10.442/542
BIOCHEMICAL ENGINEERING
PROBLEM SET NO. 2
Due February 17, 2000

1. What would you expect the overall yield (g product/g carbon source) in a batch fermentation to be for a bacterial process producing lysine ($C_6H_{14}N_2O_2$) from glucose? The average specific productivity for the organism used in this process is 1.8 g lysine /g cell-h. Assume that the maximum attainable lysine concentration is 80 g/L and state all other assumptions.

2. As a consulting engineer for Fermentations Unlimited, Ltd. , you are asked to evaluate some new technology to make citric acid from molasses. The seller of the technology claims that in a fed-batch process they can make 250 g/L of citric acid ($C_6H_8O_7$). The initial volume of the fermentor is 50% of the total and at the end of the process the liquid volume is increased to 75% of the total volume. The technology involves a proprietary schedule for feeding molasses to maintain the sugar concentration at an optimal level of 1.2 g/L for citric acid production. The initial concentration of sugar is 30 g/L. They further claim that they can get 80% of the theoretical yield of citric acid from glucose in the process. What do you estimate for the final concentration and yield of citric acid? Do you believe your client should buy the technology? Be sure to state your assumptions and give a quantitative reason for your answer.

3. Many recombinant proteins are synthesized in *E. coli* and accumulate as intracellular proteins to a level of 25% of the total cell protein. In a fermentor, these cell lines can be grown to a cell concentration of 40 g/liter (dry cell basis).

a.) Assuming that you can use a simple defined medium of glucose and appropriate mineral salts, estimate the cost of the growth medium per unit amount of the desired product. As a first estimate, you may use cost information available in a laboratory supply catalog.

b.) On an industrial scale, materials can be purchased at a lower cost. Using data in the *Chemical Marketing Reporter*, estimate the cost of the medium when components are purchased in large volume supply.

4. The following figure is taken from Kobayashi et al. (1973) Biotech. Bioengr.15. 27-45. It describes the effectiveness factor (y-axis) as a function of the modified Thiele modulus (x-axis) for mycelial pellets. These terms are defined below:

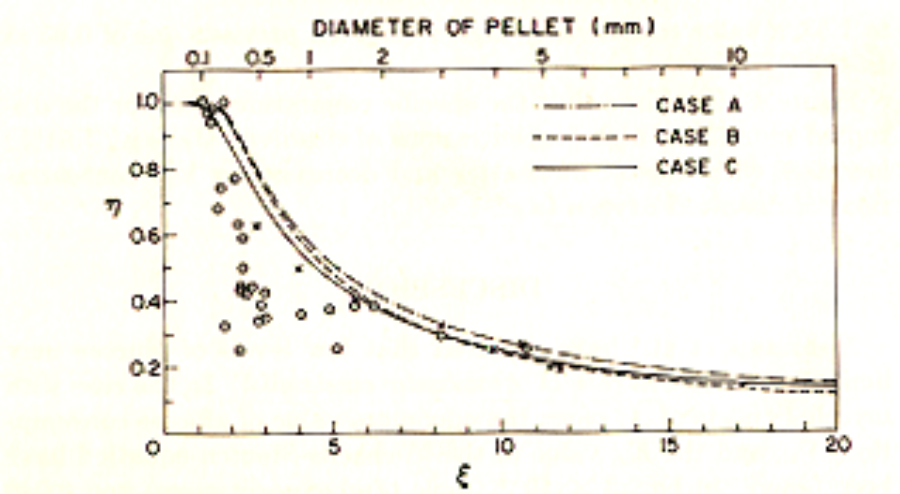

Fig. 5. Comparison between theoretical curves relating η to ξ for cases A, B, and C, and experimental data. (o) data of Yano et al.;[4] (x) this work.

$$\eta = \frac{Q}{Q_i} \qquad \frac{\text{Respiration Rate Pellet}}{\text{" " Mycelia}}$$

$$\xi = R\left(\rho_m Q_i / 2 D S_i\right)^{1/2}$$

R: radius; ρ_m: density; D: O_2 diffusivity in pellet; S_i: bulk $[O_2]$

For the case of *Aspergilis niger* growing on glucose, the value of Qi was found to be 0.12 μmole O_2/min/mg of dry cell mass. The diffusivity of oxygen within the pellet is estimated as 0.11 mm^2/min and the solubility of oxygen in the medium is approximately $2x10^{-4}$ μmole/mm^3.

a.) When the culture has reached 20 g/l, what will be the volumetric demand for oxygen when the mean pellet size is 1 mm?

b.) At what oxygen concentration in the broth will the effective growth rate fall to 90% of the maximum? What assumptions do you need to make to estimate this value?

c.) What do you estimate as the maximum specific growth rate of this organism?

d.) Plot the estimated specific rate of glucose metabolism (mg glucose/mg cell mass/h) as a function of the pellet diameter.