Photo-Biological Reactor for Organic Waste Consumption and Hydrogen Production

Leonardo F. de Souza[1]

1. Universidade Federal do Paraná, Curitiba, Paraná, Brazil

Introduction: A simple photo-fermentative biochemical model was developed using the Transport of Diluted Species physics interface. This preliminary approach is based on a dimensionless model seeking optimal physical parameters based on given biochemical parameters found in literature.

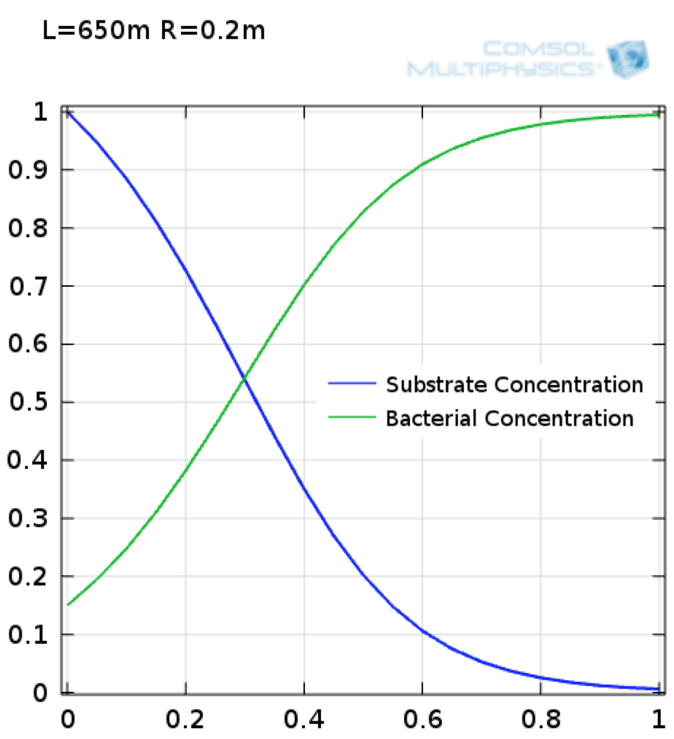

Figure 1. Reactions

Reactions:

$$\frac{\partial b}{\partial t} = \mu_{max}\left(\frac{s}{k_s + s}\right) b$$

$$\frac{\partial s}{\partial t} = -\frac{1}{y_B}\frac{\partial b}{\partial t}$$

$$\frac{\partial h2}{\partial t} = (1 - y_B) e_{H2}\frac{\partial b}{\partial t}$$

Computational Methods: By the Reynolds Theorem, a one-dimensional steady-state inflow of diluted species is used to predict substrate consumption and hydrogen production by photosynthetic bacteria. Monod equation is usually used for enzymatic reactions. Many simplifying hypothesis were made, such as complete anoxic environment and continuous sufficient light energy.

$$\frac{\partial}{\partial t}C + (\boldsymbol{u}\,.\,\boldsymbol{\nabla}\,)C - D_i\boldsymbol{\nabla}^2 C = \mu C$$

Boundary Conditions:

$$\frac{1}{P_e}\frac{\partial C_i}{\partial Z} - C_{i,o} + C_{i,in} = 0$$

$$\frac{\partial C_i}{\partial Z} = 0$$

Dimensionless Variables:

$$Z = \frac{z}{L} \qquad P_e = \frac{u_0 L}{D} \qquad S = \frac{s}{s_0}$$

$$R = \frac{r}{r_{max}} \qquad L_k = \frac{\mu_m L}{u_0} \qquad B = \frac{b}{b_{max}}$$

$$T = \frac{u_0\, t}{L} \qquad K_s = \frac{k_s}{s_0} \qquad H2 = \frac{h2}{h2_{max}}$$

(z = coordinate, L = length, r_{max} = radius, u_0 = velocity, μ_{max} = growth rate, D = diffusion, Pe = Peclet number, L_k = Damkohler number, k_s = half saturation, s_0 = initial substrate, y_b = yield , e_{H2} = efficiency, and t=time).

Results: Dimensionless approach enables physical parameters sweep without altering the mesh. Optimal length and width for complete substrate degradation were found, based on a fixed daily load. Figure 1 and 2 show an example for L=650m and r_{max}=0.2m. The dimensionless model makes it easier to visualize the reactor, as shown in Figure 3. Parameters are summarized in Table 1.

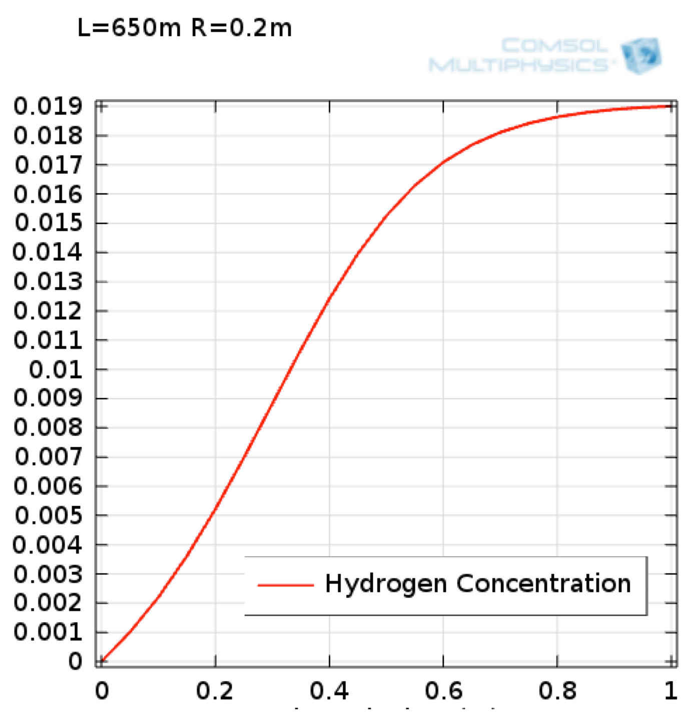

Figure 2. Production

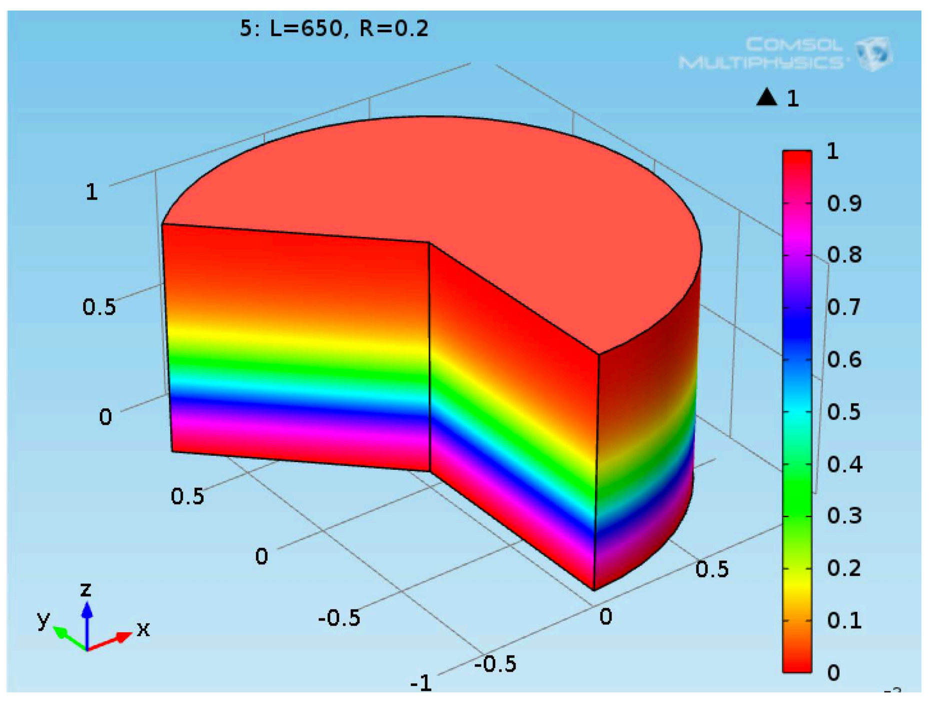

Figure 3. Dimensionless Reactor

Variable	Value
Acetic acid daily load	5.0 kg day-1
Maximum Dilution [3]	40 mmol/L
Initial Bacterial Concentration [1]	0.15 kg m^{-3}
Half Saturation Constant [2]	10 kg m^{-3}
Specific Growth rate [1]	0.025 h^{-1}
Hydrogen Yield [2]	0.02 kg kg^{-1}

Table 1. Parameters

Conclusions: This basic model leads the study for a photo-chemical reactor. Many other restrictions and limitations can easily be added, for example heat transfer and light penetration. Many studies suggest a complete system for the organic cycle, while producing useful energy, so this model becomes one part of a complex biochemical study.

References:

[1] Boran, E., et al., Biohydrogen production by Rhodobacter capsulatus in solar tubular photobioreactor on thick juice dark fermenter effluent. *Journal of Cleaner Production,* **v.31,** p.150-157 (2012)

[2] Obeid, J., et al., Modelling of hydrogen production in batch cultures of the photosynthetic bacterium Rhodobacter capsulatus. *International Journal of Hydrogen Energy,* **v.34**, p.180-185 (2009)

[3] Ozkan, E., et al., Photofermentative hydrogen production using dark fermentation effluent of sugar beet thick juice in outdoor conditions. *Internation Journal of Hydrogen Energy*, **v.37**, p.2044-2049 (2012)