BIOREACTOR ENGINEERING
Chapter 4
Operation Considerations for Bioreactor

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Chapter Description

- Topic Outcome
  - Differentiate between batch and continuous modes of bioreactor operation

- 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

- Choosing Cultivation Method

Choosing Cultivation Method

- Batch mode
- Continuous mode

Which type is more efficient?

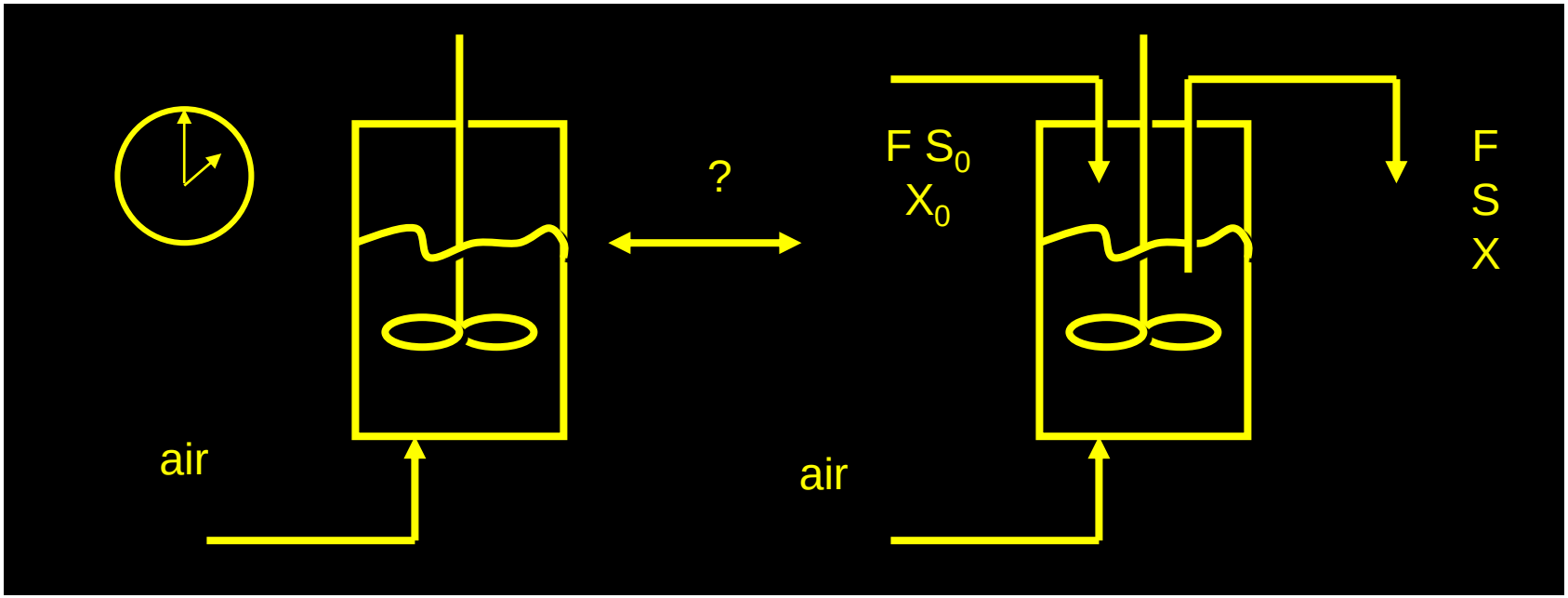
Which type is more common?

Choosing Cultivation Method

- Exercise 1

Choosing Cultivation Method

- PRODUCTIVITY: rate of product per time per volume.
  - Consider production of cell mass OR growth associated product in suspension culture



Choosing Cultivation Method

Batch mode

- Batch cycle time is: $t_{cycle} = t_b + t_{dn}$

  t_b = the time required for batch cell conversion
  t_{dn} = the downtime = preparation + lag time + harvest time

- So, $$t_{cycle} = \frac{1}{\mu_{\max}} \ln \frac{X_f}{X_i} + t_{dn}$$

- Cell production rate in one batch cycle is: $$(P_X)_{batch} = \frac{X_f - X_i}{t_{cycle}}$$

- Recall: $$Y_{X/S} = \frac{X_f - X_i}{S_i - S_f} = \frac{X_f - X_i}{S_i - 0}$$

- So, $$(P_X)_{batch} = \frac{Y_{X/S} S_i}{\frac{1}{\mu_{\max}} \ln \frac{X_f}{X_i} + t_{dn}}$$

Choosing Cultivation Method

Continuous mode

- Recall: $X = Y_{X/S}\left(S_0 - \frac{K_S D}{\mu_{\max} - D}\right)$ $D_{opt} = \mu_{\max}\left(1 - \sqrt{\frac{K_S}{K_S + S_0}}\right)$
- X at the maximum production rate:
- Productivity, P_x = DX when D = D_{opt} and X = X (at D_{opt})
- So, $(P_X)_{opt,cont} = Y_{X/S}\mu_{max}\left[1 - \sqrt{\frac{K_S}{K_S + S_0}}\right]\left[S_0 + K_S - \sqrt{K_S(S_0 + K_S)}\right]$
- when $S_o >> K_s$
- So, $(P_X)_{opt,cont} \approx \mu_{\max} Y_{X/S} S_0$

Choosing Cultivation Method

- Comparing the batch production rate and continuous production rate:

$$(P_X)_{batch} = \frac{Y_{X/S} S_i}{\frac{1}{\mu_{max}} \ln \frac{X_f}{X_i} + t_{dn}}$$

Assume → $S_i = S_o$

$$\frac{(P_x)_{opt,cont}}{(P_x)_{batch}} = \ln \frac{X_f}{X_i} + \mu_{max} t_{dn}$$

$$(P_X)_{opt,cont} \approx \mu_{max} Y_{X/S} S_0$$

- In general, $X_f >> X_o$, thus, continuous culture is better!
- Example: *E. coli* growing on glucose:

  $X_f/X_o = 20$, $\mu_{max} = 1\ h^{-1}$, $t_{dn} = 5$ h, $\frac{(P_x)_{opt,cont}}{(P_x)_{batch}} = ?$

- Even so, most industrial fermentation processes occur in a batch reactor. Why?

Choosing Cultivation Method

Batch mode is more common because:

- Productivity → Many industrial applications are for non-growth associated products.
- Genetic stability → Continuous culture is detrimental to genetically engineered organisms. This makes continuous culture less productive.
- Operability and sterility → Long term continuous culture can be problematic.
- Market Economics → Batch system is flexible, able to make more than one product with the same reactor.

Choosing Cultivation Method

Continuous mode is more efficient because:

- Higher productivity for cell and growth associated products because it offers a continuation of growth for a long period.
- It provides constant environmental conditions for growth and product formation.

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