BIOREACTOR ENGINEERING
Chapter 10
Scale-up of Bioreactor

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Chapter Description

- Topic Outcomes
  - Identify the difficulties in scale-up of bioreactor
  - Perform scale-up calculation.

- References

  - Doran, P.M. (2013) Bioprocess Engineering Principles. Elsevier.
  - Liu, S. (2013) Bioprocess Engineering: Kinetics, Biosystem, Sustainability and Reactor Design. Elsevier.
  - Rao, D.G. (2010) Introduction to Biochemical Engineering. McGraw Hill.

Topic Outline

- Introduction
- Criteria of Scale-up
- Scale-down

Introduction

- Various steps in bioprocessing operation:
  - Identification and isolation of the strain of the microorganism
  - Preservation of strain
  - Culturing or growing of inoculum
  - Pre-fermentation culturing
  - Fermentation process
  - Recovery and purification of the product
  - Treatment of effluent
- Which steps as above require effort for scale-up?

Introduction

- The “ideal” scale-up criterion is that parameter which has the same numerical value as the volumes of the geometrically similar bioreactors increase in size.
- 1st scale-up criterion: Geometrical Similarity
  - $H_{L1}/D_{t1} = H_{L2}/D_{t2} = \ldots\ldots = H_{L3}/D_{t3}$

Introduction

- Exercise 1

Criteria of Scale-up

- Physical conditions in a large bioreactor can never exactly duplicate those in a smaller bioreactor if geometric similarity is maintained:
  - During scale-up, if the height-to-diameter ratio remains constant, the surface-to-volume ratio decreases dramatically → decrease the surface aeration to O_2 supply and dissolved CO_2 removal.
  - During scale-up, volume increases, the diameter and height of the bioreactor increase → time spent by the bubble in reactor is more, does not contribute to mass transfer.
  - Problem in homogeneity.
- In general, two criteria to ensure similarity during scale-up:
  - Geometric similarity of the physical boundary
  - Dynamic similarity of the flow fields

Criteria of Scale-up

- The scale-up methods for aeration and agitation:
  - Constant mass transfer coefficient
  - Constant ratio of agitation power input per unit volume of fluid (P/V)
  - Constant impeller tip speed (N_iD_i)
  - Constant mixing time (pumping rate of impeller per unit volume, (Q/V)
  - Constant Reynolds number $\left(\frac{N_i D_i^2 \rho}{\mu}\right)$

- $P \alpha N_i^3 D_i^5$
- $V \alpha D_i^3$
- $Q \alpha N_i D_i^3$

Criteria of Scale-up

- Exercise 2

Scale-down

- Scale-down is required:
  - to provide smaller scale experimental system, hence many parameter can be tested more quickly and inexpensively
  - to estimate the system's response (e.g., growth rate, product formation, and formation of by-product) when:
    - Change in medium composition
    - Introduction of modified production strain
    - Use of different inoculum preparations
    - Use of new antiform agents
  - Corrective protocol can be suggested for use in large-scale system by simulating the response to pH or oxygen-probe failure or compressor failure.

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