



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

TUTORIAL ON ANAEROBIC DIGESTION

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Problem 1

In a high rate biogas plant food waste is anaerobically digested to produce biogas. The slurry contains 8 % of solid food grains. The elemental composition of the food grains on dry basis is C: 58%, H:8%, O:26%, N:8% (mass basis). Around 80 % of the food grains are converted to biogas and all the converted hydrogen forms methane. If the flowrate of the slurry is 4500 litre per day, calculate the rate of biogas ($\text{CO}_2 + \text{CH}_4$) production.

Solution

Basis

Flow rate of the slurry = 4500 L

Dry solid food grains used
= $4500 \times 0.08 = 360 \text{ kg}$

Assuming density of slurry = 1 kg/L

C present in 360 kg dry food grains = $360 \times 0.58 = 208.8 \text{ kg}$

H present in 360 kg dry food grains = $360 \times 0.08 = 28.8 \text{ kg}$

O present in 360 kg dry food grains = $360 \times 0.26 = 93.6 \text{ kg}$

N present in 360 kg dry food grains = $360 \times 0.08 = 28.8 \text{ kg}$



Since 80 % food grains are converted to biogas

C converted to biogas = $0.8 * 208.8 \text{ kg} = 167.04 \text{ kg}$

H converted to biogas = $0.8 * 28.8 \text{ kg} = 23.04 \text{ kg}$

Since all the H is converted to CH_4 ,

The methane production = $(16/4) * 23.04 \text{ kg} = 92.16 \text{ kg} = 5.76 \text{ kmole}$

C used for methane production = $92.16 * (12/16) \text{ kg} = 69.12 \text{ kg}$

C used for CO_2 production = $167.04 - 69.12 \text{ kg} = 97.92 \text{ kg}$

CO_2 produced = $97.92 * (44/12) \text{ kg} = 359.04 \text{ kg} = 8.16 \text{ K mole}$

$\text{CH}_4 + \text{CO}_2 = 92.16 \text{ kg} + 359.04 \text{ kg} = 451.2 \text{ kg}$

Or $5.76 + 8.16 = 13.92 \text{ Kmole}$



Problem 2

In the above plant the effluent from the digester is used for the production of manure through composting. If 75 % of the organic compounds present in the effluent are converted to manure, what is the rate of manure production?

Solution

Organic compounds present in the digested effluents = $360 \text{ kg} \times 0.2 = 72 \text{ kg}$

Manure production = $72 \times 0.75 \text{ kg} = 54 \text{ kg per day}$ (considering no mass change due to microbial action during manure production)



Problem 3

A family having 15 cows of bodyweight 200 kg each and 20 chicken of body weight 1.5 kg each, wants to setup a bio-gas production plant. What should be the volume of the anaerobic digestion unit suitable for this application and mention volume of various zones of the unit. Assume discharge per day of each cow is 10 kg and TS value is 16 % of the discharge. Similarly for chicken these values are 0.1 kg per day and 20 % respectively. HRT is 40 days. Daily gas production rate is $0.28 \text{ m}^3/\text{kg TS/day}$ or $0.4 \text{ m}^3/\text{digester volume per day}$. If total volume of the digestion unit (V) is related with the diameter of the cylindrical portion as $D = 1.3078 V^{1/3}$, calculate the height of the cylindrical part of the unit assuming its volume as $V_3 = 0.3142 D^3$. Also calculate the volume of sludge zone, active digestion zone, gas collection zone and gas storage zone.



Solution

$$\text{Total discharge} = 15 * 10 + 20 * 0.1 \text{ kg} = 150 + 2 = 152 \text{ kg}$$

$$\text{TS in total discharge} = 150 * 0.16 + 2 * 0.2 = 24.4 \text{ kg}$$

8 kg of TS is required to make 100 kg slurry (Since 8 % slurry is required for AD)

Hence 24.4 kg TS will be available in $(100/8) * 24.4 \text{ kg} = 305 \text{ kg slurry} \sim 305 \text{ L}$ (slurry density = 1 kg/L)

Thus, water to be added with 152 kg of discharge = $305 - 152 \text{ kg} = 153 \text{ kg}$

Now

Gas storage volume(V_{gst}) + active digestion volume(V_d) = Slurry feeding rate (Q)*HRT

$$V_{gst} + V_d = \text{Slurry feeding rate (Q)} * \text{HRT}$$

$$V_{gst} + V_d = 305 \text{ (L/day)} * 40 \text{ day} = 12200 \text{ L} = 12.2 \text{ m}^3$$



Again

$$V_{gst} + V_d = 0.8 * V \quad \Rightarrow \quad V = 12.2 / 0.8 \text{ m}^3 = 15.25 \text{ m}^3$$

$$\text{Given } D = 1.3078 V^{1/3} = 1.3078 * (15.25)^{(1/3)} = 3.24 \text{ m}$$

Further

$$V_3 = 0.3142 D^3 = \pi \left(\frac{D^2}{4} \right) * H \quad \Rightarrow \quad H = (0.314 * 4 * D) / \pi = (0.314 * 4 * 3.24) / \pi = 1.29 \text{ m}$$

$$V_{col} = 0.05 V = 0.05 * 15.25 \text{ m}^3 = 0.7625 \text{ m}^3$$

$$\text{Assuming } V_{sl} = 15 \% \text{ of } V = 15.25 * 0.15 = 2.288 \text{ m}^3$$

$$V_{gst} = 0.5 * (V_{gst} + V_d + V_{sl}) * K = 0.5 * (V - V_{col}) * K = 0.5 * (15.25 - 0.7625) * 0.4 = 2.898 \text{ m}^3$$

Alternatively,

$$\begin{aligned} V_{gst} &= 50 \% \text{ of daily gas yield} = 0.5 * TS * \text{gas production rate (m}^3 \text{ per kg TS/day)} \\ &= 0.5 * 24.4 * 0.28 \text{ m}^3/\text{kg TS} = 3.416 \text{ m}^3 \end{aligned}$$

Thus conservative value of $V_{gst} = 3.416 \text{ m}^3$

Now

$$V_d = (V - V_{gst} - V_{col} - V_{sl}) = 15.25 - 3.416 - 0.763 - 2.288 = 8.738 \text{ m}^3$$

Thanks...

