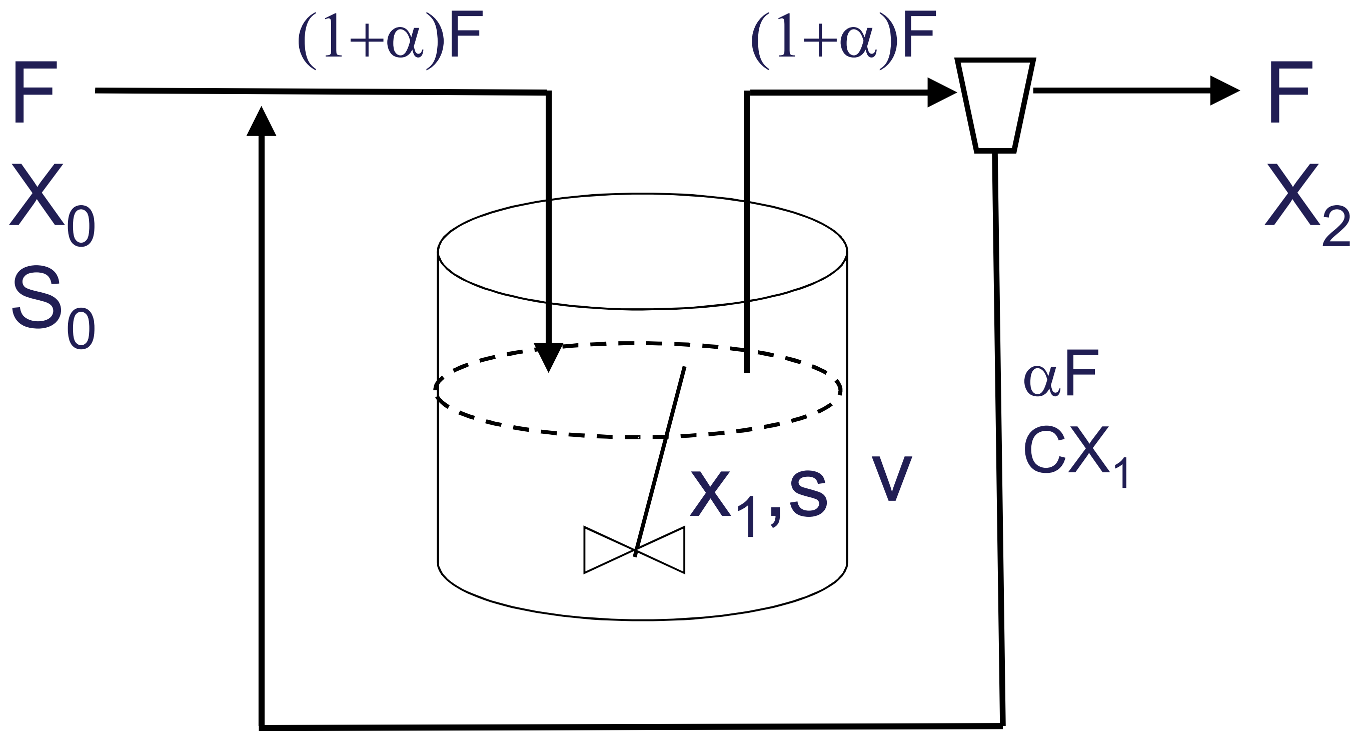
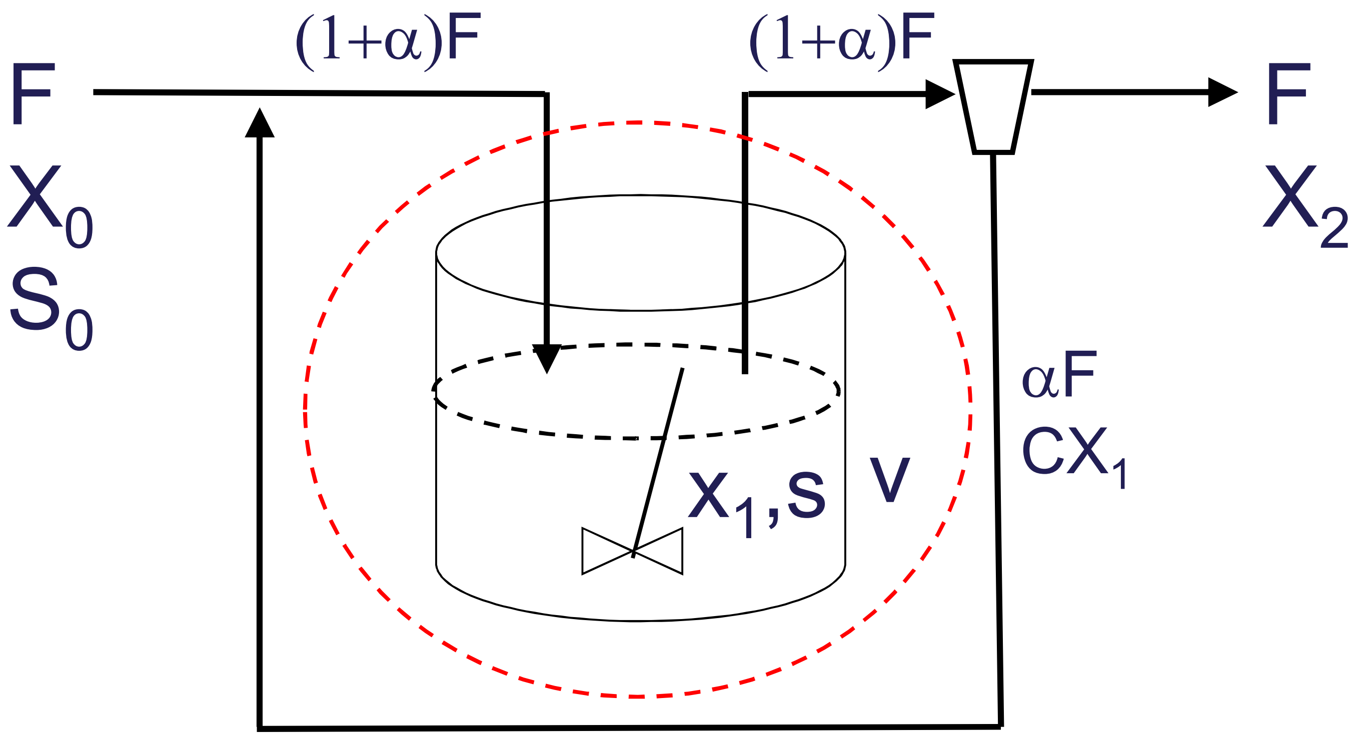
# Chemostat with Recycle



# 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

**Acc = In – Out + Gen – Con**

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

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

# Mass Balances

**- cell**

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

**At steady state**

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

# Mass Balances

**At steady state**

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

**/ V**

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

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

# At steady-state

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

**C > 1 → α(1-C) < 0 → 1+α(1-C) < 1**

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

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

# Mass Balances

**- substrate**

$$\frac{d(SV)}{dt} = S_0F + S\alpha F - S(1+\alpha)F - \frac{\mu X_1 V}{Y} \;.....(5)$$

**At steady state**

$$S_0D + S\alpha D - S(1+\alpha)D = \frac{\mu X_1}{Y}$$

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

**(3)**

**(6)** → 

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

# At steady-state

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

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)**

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

$$S=\frac{kDK_S}{\mu_m-kD}\text{........}(8)$$

where k= (1+α-αC)

# Concentrations at Steady State

(7) → $$X_1 = \frac{Y(S_0 - S)}{k}$$

↑

(8)

$$= \frac{Y}{k}\left(S_0 - \frac{kDK_S}{\mu_m - kD}\right) \quad \text{.........(9)}$$

where k= (1+α-αC)

# Mass Balances

**- Cell mass balance around the cell separator**

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

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

$$= kX_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

# Productivity

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

$$DX_2 = kDX_1$$

**(10)**

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

**(9)**

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

# Productivity

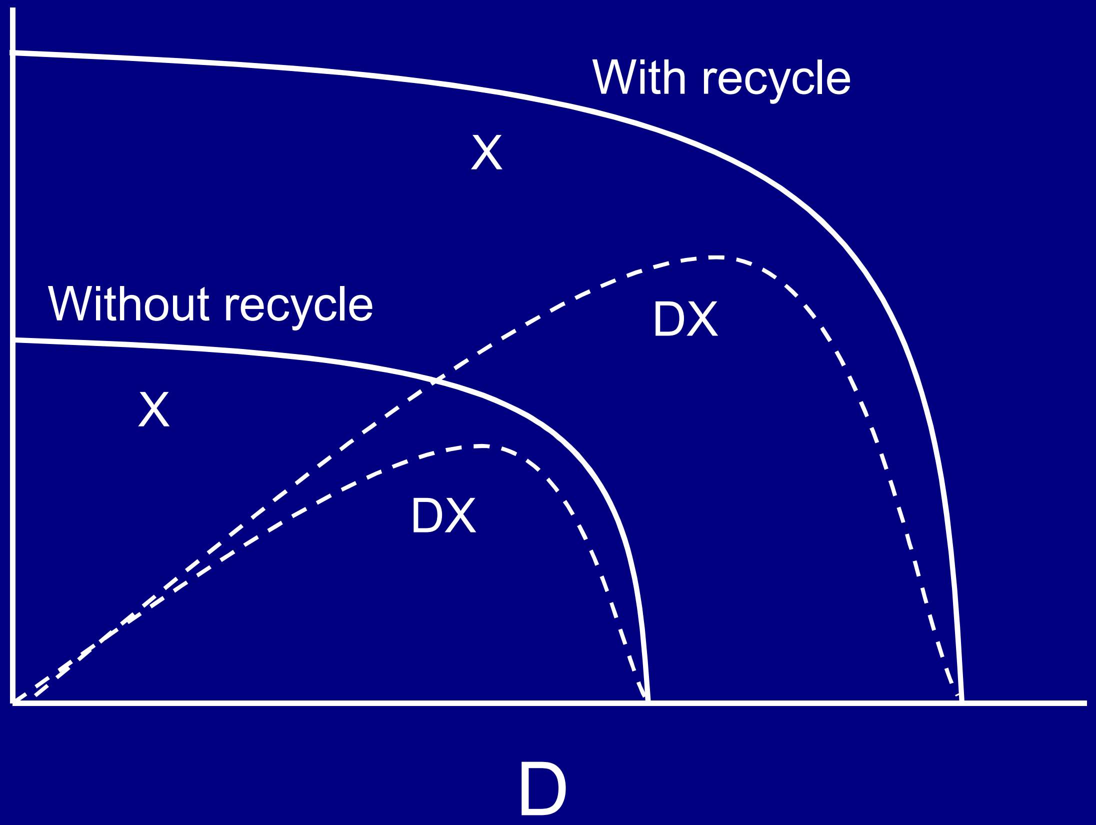
$$DX_2 = Y\left(S_0 D - \frac{D^2 K_S}{\frac{1}{k}\mu_m - D}\right) \text{.......}(11)$$

where k= 1+α(1–C)<1 ← C>1

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

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

# 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**