Hands-on Assignment Bioprocess Modelling

Seminal papers dating back to the 1980ies [Sonnleitner & Käppeli. Biotechnol. Bioeng. 28(6): 927-937, 1986] have described the interplay of Glucose and Ethanol utilization in yeast, and - via a model-based approach – have identified the bottlenecks governing the pathways involved under different oxidation conditions.

Based on the same approach, and using the same equations and parameters, you are asked to implement a simple simulation of a yeast batch bioprocess.

Step 1: Implement & perform the simulation of a batch process with the parameters given below.

For technical implementation, use any programming framework of your choice (recommended: MATLAB, R or Python).

Model:

Mass balance for batch process:

$$\frac{dBM}{dt} = \mu \cdot BM$$

$$\frac{dGlc}{dt} = -(q_{Glc,ox} + q_{Glc,red}) \cdot BM$$

$$\frac{dEth}{dt} = -q_{Eth,ox} \cdot BM + Y_{EthGlcred} \cdot q_{Glc,red} \cdot BM$$

Reaction kinetics:

$$q_{Glc} = q_{Glc,max} \cdot \frac{Glc}{Glc+K_{Glc}}$$

$$q_{O_2} = q_{O_2,max}$$

$$q_{Glc,ox,max} = \frac{q_{O_2}}{Y_{O_2/Glc}}$$

$$q_{Glc,ox} = \min\left(q_{Glc,max}, q_{Glc,ox,max}\right)$$

$$q_{Glc,red} = q_{Glc,max} - q_{Glc,ox}$$

$$q_{Eth,prod} = Y_{eth/Glc,red} \cdot q_{Glc,red}$$

$$q_{Eth,uptake,theo} = q_{Eth,max} \cdot \frac{Eth}{Eth+K_{Eth}} \cdot \frac{k_i}{k_i+Glc}$$

$$q_{Eth,uptake,max} = \frac{q_{O_2} \cdot Y_{O_2/Glc}}{Y_{Glc/Eth}}$$

$$q_{Eth,ox} = \min\left(q_{Eth,uptake,theo}, q_{Eth,uptake,max}\right)$$

$$\mu = Y_{BM,Glc,ox} \cdot q_{Glc,ox} + Y_{BM,Glc,red} \cdot q_{Glc,red} + Y_{BM,Eth,ox} \cdot q_{Eth,ox}$$

Table 1: Model parameters for the simulation study

Parameter	Value	Unit	Parameter	Value	Unit
$q_{Glc,max}$	2.5	[g/g/h]	$Y_{BM,Glc,red}$	0.05	[g/g]
$q_{O2,max}$	7.5	[mmol/g/h]	$Y_{BM,Eth,ox}$	0.72	[g/g]
$q_{Eth,max}$	1	[g/g/h]	$Y_{O_2/Glc}$	12.4	[mmol/g]
k_{Glc}	0.1	[g/l]	$Y_{Eth/Glcred}$	10.5	[mmol/g]
k_{Eth}	0.1	[g/l]	$Y_{Glc/Eth}$	0.48	[g/g]
k_i	0.1	[g/l]	$Y_{CO2/Eth}$	14.2	[mmol/g]
$Y_{BM,Glc,ox}$	0.49	[g/g]			

initial conditions for simulation

Biomass = 0.25 [g/L]

Glucose = 10 [g/L]

Ethanol = 0 [g/L]

Step 2: Outgoing from the basic scenario, select two model parameters (table 1) for modification and perform the simulation again under changed conditions. Try to consider parameter modifications that make sense from physiologic / close-to-reality point of view (e.g. conditions that may be encountered in practice). Explain shortly the impact of the parameter change.

Deliverable:

Summarize your results in a written report of max. 3 pages (A4, incl. figures), adhering to the following:

- Explain your results on Glucose and Ethanol utilization and interpret them against your background knowledge on this type of biological cultivation.
- Show at least 2 plots of the simulated variable time course which compares the basic starting conditions with the modified simulation conditions.
- Explain the parameters you selected for modification (why were they chosen) and the ranges you defined for their variation. Please also explain any limitations applying to your model.
- In the appendix (not part of the page count), list the model equations and parameters used in your simulation, as well as the modified values tested.

Submission:

The report document (pdf) and associated datafiles should be submitted via Moodle (see course section) latest until **10.02.2025**