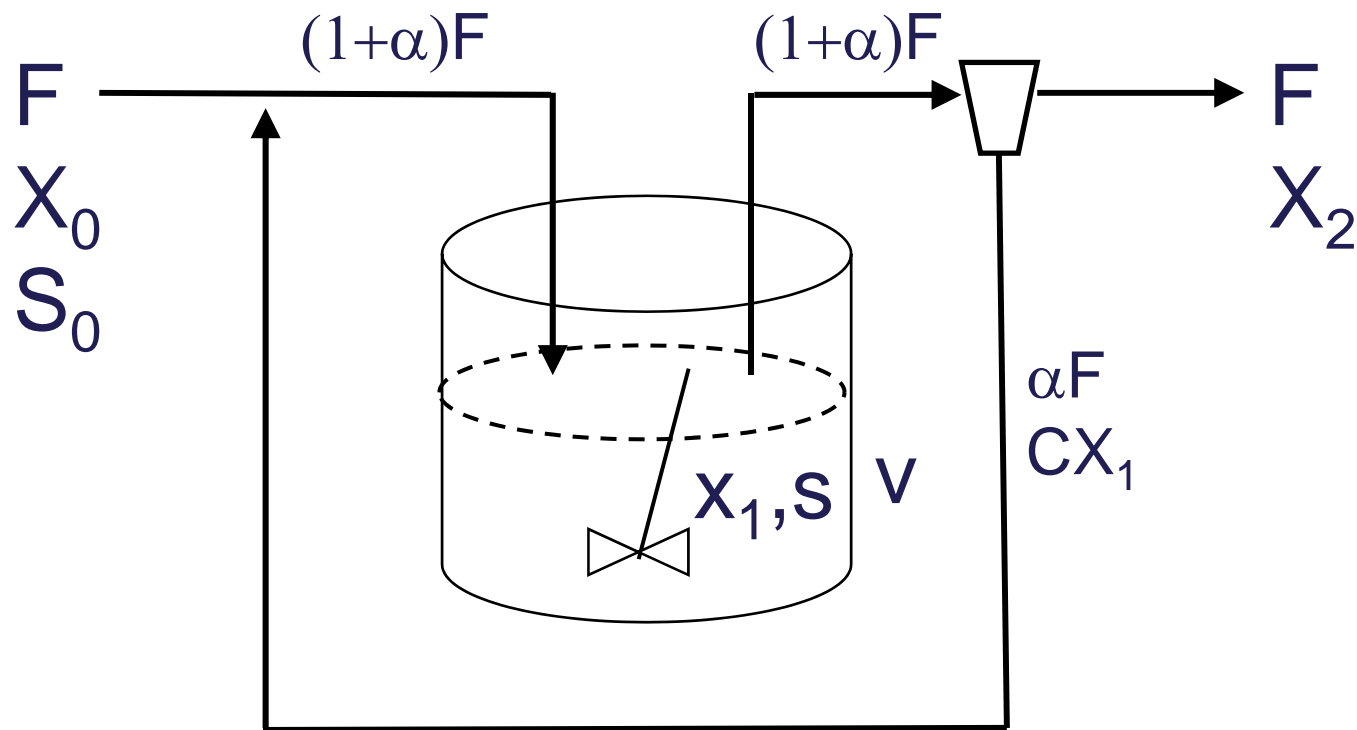


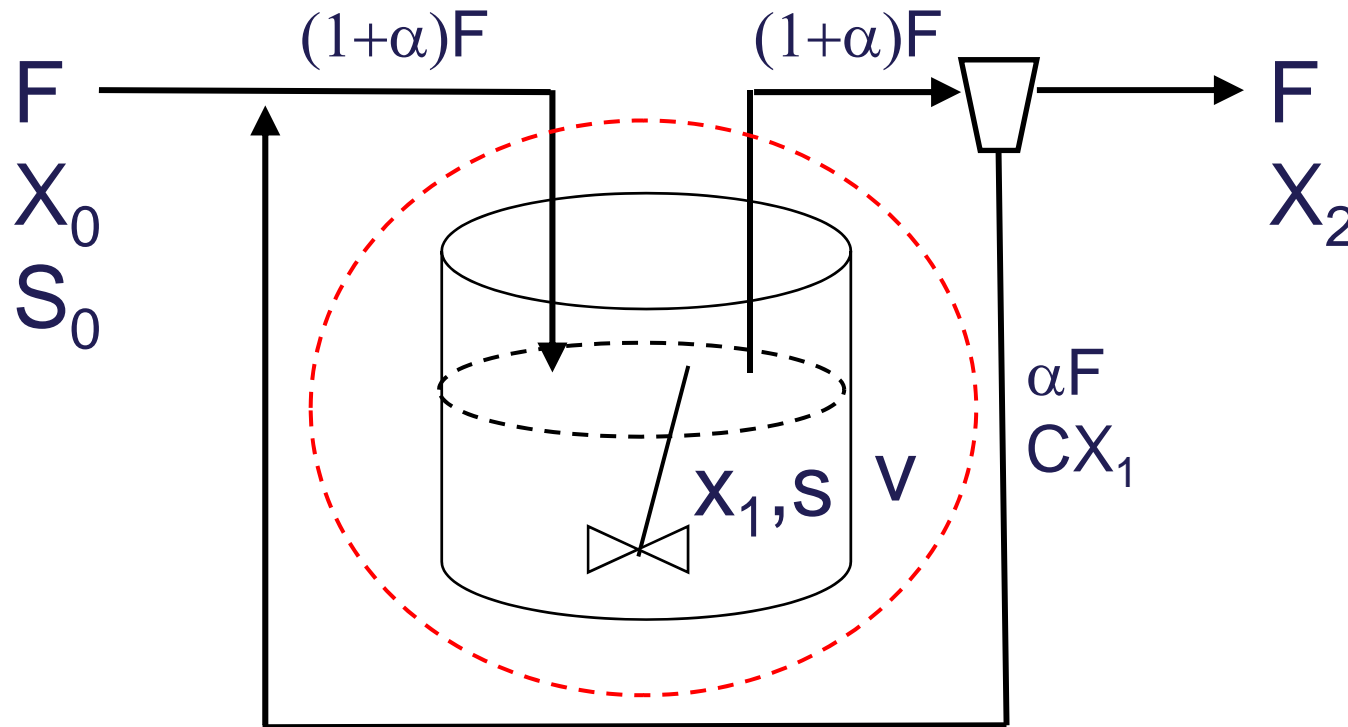
Chemostat with Recycle



Chemostat with Recycle

- Higher cell concentration
- Longer residence time
 - high specific productivity
- Higher stability
 - Ex: waste-water treatment
 - Minimizing the effects of process perturbation

Chemostat with Recycle



F (L/h) : Flow Rate
 X (g/L) : Cell Concentration
 S (g/L) : Substrate Concentration

V (L) : Working Volume
 α : Recycle Ratio
 C : Concentration Factor

Mass Balance

$$\text{Acc} = \text{In} - \text{Out} + \text{Gen} - \text{Con}$$

Accumulation rate = Input rate – Output rate + Generation rate – Consumption rate

$$\frac{d(\quad)}{dt} =$$

Mass Balances

- cell

$$\frac{d(X_1V)}{dt} = \alpha FCX_1 - (1 + \alpha)FX_1 + \mu X_1V \dots(1)$$

At steady state

$$\{\alpha FC - (1 + \alpha)F + \mu V\}X_1 = 0 \dots(2)$$

Mass Balances

At steady state

$$\{ \alpha FC - (1 + \alpha)F + \mu V \} X_1 = 0 \dots (2)$$

$/V$

$$\{ (\alpha C - 1 - \alpha)D + \mu \} X_1 = 0$$

$$\mu = (1 + \alpha - \alpha C)D \dots (3)$$

At steady-state

$$\mu = (1 + \alpha - \alpha C)D \dots\dots(3)$$

$$C > 1 \quad \rightarrow \quad \alpha(1-C) < 0 \quad \rightarrow \quad 1 + \alpha(1-C) < 1$$

$$\mu < D \dots\dots(4)$$

A chemostat can be operated at dilution rates higher than the (maximum) specific growth rate when cell cycle is used.

Mass Balances

- substrate

$$\frac{d(SV)}{dt} = S_0 F - S \alpha F - S(1 + \alpha)F - \frac{\mu X_1 V}{Y} \dots (5)$$

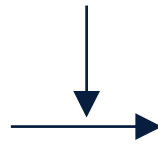
At steady state

$$S_0 D + S \alpha D - S(1 + \alpha)D = \frac{\mu X_1}{Y}$$

(3)

$$(S_0 - S)D = \frac{\mu X_1}{Y} \dots (6)$$

(6)



$$X_1 = \frac{Y(S_0 - S)}{1 + \alpha - \alpha C} \dots (7)$$

At steady-state

$$X_1 = \frac{Y(S_0 - S)}{1 + \alpha - \alpha C} \dots\dots\dots(7)$$

Compare with the X in chemostat without cell recycle

$$X = Y(S_0 - S)$$

The steady-state cell concentration in a chemostat is increased by a factor of $(1 + \alpha - \alpha C)$ by cell recycle. (Not exactly!)

↑
k

Concentrations at Steady State

$$(1 + \alpha - \alpha C)D = \mu$$

(By Monod equation)

$$= \frac{\mu_m S}{K_s + S}$$

$$S = \frac{kDK_s}{\mu_m - kD} \dots\dots(8)$$

where $k = (1 + \alpha - \alpha C)$

Concentrations at Steady State

$$(7) \quad \longrightarrow \quad X_1 = \frac{Y(S_0 - S)}{k}$$

(8)

$$= \frac{Y}{k} \left(S_0 - \frac{kDK_s}{\mu_m - kD} \right) \dots \dots (9)$$

where $k = (1 + \alpha - \alpha C)$

Mass Balances

- Cell mass balance around the cell separator

$$(1 + \alpha)FX_1 = FX_2 + \alpha FCX_1$$

$$X_2 = (1 + \alpha - \alpha C)X_1$$

$$= kX_1 \dots \dots \dots (10)$$

Productivity

$$Productivity = \frac{X_2 (g/L) \times F (L/hr)}{V(L)} = DX_2$$

$$DX_2 = kDX_1$$

$$(10) \quad \overset{\uparrow}{=} Y \left(S_0 D - \frac{kD^2 K_s}{\mu_m - kD} \right)$$

(9)

$$= Y \left(S_0 D - \frac{D^2 K_s}{\frac{1}{k} \mu_m - D} \right) \dots \dots (11)$$

Productivity

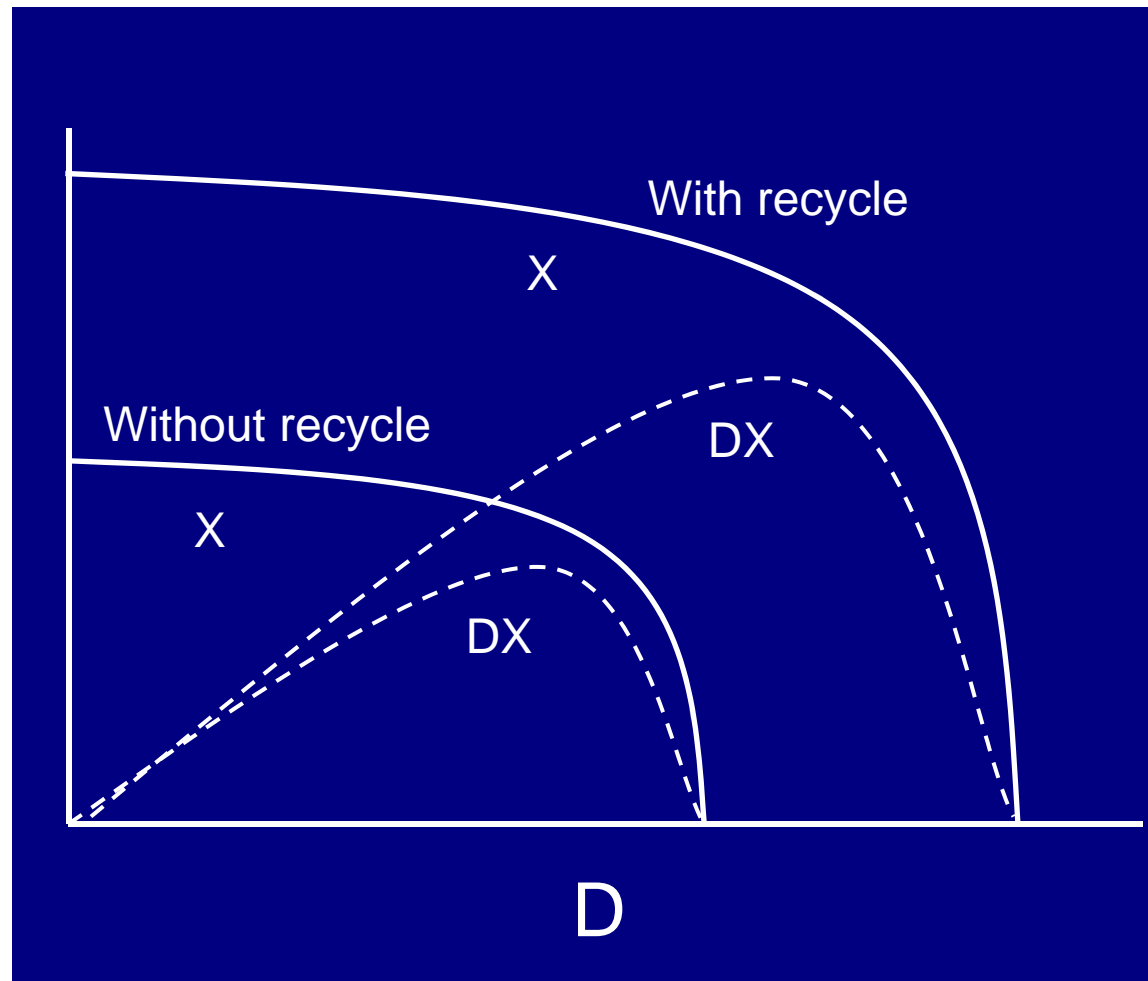
$$DX_2 = Y \left(S_0 D - \frac{D^2 K_s}{\frac{1}{k} \mu_m - D} \right) \dots\dots(11)$$

where $k = 1 + \alpha(1 - C) < 1 \quad \leftarrow C > 1$

Compare Eq.(11) with the productivity without cell recycle.

$$DX = Y \left(S_0 D - \frac{D^2 K_s}{\mu_m - D} \right)$$

Chemostat with Cell Recycle



Cell Recycle System

Cell concentrations and productivities are higher with cell recycle, resulting in higher rates of substrate consumption.

**Recycle system --- used extensively in waste treatment
--- increasing use in ethanol production**