9.2. CHOOSING THE CULTIVATION METHOD

One of the first decisions is whether to use a batch or continuous cultivation scheme. Although a simple batch and continuous-flow stirred-tank reactor (CFSTR) represent extremes (we will soon learn about other reactors with intermediate characteristics), consideration of these two extreme alternatives will clarify some important issues in reactor selection.

First, we can consider productivity. The simplest case is for the production of cell mass or a primary product. For a batch reactor, four distinct phases are present: lag phase, exponential growth phase, harvesting, and preparation for a new batch (e.g., cleaning, sterilizing, and filling). Let us define t_l as the sum of the times required for the lag phase, harvesting, and preparation. The value for t_l will vary with size of the equipment and the nature of the fermentation but is normally in the range of several hours (3 to 10 h). Thus, the total time to complete a batch cycle (t_c) is

$$t_c = \frac{1}{\mu_m} \ln \frac{X_m}{X_0} + t_l \tag{9.1}$$

where X_m is the maximal attainable cell concentration and X_0 is the cell concentration at inoculation.

The total amount of cell mass produced comes from knowing the total amount of growth-extent-limiting nutrient present and its yield coefficient:

$$X_m - X_0 = Y_{X/S} S_0 \tag{9.2}$$

The rate of cell mass production in one batch cycle (r_b) is

$$r_b = \frac{Y_{X/S} S_0}{(1/\mu_m)\ln(X_m/X_0) + t_l} \tag{9.3}$$

As discussed in Chapter 6, the maximum productivity of a chemostat is found by differentiating DX with respect to D and setting dDX/dD to zero. The value for D optimal when simple Monod kinetics apply is given by eq. 6.83, and the corresponding X can be determined to be

$$X_{\text{opt}} = Y_{X/S}\left\{S_0 + K_s - \sqrt{K_s(S_0 + K_s)}\right\} \tag{9.4}$$

Thus, the best productivity that could be expected from a chemostat where Monod kinetics apply is $D_{\text{opt}} \cdot X_{\text{opt}}$, or

$$D_{\text{opt}} X_{\text{opt}} = Y_{X/S}\, \mu_m \left[1 - \sqrt{\frac{K_s}{K_s + S_0}}\right]\left[S_0 + K_s - \sqrt{K_s(S_0 + K_s)}\right] \tag{9.5}$$

Under normal circumstances $S_0 >> K_s$, so the rate of chemostat biomass production, r_c, is approximately

$$r_{c,\text{opt}} = D_{\text{opt}} X_{\text{opt}} = \mu_m Y_{X/S}\, S_0 \tag{9.6}$$