ABE 580

Homework 2: Modeling Exponential Growth and Substrate Utilization
Due Wednesday January 30, 2019

Objectives:

1. Develop system of ODE's to model ethanol production by *S. cerevisiae* as a Type I fermentation that include substrate utilization, product formation (and inhibition), and cell growth.

3. Successfully program and run SIMBAS, MatLAB, or other ODE numerical solver to model the exponential growth of microbial cells and substrate utilization.

Software:

1. Microsoft Excel (version 95 or newer) with macros enabled or MatLAB.

2. SIMBAS Runge-Kutta ODE solver (simbas.xls)

Instructions:

1. Simulate the time course of the ethanol fermentation using the equations and conditions below. Your plot should show changes in glucose, ethanol, cell mass, accumulated and **the mass of CO_2 generated as a function of time**. Give the basis for any calculations and show your work.

   Resources:

   a) Maiorella *et al.,* "By-Product Inhibition Effects on Ethanolic Fermentation by *S. cerevisiae*," *Biotech. Bioeng.* 25, 103-121 (1983).

   b) Maiorella *et al.,* "Economic Evaluation of Alternative Ethanol Fermentation Processes," *Biotech. Bioeng.* 26, 1003-1025 (1984).

   c) Textbook pages 124-127.

Cell Conc. Equation (1) : $\frac{dX}{dt} = E\nu \cdot X$

$$E\nu = \mu$$

$$\nu = \nu_{max}\left[\frac{S}{K_s + S}\right]\left[1 - \frac{P1}{P1_{max}}\right]^n$$

Substrate Equation (2) : $\frac{dS}{dt} = -\frac{1}{Yxs}\frac{dX}{dt}$

Product (ethanol) Equation (3) : $\frac{dP1}{dt} =$ …… (you will need to figure this out)

Product (CO2) Equation (4) : $\frac{dP2}{dt}$ = …… (you will need to figure this out)

Initial conditions : at time t=0

X(0)=1 g/L
S(0)=150 g/L (should not exceed 200g/L due to substrate inhibition)
P(0)=0 g/L

Constants: Ks = 0.315 g/L
Pmax = 87.5 g/L
ν_m = 1.15 g ethanol / g cells / hr
E = 0.249 g cells / g ethanol
Yxs = 0.07 Δg, cells / Δg, glucose
Yps = 0.434 Δg ethanol / Δg, glucose
n = 0.36

2. Write a report on the results of your model. Your report should include:

a) A derivation of the overall reaction stoichiometry and a calculation of the theoretical yield of ethanol from glucose in moles and in mass (grams of ethanol per gram of glucose).

b) The results from your model, including:
   a. maximum ethanol concentration
   b. maximum cell mass
   c. CO_2 generated
   d. Time required to consume the initial substrate
   e. Graphs showing the fermentation time course with the axes and lines labeled
   f. A copy of your Visual Basic or MatLAB code.

c) A sensitivity analysis of the model parameters including:
   a. n (sensitivity to ethanol): How long does it take for the glucose to be utilized if n is increased? Decreased? What are the final ethanol and cell concentrations? How much time is required to fully consume the initial glucose? Explain why the results are/are not different from the original parameter values.
   b. ν_m (maximum specific ethanol production rate): What happens if ν_m is increased? Decreased?
   c. E (cell yield): What happens if ν_m is increased? Decreased?