Simulation of metebolite production in the Escherichia coli model

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Metabolic processes are essential for the cell to extract energy from substrates to survive. In this paper, we will study how biomass production can be affected by using different substrates: glucose, fructose, glutamine and succinate; or different conditions: aerobic and anaerobic through the OptFlux. Eventually we found the bigger the quantity of carbon the bigger the growth rate and of course, aerobic processes are more efficient than anaerobic.

I. INTRODUCTION

The E. coli model try to reproduce computationally the Escherichia coli behavior. This model allows prediction of biomass production under different conditions due to the large amount of data available [1].
The OptFlux sofware is platform for carrying out metabolic engineering tasks. This tool is an open source software compatible with the SBML standard that allows us to create certain conditions in the framework of different metabolic models to extract some data. In this work we will use it to calculate the biomass yield for four different substrates in the E. coli model for the aerobic and anaerobic cases.
The OptFlux has different methods to perfomr the simulations. We will use the flux balance analysis (FBA) and the "wild-type" simulation. the FBA is an approach to study biochemical networks. This networks contain all the metabolic reactions and the genes in charge of encoding enzimes. FBA calculates the flow of metabolites this is used to predict the groth rate of an organism or the rate of preoduction of a metabolite [2].
By simulating the growth of E. coli using different substrates we want to maximize biomass production under both aerobic and anaerobic conditions. In the presence of oxygen E. coli uses the substrate as an energy source and is very efficient as an ATP producer. In contrast, for the anaerobic cases E. coli uses fermentation processes to produce energy. The anaerobic case is less efficient but developed as a survival mechanism [3].

II. METHODOLOGY

The OptFlux software configured with the E. coli model is used. To obtain the biomass yield for the different substrates the first thing is to set the environmental conditions. For each substrate we will set the condition -20 for the lower limit and 1000 for the upper limit, in addition, we will include a glucose drain reaction with lower limit 0 and upper limit 1000. This will give us an aerobic environment. For the anaerobic cases it is necessary to include another drain reaction, the oxigen from 0 to 1000. This conditions let the progam know what it can consume. For example the -20 indicates the system has $20\frac{mmol}{gDW\cdot h}$ of substrate to consume, the 0 means there is no presence at the begining of the simulation but as we declare them (glucose or oxygen) they can appear as a reactions products.
We will study four substrates: glucose (in this particular case we will set it from -10 to 1000 due to the big carbon disponibility), fructose, glutamine and succinate. Then the biomass yield comes from:

$$Biomass\,Yield = \frac{m_{biomass\ produced}}{m_{substrate\ consumed}} \tag{1}$$

This $m_{biomass\ produced}$ is proportioned by OptFlux as "Biomass value" and $m_{substrate\ consumed}$ comes from the following calculus:

$$m_{subs\ consum} = \frac{Subs.Consum \cdot Molec.Weight}{1000} \tag{2}$$

The molecular weight for each substrate is: glucose and fructose 180.16 g/mol, glutamine 146.14 g/mol and succinate 118.09.

III. RESULTS

Substrate	Biomass Yield	
	Aerobic	Anaerobic
Glucose	0.486	0.118
Fructose	0.497	0.143
Glutamine	0.398	Nan
Succinate	0.356	Nan

TABLE I: This table shows a summary of the biomass yield for the aerobic and anaerobic cases for the different substrates.

We observe the aerobic cases show a bigger rate of biomass production for each substrate. Fructose and glucose have a similar rate because their chemical composition is very similar. We can also see glutamine and succinate anaerobic cases doesn't show a rate.

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IV. CONCLUSIONS

As expected, the presence of oxygen allows the system to grow more than in the anaerobic case. It is also true that glucose and fructose which have more carbon available make the system grow more. The fact that there are two Nan in the table may be associated with the fact that E. coli cannot ferment those substrates, or that the energy is low enough not to be used by the bacteria to grow.

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