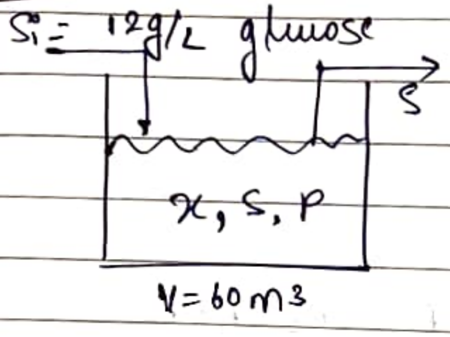
$$\frac{dx}{dt} = \frac{F}{V} x_i + x\left(\mu - k_d - \frac{F}{V}\right)$$

$$\frac{dx}{dt} = x(\mu - D)$$



Ethanol production by Z-mobilis. product synthesis is coupled to energy metabolism.

$\mu_{max} = 0.3 h^{-1}$

$K_s = 0.2\ g/L$

$m_s = 2.2\ g g^{-1} h^{-1}$ $q_p = 3.4\ h^{-1}$

$Y_{xs} = 0.06\ g g^{-1}$

$Y_{px} = 7.7\ g/g$ | $Y_{ps} = Y_{xs} Y_{px}$

Monod : $\mu = \frac{\mu_{max} s}{K_s + s}$

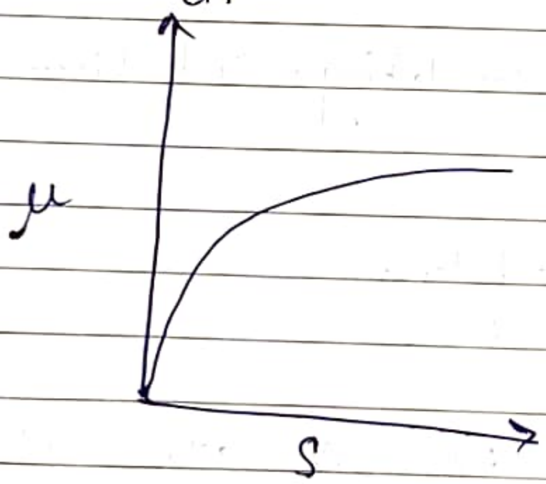
If $s = 1.5\ g/L$, find.

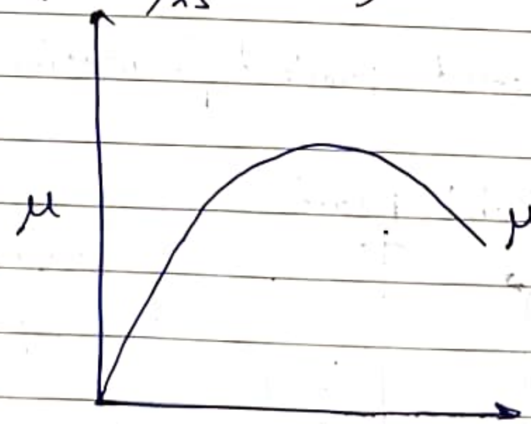
(a) F

(b) x

(c) P.

Sol^n (a) $\frac{d(sV)}{dt} = FS_i - FS - \left(\frac{\mu}{Y_{xs}} + m_s\right) xV$





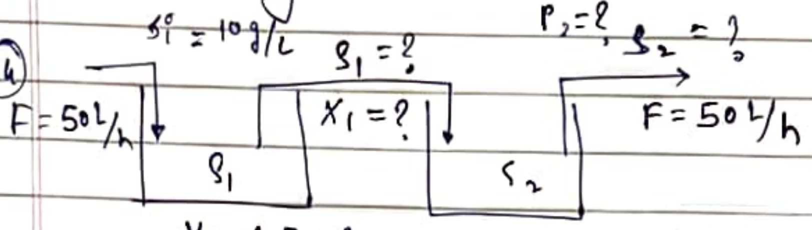
$\mu = \frac{\mu_{max} s}{K_s + s + \frac{s^2}{K_I}}$

K_I inhibitory constant

chemostat

→ Productivity in CSTR is more than batch reactor

(4)



$V_1 = 0.5\ m^3$ — only growth; product synthesis is ~~neglig~~ negligible

$V_2 = 0.5\ m^3$ — only product formation; growth is negligible.

$Y_{XS} = 0.5\ kg/kg$
$m_S = 0.025\ kg\,kg^{-1}h^{-1}$
$K_S = 1\ kg/m^3$
$\mu_{max} = 0.12\ h^{-1}$
$q_P = 0.16\ kg\,kg^{-1}h^{-1}$
$Y_{PS} = 0.85\ kg/kg$

Find
a) Overall substrate conversion?
b) final product concentration, P_2?

1st stage. $D = 50\times10^{-3}/0.5 = 0.1\ h^{-1}$

$$S = \frac{D K_S}{\mu_{max} - D} = \frac{0.1\times 1}{0.12 - 0.1} = 5\ g/L.$$

~~$x_1 = (S_i - S)Y_{XS} = (50-5)0.5 = 22.5\ g/L$~~

2nd stage

$$x_1 = \frac{D(S_i - S_1)}{\frac{D}{Y_{XS}} + m_s} = \frac{0.1\times(10-5)}{\frac{0.1}{0.5} + 0.025} = 2.2\ g/L$$

2nd stage

$$FS_1 - FS_2 - \left(\frac{\mu}{Y_{XS}} + \frac{q_P}{Y_{PS}} + m_s\right) x_1 V = 0$$

($S_1 = 5\ g/L$, $\mu = 0$, $x_1 = 2.2\ g/L$)

⇒ $S_2 = ?$ consider $\mu = 0$ $\quad S_2 \approx 0.3\ g/L$

overall substrate conversion $= \left(\frac{S_i - S_2}{S_i}\right)\times 100\% = 97\%.$

b) $FP_1 - FP_2 + q_P x V = 0$ ($P_1 = 0$)

$$P_2 = ? \quad \frac{q_P x V}{F} = \frac{0.16\times 2.2\times 0.5}{0.05} = 3.52\ g/L.$$

$$\frac{dx}{dt} = \mu x \; \frac{\mu_{max}}{k_s + S} x, \quad \mu = \mu_{max}$$

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$$\frac{ds}{dt} = -\left[\frac{\mu}{Y_{xs}} + \frac{q_p}{Y_{ps}} + m_s\right] x_0 e^{\mu_{max} t}$$

$$t_b = \frac{1}{\mu_{max}} \ln\left[1 + \frac{Y_{xs}}{x_0}(s_0 - s_f)\right]$$

integrate

$t=0, t=t_b$
$S=S_0, S=S_f$

$$t_b = \frac{1}{0.44} \ln\left[1 + \frac{0.41}{0.1}(0.98 \times 40)\right]$$

$$= 11.58 \text{ h}$$

Cell concentration at $t_b = x_f = x_0 e^{\mu_{max} t_b}$

$$= 0.1 e^{0.44 \times 11.55}$$

$$= 16.1 \text{ g/L / kg/m}^3$$

~~Total biomass in a batch~~ =

Mass of cells produced per batch $= (x_f - x_0) V = 16 \times 1000$

$$= 16 \times 10^3 \text{ kg}$$

$t_{total} = t_b + t_{downtime} = 11.55 + \cancel{7.2}\ 20$

$t_{total} = 31.55 \text{ h}$

No. of batches per year = 278

$\therefore$ Anual production $= 16 \times 10^3 \times 278$

$= 4448$ ton

for continous

$$x = (S_i - S) Y_{xs}$$

$$= (40 - 0.8)\, 0.41 = 16.072$$

$$\mu = D = \frac{\mu_{max} S}{k_s + S} = \frac{0.44 \times 0.8}{0.7 \times 10^{-3} + 0.8}$$

$$D = 0.4396 \text{ h}^{-1} \approx 0.44$$

$F = \frac{lit}{hr}$

$x = g/lit$

$F = DV$ g/hr

$$\text{Product} = F x (365 - 25) \times 24$$

$$= (0.4396 \times 1000)(16.072)(340)(24)$$

$$= 57654 \text{ ton}$$

$$S_i - \frac{D k_s}{\mu_{max} - D} = D\left[\frac{k_s(\mu_{max} - D) - k_s}{\mu_{max} - D}\right]$$

$$\boxed{D_{opt} = \mu_{max}\left[1 \mp \sqrt{\frac{k_s}{k_s + S_i}}\right]}$$

$$= \underline{0.36} \ \underline{h^{-1}}$$

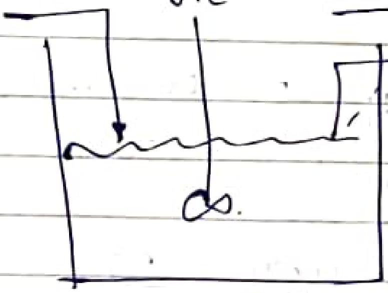
$$\boxed{D_{crit} = \frac{\mu_{max} S_i}{k_s + S_i}} = \frac{0.45 \times 20}{0.8 + 20} = \underline{\underline{0.4326 \ h^{-1}}}$$

$$\text{Max } DX = D\left[S_i - \frac{D k_s}{\mu_{max} - D}\right] Y_{xs}$$

$$= 0.36\left[20 - \frac{0.36 \times 0.8}{0.45 - 0.36}\right] 0.55$$

$$= \underline{3.3264}$$

(3) $S_i = 40$ g/L



$\rightarrow S = 0.8$ g/L

98% conversion is required

Single cell protein (biomass) production

$V = 1000$ m3

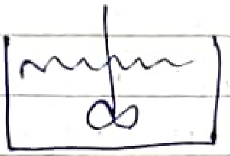
$\mu_{max} = 0.44 \ h^{-1}$

$k_s = 0.7$ mg/L

$Y_{xs} = 0.41$ g/g

Downtime = 25 days/year

Annual biomass production?



$S_0 \longrightarrow S_f$

Batch

inoculum $x_0 = 0.1$ g/L

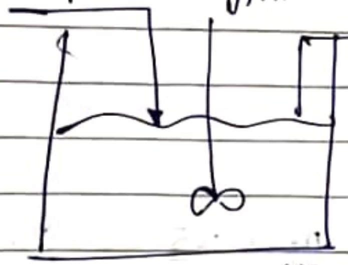
Downtime between batches = 20h

$Y_{xs} = \frac{r_x}{r_s}$ $\quad Y_{ps} = Y_{px} Y_{xs}$

$Y_{px} = \frac{r_p}{r_x}$

$S_i^{\circ} = 20\ kg/m^3 = 20\ g/L$

(2)



$\rightarrow$ 90% substrate conversion required

$\therefore S = 2\ g/L$

Neglect q_p, m_s

$\mu_{max} = 0.45\ h^{-1}$

$k_s = 0.8\ kg/m^3$
$= 0.8\ g/L$

$Y_{xs} = 0.55\ g\,g^{-1}$

90% conversion req. $\quad V = 5\ m^3$

a) $F = ?$, biomass productivity $= ?$ $\quad$ Dx

(b) Max. biomass productivity $= ?$

Sol^n

a) $\mu = D = \frac{\mu_{max} S}{k_s + S} = \frac{0.45 \times 2}{0.8 + 2} = 0.32$

$F = DV = 1.6\ \frac{m^3}{h}$

$FS_i - FS - \left(\frac{\mu}{Y_{xs}} x V\right) = 0$

$\frac{D(S_i - S)}{\mu / Y_{xs}} = x$

$x = (S_i - S) Y_{xs}$

$= (20 - 2)\, 0.55$

$\boxed{x = 9.9\ g/L}$

$\boxed{Dx = 0.32 \times 9.9 = 3.168\ g/L\,h}$

b) $Dx = D\left[S_i - \frac{D k_s}{\mu_{max} - D}\right] Y_{xs}$

$Dx = D\left[S_i - \frac{D k_s}{\mu_{max} - D}\right] Y_{xs}$

$\frac{dDx}{dD} = 0 \Rightarrow \left[S_i - \frac{D k_s}{\mu_{max} - D}\right] Y_{xs} + D Y_{xs}\left[0 - \left[\frac{k_s(\mu_{max} - D) - k_s}{(\mu_{max} - D)^2}\right]\right] = 0$

$$\frac{d(x\overset{0}{V})}{dt} = \overset{0 \text{ sterile feed}}{\cancel{F x_i}} - Fx + \mu x V$$

$(D - \mu)x = 0$

$$\Rightarrow \mu = D = \frac{\mu_{max} S}{k_s + S} = \frac{0.3 \times 1.5}{0.2 + 1.5} = \underline{0.2647}$$

$$\frac{F}{V} = \frac{\mu_{max} S}{k_s + S}$$

$$F = V\left[\frac{\mu_{max} S}{k_s + S}\right]$$

$$F = 15.88 \frac{m^3}{h}$$

b) $F(S_i - S) - \left(\frac{\mu}{Y_{xs}} + m_s\right) x V = 0$

$$x = \frac{F(S_i - S)}{V\left[\frac{\mu}{Y_{xs}} + m_s\right]}$$

$$= \frac{15.88[12 - 1.5]}{60\left[\frac{1}{0.06} \times D + 2.2\right]}$$

$$= \frac{0.2647[12 - 1.5]}{\left[\frac{0.2647}{0.06} + 2.2\right]}$$

$$\boxed{x = 0.42 \ g/L}$$

c) $\cancel{\frac{d(\overset{0}{p}V)}{dt}} = \cancel{F\overset{0}{P_i}} - FP + \cancel{q_p V x} (q_p x) V$

$$P = \cancel{\frac{q_p V x}{F}} = \cancel{3.4} \frac{(q_p x)V}{F}$$

$$P = \frac{q_p x}{D} = \frac{3.4 \times 0.42}{0.2647} = 5.395 \ g/L$$