of glycerol feed concentration and dilution rate on 1,3-PDO productivity. ■ 60g/L glycerol, ● 30g/L glycerol.

3 ETHANOL RECYCLING

Another recirculation present in this process is the one that allows reusing the alcohol. Taking into account the huge amount of alcohol used, this is important in terms of economics, since the price of ethyl alcohol is too high to use new alcohol in each extraction.

2 CELL RECYCLING

The immobilization of the cells has been considered instead of recirculation in the continuous process.

Disadvantages of immobilization:

- The cells can experience a loss of activity in immobilization conditions.
- The cells can disadsorb and be released to the medium.
- Diffusion limitations that either cannot enable the substrate to enter into the cell or difficult the release of the products to the medium.

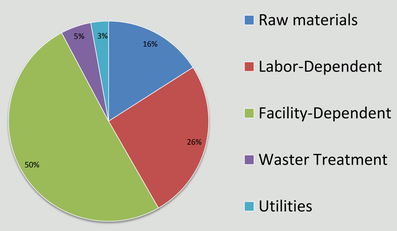
Advantages of cell recycling:

- There is no loss in cell activity due to immobilization
- The biomass control inside the bioreactor can be easily carried out thanks to the purge flow control.

ECONOMIC & ENVIRONMENTAL ANALYSIS

ANNUAL OPERATING COST

The most outstanding item in the annual operating cost is **facility-dependent**. Although this cost has been reduced in comparison with a batch process, it still represents half of the annual operating cost.



Concept	Continuous process	Batch process	Difference
Total investment ($)	64.928.000	91.531.000	29,06 % ↓
Annual Operating Cost ($)	22.746.000	27.789.000	18,15% ↓
Total Revenues ($/yr)	208.526.000	233.911.000	10,85% ↓
Unit production cost ($/kg)	6,69	7.37	9,50% ↓
Unit production revenue ($/kg)	61,36	62.05	1,11% ↓
Unit production revenue / Unit production cost	9,17	8,41	8,29% ↑
Payback time (yr)	0,55	0,69	14,5 ↓

Waste generated in this process can be classified intro three different types. 98,38% is an **aqueous waste** to be treated in a waste water treatment plant. The remaining percentage corresponds to **solid waste** and **organic waste** that will be processed in an anaerobic digestion plant.

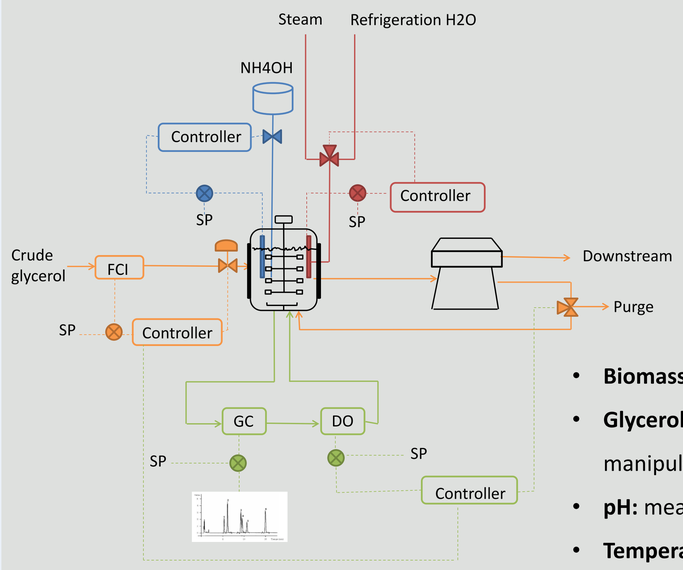
CONTROL

Goal: maintain final product concentration

Measured by gas chromatography

The final product concentration depends on the **cells' metabolic condition**

Number of cells measured by optical density



Depending on the difference between the set point and the calculated value, the controller will manipulate the variables that may have an influence on the reaction yield, which are the biomass and substrate concentration.

- **Biomass concentration:** controlled through the purge's valve.
- **Glycerol concentration:** measured with a flow controlled and manipulated with the valve.
- **pH:** measured with a probe and fixed by base addition.
- **Temperature:** measured with a probe and adjusted by adding steam or refrigeration water.

CONCLUSIONS

The **continuous process** is a better option for the production of 1,3-PDO. **Why?**

- Higher **productivity.** The productivity for 1,3-PDO is 7,85 g/Lh, value that approximately corresponds to the maximum experimentally achieved value in previous research.
- Lower **initial investment** and **annual operating cost.** A higher **unit production cost/unit production revenue ratio** allows thinking of a possible plant extension in the future
- **Low environmental impact,** 99% of waste is an aqueous waste.

What is next? Possibility of increasing production in a near future and purify more products from the same process.

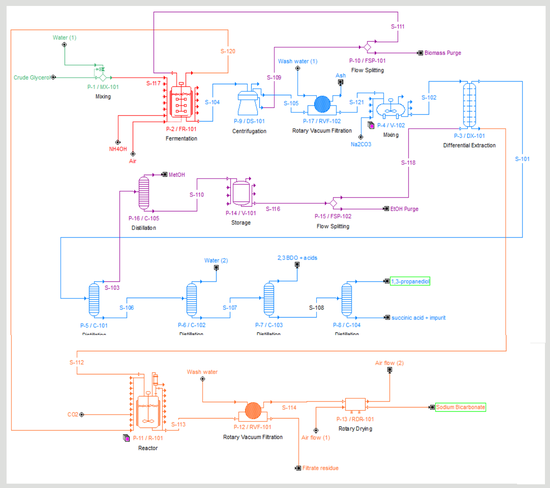


Figure 2: Continuous process flux diagram designed with SuperPro designer. All flows and equipment have been characterized in detail.

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