XilaCat SA

Industrial Process Design
2. The process

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Introduction

Flux diagrams represent all the operations that a process is made of. Firstly, an initial approximation of the calculus was done based on the bibliographic data obtained. This gave us a starting point with which SuperPro Desginer performed its simulations. Afterwards, control set points were designed in order to assure the correct functionality of the process. Finally, data from the simulation was taken.

Preliminary Project Calculations and Design

Stoichiometry

One of the requisites that SuperPro Designer has in order to carry on its simulations is the stoichiometry of the reaction. There were some assumptions that had to be made in order to successfully simulate the stoichiometry of the process. Bran was assumed to be glucose during stoichiometric calculus and a general biomass stoichiometry was used. The respiratory ratio and the Yield Product/Substrate were taken from bibliographic sources.

	a $C_6H_{12}O_6$	b O_2	c $CO(NH_2)_2$	-->	BM	d CO_2	e H_2O	f Xyl
C	6	0	1		1	1	0	1
H	12	0	4		1,84	0	2	1,55
N	0	0	2		0,2	0	0	0,25
O	6	2	1		0,56	2	1	0,3
CO_2/O_2	0	1,02	0		0	1	0	0
$Y_{P/S}$	1,09E-06	0	0		0	0	0	1

The resolution of the above equation system let to the following adjusted stoichiometry:

1.255 Bran(Glucose) + 6.5 O_2 + 0.1 Urea → 1 Biomass + 6.63 CO_2 + 6.81 H_2O

Market

The design of any process passes through the definition of the target market. We gathered data of the bread consumption in Spain and, knowing the amount of xylanase needed to process one kilogram of flour, we determined our production.

Xylanase Market		
Bread consumption	2.00E+06	tons bread/year
Pa en farina	0.75	m flour/m bread
Dosi pa	120	FXU/kg
Disponibilitat arròs		
Rice Albufera + D.Ebre	2.25E+05	Tons of rice/year

$$2 * 10^6 \frac{tonspa}{year} * 0.75 = 1.5 * 10^6 \frac{tonsflour}{year}$$

$$1.5 * 10^6 \frac{tons\ farina}{year} * \frac{10^3\ kg\ flour}{1\ tona\ flour} * \frac{120\ \mu mol\ Xyl}{min \cdot kg\ flour} = 1.8 * 10^{11} \frac{IU}{year}$$

$$\frac{1.8 * 10^{11}\ IU/year}{5890\ IU/mg\ Xyl} * \frac{1\ kg\ Xyl}{10^6 mg\ Xyl} = 30.6\ kg\ xyl/year$$

$$30.6\ kg\ Xyl/any * \frac{1\ any}{59\ batch} = 0.518\ kg\ xyl/batch$$

Dimensioning

In the bibliography, data of the xylanase activity obtained by using wheat bran is provided. The ratio in which the wheat bran(WB) yield a higher than rice bran (RB) was estimated from the data gathered. Knowing the necessary activity to cover our market, we could infer the amount of bran that was going to be needed in each batch.

Yield Xyl/subs		
IU with WheatBran	4465	IU/grams of substrate
IU with RiceBran	4197	IU/gos

Productivity --> $RB = 0.94 * WB$

$$4465\ IU/g\ WB * 0.94 = 4197\ IU/g\ RB$$

$$1.8 * 10^{11}\ IU/year * \frac{1\ g\ bran}{4197\ IU} * \frac{1\ ton\ bran}{10^6 g\ bran} = 42.9\ tons\ of\ bran/year$$

$$43\ tons\ of\ bran/batch * \frac{1\ year}{59\ batch} = 0.73\ tons\ bran/batch = 730\ kg\ bran/batch$$

To determine the volume of the reactor, we carried out an experimental process to find out rice bran's apparent density. With that, and the amount of bran needed per batch, we established our initial value for the reactor's volume.

Segó		
Density	0,24	kg/L

$$730\,kg\ bran/batch * \frac{1\ L}{0.24\ kg\ segó} = 2983.3\ L = 3000L$$

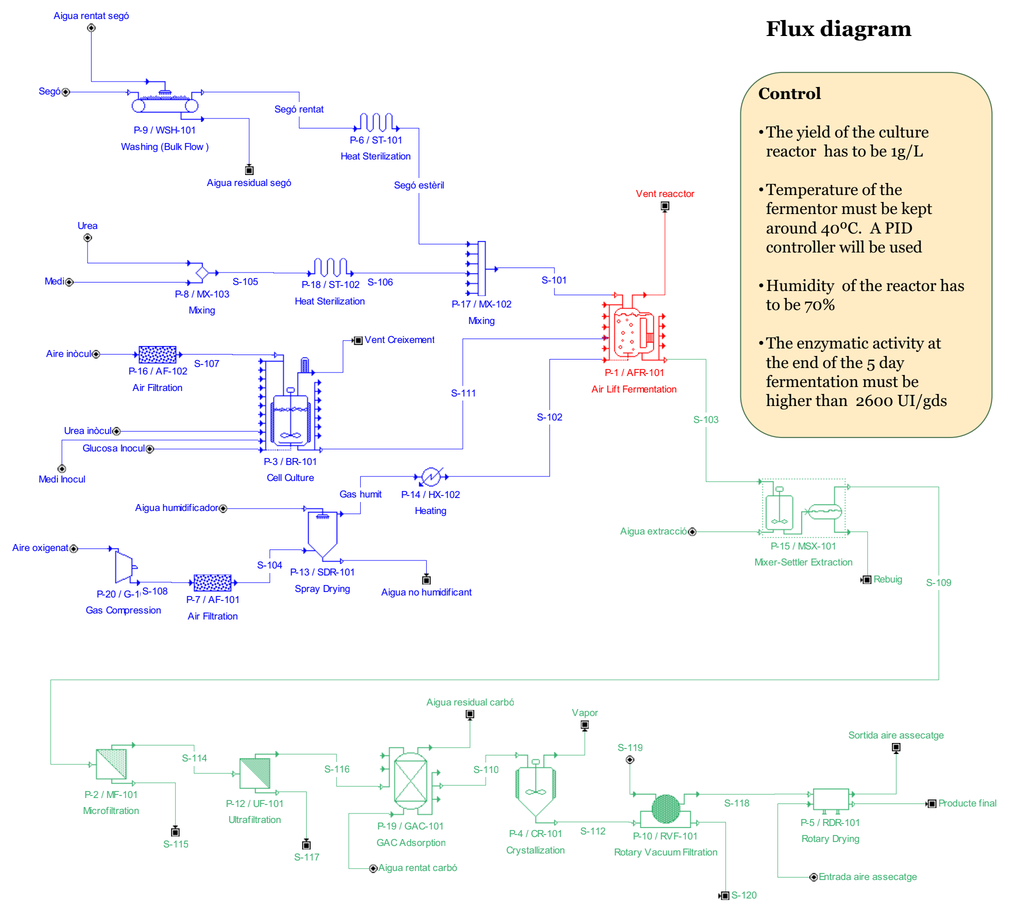
Upstream

- Bran is washed to remove sand or any other undesired component
- Urea is the source of nitrogen for the process. It is mixed with the growth medium before entering the reactor
- A culture reactor is used to produce the inoculum for the main fermentation
- Air is humidified, filtered and heated before entering the reactor
- Raw materials and air are sterilized by heat

Fermenter

- Solid state fermentation is used to produce Xylanase
- The reactor rotates periodically to assure good energy and mass transfer
- The product is found both in the liquid phase and the solid support of the process

Flux diagram



Control

- The yield of the culture reactor has to be 1g/L
- Temperature of the fermentor must be kept around 40ºC. A PID controller will be used
- Humidity of the reactor has to be 70%
- The enzymatic activity at the end of the 5 day fermentation must be higher than 2600 UI/gds

Downstream

- Periodic analysis of the enzymatic activity of waste streams will be carried out to ensure the process stability
- All waste currents will be periodically analysed in an external laboratory
- Downstream starts an extraction using water to recover the product
- Steps of filtration, ultrafiltration, adsorption, crystallization and drying are used

Final product properties

- The final product is a solid with a xylanase activity of 5890 UI/mg.
- If the process works properly, no further control is required
- All the venting emissions are periodically analysed to ensure no contaminant is being released.

Final relevant data

Reactor	Bran consumed	Batch	Production
75% of working volume	2100 kg / batch	59 batch / year	0.54 kg xylanase / batch
3900 l of working volume	123 900 kg / year	131.9 hours / batch	32.11 kg xylanase / year
5200 l of total volume		Air humidity: 80%	
		Water for extraction: 100 kg / batch	

A. Pal, F. Khanum. *Production and extraction optimization of xylanase from* Aspergillus niger *DFR-5 through solid-state-fermentation.* Bioresource Technology 101, 7563–7569 (2010)
M. Flickinger, S. Drew. *Encyclopedia of bioprocess technology fermentation, biocatalysis and bioseparation.* John Wiley & Sons, Inc. (1999)