15 Growth Kinetics in SSF Systems: Experimental Approaches

15.1 Experimental Systems for Studying Kinetics

In order to establish the kinetic profile, a small-scale experimental system should be used so that heat transfer and inter-particle mass transfer will not be limiting. The idea is that the conditions within the substrate bed are those that you wish the organism to experience; therefore heat and mass transfer limitations should not cause significant deviations from these conditions. In other words, the aim is to characterize the growth kinetics of the organism without interference from bulk transport phenomena, to the extent that is possible. Of course, when empirical equations are used to describe the kinetics, the intra-particle transport phenomena are subsumed in the overall kinetic equation. This is impossible to avoid, since intra-particle transport limitations are an intrinsic characteristic of SSF (Chap. 2).

As mentioned in Chap. 14, you will undertake these kinetic studies once you have identified a substrate composition and environmental conditions that allow reasonably good growth of the organism. The most important conditions to control are the gas phase composition and the temperature and the water activity of the substrate bed. The two basic experimental strategies available are: (1) The use of multiple erlenmeyer flasks (or similar vessels) within an incubator and (2) the use of multiple columns within a waterbath.

Kinetic studies are typically done in these systems, rather than in laboratory-scale bioreactors, because such bioreactors are commonly not well-mixed, and therefore it is difficult to remove representative samples from them (Fig. 15.1). The problem is most evident in the case where it is desirable to leave the bed totally static, in which case it is impossible to avoid heterogeneity in beds containing even as little as a few hundred grams of substrate. There will be differences between inner and outer regions of the bed, and samples cannot be removed from anywhere other than the exposed surface without disrupting the bed. This disruption will affect growth of the microorganism in the part of the bed left behind after the sample is removed. In systems that involve multiple flasks or columns, individual units can be sacrificed at each sampling time. Even though within individual flasks or columns with less than 100 g of substrate there might still be some heterogeneity in the substrate bed (for example, from top to bottom of a column or...
from the inner to the outer regions within a flask), each flask or column should be identically heterogeneous, and therefore representative of all the other flasks.

Even though each flask or column should be identical with the others, there will always be some variation. Therefore it is important to establish, before the fermentation, the order in which the flasks or columns will be removed. If the decision were made at the time of sampling, then it would be possible to be influenced by the relative appearance of the different flasks or columns. Also, given the possibility that the conditions in a waterbath or incubator might vary with position due to imperfect circulation patterns, the pattern of removal should be random (Fig. 15.1(b)).

Fig. 15.1. Basic considerations about kinetic studies. (a) It is better to use multiple small containers in which individual containers are sacrificed at each sampling time rather than to remove subsequent samples from a larger mass; (b) The individual containers should be removed in random order

15.1.1. Flasks in an Incubator

This system is very commonly used. Its basic features are shown in Fig. 15.2. Ideally the substrate layer should not be thicker than 1 to 2 cm, although even with this thickness growth at the bottom of the layer may be limited by poor O₂ supply.