



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

TUTORIAL ON FERMENTATION

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Problem 1.

During pre-treatment, 50 % of the mass of a lignocellulosic waste is converted to monosaccharides ($C_6H_{12}O_6$ and $C_5H_{10}O_5$) and disaccharides ($C_{12}H_{22}O_{11}$ and $C_{10}H_{18}O_9$) in the mass ratio of 6:4. The monosaccharides produce 510 g ethanol/kg monosaccharides, while the disaccharides produce 540 g ethanol / kg disaccharide. Assuming same mole ratio of both monosaccharides as well as disaccharides as 1:1 in the respective saccharide types, calculate the yield of ethanol with respect to total sugar and LCB. Also calculate the % contribution of each saccharide on the ethanol production.



Solution

Basis 100 kg of LCB

Monosaccharide and disaccharide produced = 50 kg

Mass ratio of monosaccharide and disaccharide is 6:4

Mass of monosaccharide ($C_6H_{12}O_6$ and $C_5H_{10}O_5$) = $6/10 * 50 = 30$ kg

Mass of disaccharide ($C_{12}H_{22}O_{11}$ and $C_{10}H_{18}O_9$) = $4/10 * 50 = 20$ kg

Since 1 kg monosaccharide produces 0.510 kg ethanol

Ethanol produced from monosaccharide = $30 * 0.51 = 15.3$ kg

Similarly ethanol produced from disaccharide = $20 * 0.54 = 10.8$ kg



Total ethanol produced = $15.3 + 10.8 = 26.1$ kg

Thus, Ethanol yield with respect to total sugar = $26.1/50 = 0.522$ kg ethanol / kg sugar

Ethanol yield with respect LCB = $26.1/100 = 0.261$ kg ethanol / kg LCB

Molecular weight of $C_6H_{12}O_6 = 12*6 + 1*12 + 16*6 = 180$

Molecular weight of $C_5H_{10}O_5 = 12*5 + 1*10 + 16*5 = 150$

Average molecular weight = $(180+150)/2 = 165$

Thus, number of moles of total monosaccharide = $30*1000/165 = 182$

Moles of $C_6H_{12}O_6 = C_5H_{10}O_5 = 182/2 = 91$

Thus, mass of $C_6H_{12}O_6 = 91 * 180/1000 = 16.38 \text{ kg}$

Similarly, the mass of $C_5H_{10}O_5 = 91 * 150/1000 = 13.65 \text{ kg}$

Therefore ethanol produced from $C_6H_{12}O_6 = 16.38 * 0.51 = 8.354 \text{ kg}$

And ethanol produced from $C_5H_{10}O_5 = 13.65 * 0.51 = 6.962 \text{ kg}$

Further,

Molecular weight of $C_{12}H_{22}O_{11} = 12*12 + 1*22 + 16*11 = 342$

Molecular weight of and $C_{10}H_{18}O_9 = 12*10 + 1*18 + 16*9 = 282$

Average molecular weight = $(342 + 282)/2 = 312$

Thus, number of moles of total disaccharide = $20*1000/312 = 64$

Moles of $C_{12}H_{22}O_{11} = C_{10}H_{18}O_9 = 64/2 = 32$



Thus, mass of $C_{12}H_{22}O_{11} = 32 * 342/1000 = 10.944$ kg

Similarly, the mass of $C_{10}H_{18}O_9 = 32 * 282/1000 = 9.024$ kg

Therefore ethanol produced from $C_{12}H_{22}O_{11} = 10.944 * 0.54 = 5.91$ kg

And ethanol produced from $C_{10}H_{18}O_9 = 9.024 * 0.54 = 4.873$ kg

% contribution of $C_6H_{12}O_6 = 8.354 * 100 / 26.1 = 32$

% contribution of $C_5H_{10}O_5 = 6.962 * 100 / 26.1 = 26.7$

% contribution of $C_{12}H_{22}O_{11} = 5.91 * 100 / 26.1 = 22.6$

% contribution of $C_{10}H_{18}O_9 = 4.873 * 100 / 26.1 = 18.7$

Problem 2.

A food waste is digested through thermochemical as well as biochemical routes. In the first case the energy requirement is 30 % higher than the 2nd case. Whereas the sugar production per unit mass of food wastes is 20 % more in 1st case than that of 2nd case. Compare the pretreatment energy efficiency for these two routes.

Solution

We know that

$$\eta = TSY / TEC$$

where, η = Pretreatment energy efficiency (kg/MJ);

TSY = Total soluble (monomeric) sugar yield (kg);

TEC = Total energy consumption during pretreatment(MJ)

Assume the mass of the food wastes = 100 kg

Biochemical routes uses X MJ of power and produces Y kg of sugar from 100 kg wastes

Thermochemical route uses $X*1.3$ MJ of power and produces $Y*1.20$ kg of sugar from 100 g wastes

Pre treatment energy efficiency for biochemical route = Y/X (kg/MJ)

Pre treatment energy efficiency for thermochemical route = $1.2*Y/1.3*X$ (kg/MJ)
 $= 0.92 *(Y/X)$

Therefore, the pre treatment energy efficiency for thermochemical route = 92 % of that of biochemical route



Problem 3

Eight percentage slurry of monosaccharides containing glucose and xylose in the mass ratio of 6:4 is converted to ethanol in fermenter having a working volume of 100 L. If the maximum conversion of glucose and xylose are 90 % and 70 % respectively after 2 h of operation. Determine the ethanol yield and productivity.

Solution

(density of the solution is assumed as 1 kg/L) & sugar concentration is 8%

Basis: 100 L solution = 100 kg solution = $100 \times 0.08 = 8$ kg monosaccharide

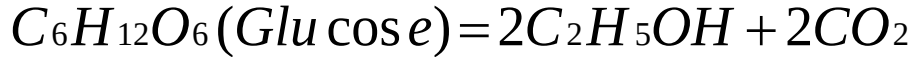
Glucose = $8 \times 0.6 \text{ kg} = 4.8 \text{ kg}$

Glucose converted = $4.8 \times 0.9 = 4.32 \text{ kg}$

Xylose = $8 \times 0.4 \text{ kg} = 3.2 \text{ kg}$

Xylose converted = $3.2 \times 0.7 = 2.24 \text{ kg}$

Fermentation reaction for glucose



$$\begin{aligned} &6 \cdot 12 + 12 \cdot 1 + 16 \cdot 6 \\ &= 72 + 12 + 96 \\ &= 180 \text{ g} \end{aligned}$$

$$\begin{aligned} &2 \cdot (12 \cdot 2 + 6 \cdot 1 + 16 \cdot 1) \\ &= 2 \cdot (24 + 6 + 16) \\ &= 92 \text{ g} \end{aligned}$$

$$\begin{aligned} &2(12 + 16 \cdot 2) \\ &= 2 \cdot (44) \\ &= 88 \text{ g} \end{aligned}$$

Therefore 4.32 kg glucose produces $(92/180) \cdot 4.32 \text{ kg}$ of ethanol = 2.208 kg of ethanol

Fermentation reaction for xylose



$$\begin{aligned} &3(5 \cdot 12 + 10 \cdot 1 + 16 \cdot 5) \\ &= 3(60 + 10 + 80) \\ &= 450 \text{ g} \end{aligned}$$

$$\begin{aligned} &5 \cdot (12 \cdot 2 + 6 \cdot 1 + 16 \cdot 1) \\ &= 5 \cdot (24 + 6 + 16) \\ &= 230 \text{ g} \end{aligned}$$

$$\begin{aligned} &5(12 + 16 \cdot 2) \\ &= 5 \cdot (44) \\ &= 220 \text{ g} \end{aligned}$$

Therefore 2.24 kg xylose produces $(230/450) \times 2.24$ kg of ethanol = 1.145 kg of ethanol

Total ethanol produced = $2.208 + 1.145 = 3.353$ kg

Ethanol concentration = $3.353 \text{ kg} / 100\text{L} = 33.53(\text{g/L})$

Ethanol yield

$$Y_{\text{EtOH}} = \frac{CV}{m}$$

$$= (33.53(\text{g/L}) \times 100 (\text{L})) / 8(\text{Kg})$$

$$= 419 \text{ g/Kg}$$

Where, Y_{EtOH} is ethanol yield (g/kg),

C is ethanol concentration (g/L),

V is initial volume of liquid medium (L),

and m is the mass of the substrate (kg).

$$Q_{EtOH} = \frac{CV}{mt} = \frac{1000Y_{EtOH}}{t} \quad (6.11)$$

Where, Q_{EtOH} is the ethanol productivity (mg/kg h), and t is the time at which the ethanol concentration produced on substrates is maximum (h).

In the present case Productivity = $1000 * 419 / 2$ (mg/Kg h) = 209500 mg/Kg h

Thanks...

