Project 4: Fed-batch Reactor

10.05.2024

The report has to be uploaded in Moodle by Thursday the 23rd of May at 23:59 h.

It should be uploaded in 1 pdf file containing max. 9 pages per group.

You can use the template (find it on Moodle) to this effect

In this report, we expect that you:

(i) report the numerical answers and plots obtained defining the correct units!
(ii) briefly explain how you have obtained these answers.
(iii) give an interpretation of the values/plots obtained.

You also need to upload separately all the *code files* that you created and used to produce the results. Try to separate the files in sections, following a detailed structure and adding comments to document the procedure.

Code should run by simply executing the script/main function.

No extra arguments. No external data.

EXERCISE 1

In a realistic fed batch system, harvesting step cannot be instantaneous, thus the reactor operates according to the scheme given in Figure 1:

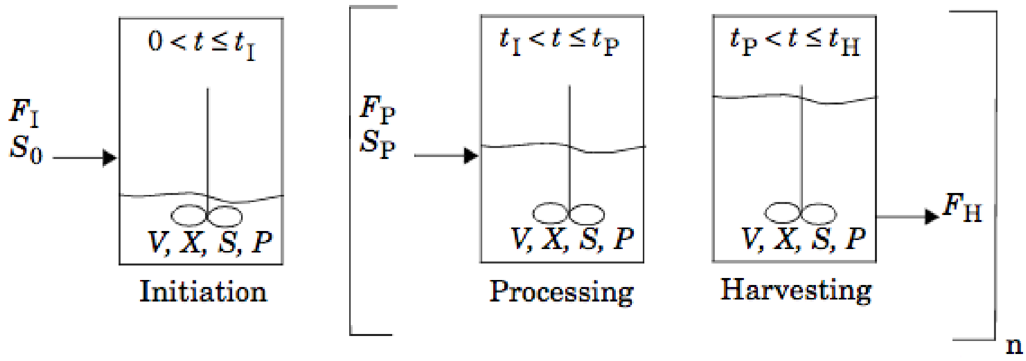

Figure 1: Operating scheme of a semi-continuous fed batch reactor

Consider the fed-batch operation of a laboratory pilot plant antibiotic fermentation bioreactor where the glucose is added to the fermentation culture in order to minimize the glucose substrate inhibition. The bio-reaction kinetics are: μ_{max}= 0.3 h-1, K_S=0.8 g glucose/L, K_I = 100 (g glucose/L), $Y_{X/S}$=0.45 g cells/g glucose, and $Y_{X/P}$= 0.15 g cells/g product.
The cell death rate and endogenous metabolism can be neglected. Thus: For $\mu_{net}(S)$ consider an appropriate growth rate that account for **substrate inhibition.** Substrate acts as an uncompetitive inhibitor.

The initiation mode is started at t = 0 h with a volume of 0.85 L containing 30 g cells/L and negligible glucose. The glucose concentrations are fixed at $S_0 = S_P$ = 80 g glucose/L. Initial operation is such that F_I= 0.2 L/h until t = 1.0 h. Then F_P= 0.5 L/h until t= 6 h and F_H= 2.5 L/h until t= 7 h

Table 1: Differential equations for the **mass of cell**, substrate and product and the volume.

Differential Equations	Initiation	Processing	Harvesting
$\frac{dN_X}{dt}=$	$\mu_{net}XV$	$\mu_{net}XV$	$-F_HX+\mu_{net}XV$
$\frac{dN_S}{dt}=$	$F_IS_0-\frac{\mu_{net}XV}{Y_{X/S}}$	$F_PS_P-\frac{\mu_{net}XV}{Y_{X/S}}$	$-F_HS-\frac{\mu_{net}XV}{Y_{X/S}}$
$\frac{dN_P}{dt}=$	$\frac{\mu_{net}XV}{Y_{X/P}}$	$\frac{\mu_{net}XV}{Y_{X/P}}$	$-F_HP+\frac{\mu_{net}XV}{Y_{X/P}}$
$\frac{dV}{dt}=$	F_I	F_P	$-F_H$

a) Create a single graph of the **concentrations** (S, X, and P) within the bioreactor as function of time for the fed-batch operation to time t_h = 7 hr. Plot the product concentrations on a separate axis. This represents the Initiation and the first cycle of processing and harvesting.

b) Repeat part (a) for the case where the initiation is followed by ten complete cycles of processing and harvesting. Plot the **concentrations** (S, X, and P) as a function of time. Calculate the production rate of P in g/hr under continuous cycling **(production rate = (grams of P produced at the 10th cycle – grams of P harvested at the 10th cycle)/(production and harvest cycle time))**. Assume therefore that the system has reached quasi-steady state after ten cycles.

EXERCISE 2

Optimize the substrate feed concentration to the fed-batch process (S_P) in Exercise 1 part (b) that will maximize the production rate of P. All processing conditions and times remain the same. Calculate the production rate of P in g/hr under continuous cycling as a function of the substrate feed concentration. (Assume the tenth cycle represents the cyclic operation.)
What concentration do you choose and why? Discuss your choice with the background that under real conditions the concentration of the feed will fluctuate.
Hint: Use ode15 or ode23 for MATLAB and the BDF method for Python.