Design of Upflow Anaerobic Sludge Blanket (UASB) reactor for Jam Industry Wastes

M.M.C.Rajivgandhi [1] and M.Singaravelu [2]
[1]Research scholar, [2]Professor, Department of Bioenergy,
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore- 641 003.

Abstract

Upflow Anaerobic Sludge Blanket (UASB) reactors have been widely used for the treatment of industrial wastewater. An Upflow Anaerobic Sludge Blanket Reactor was designed to handle 8,800 liters per day of the influent and field tested for energy production from biomethanation of papaya fruit processing jam industry wastes. The reactor has the total height of 5.4 m and diameter of 1.6 m. Effective volume and total volume of the reactor are 8.84 m^3 and 10.8 m^3 respectively. The optimum organic loading rate (OLR) observed to be 2.67 kg of COD. m^{-3} day^{-1}, when the reactor was operated at three days HRT. The COD removal efficiency is 70 % and the specific gas production is 0.577 m^3 kg^{-1} of COD removed per day.

Keywords: *Biomethanation, Fruit wastes, UASB reactor, UASB design*

1. Introduction

Upflow Anaerobic Sludge Blanket (UASB) reactor in the late 1970s in the Netherlands by Lettinga. UASB process is used most commonly, with over 1500 installations treating wide range of industrial waste waters.

Papaya and pineapple are the fruits which are widely being processed for manufacturing the finished products such as jam, jelly, etc. Utilization of these commodities results in 30 to 35 % of waste generation (Rajivgandhi *et al.*, 2013). These wastes are either uneconomically utilized or disposed of as such, thereby causing serious pollution problems.In recent years, attention is being given to treating the fruit wastes and waste water chemically or biologically to obtain useful by-products before the final disposal. Of the many alternatives, biomethanation of fruit wastes is the best suited treatment, as the process not only adds energy in the form of methane, but also results in a highly stabilized effluent which is almost neutral in pH and is odourless (Bardiya *et al.*, 1996). Fruit-processing wastes are highly biodegradable as they are rich in organic matter and have a high (above 50%) moisture content. It has been established that bio-conversion processes are more suitable than thermo-conversion processes. So, there exists a vast scope for the energy recovery as well as waste management, through establishment of proper design of biomethanation plants for the fruit industries.

2. Materials and methods

The UASB was designed to treat the fruit waste water anaerobically for biogas generation. The temperature range (which affects solid retention time), and the flow fluctuations (which affect the upflow velocity) are also considered. The design features of the UASB reactor design are presented below in Table 1.

Table 1.Important design features of UASB reactor

S. No	Parameters	Assumptions	Ref.
1.	Solid retention time	40 days	[6]
2.	Temperature of reactor	20º - 32º C	[4]
3.	BOD removal yield coefficient	0.1 g VSS /g $BOD_{removed}$	[2]
4.	Degradable residues of VSS coming in the inflow	90%	[6]
5.	COD removal efficiency	80 %	[6]
6.	Reactor height	4 – 5.9 m	[2]
7.	Average concentration of sludge in blanket	75 %	[2]
8.	Effective depth of sludge blanket	2.2 m	[2]
9.	Theoretical CH_4, m^3 / kg COD removed	0.35 m^3	[2]

Analysis

Parameters like pH, total solids (TS), volatile solids (VS), total suspended solids (TSS), volatile suspended solids (VSS) and Chemical Oxygen Demand (COD) were analyzed as per the APHA (1998) methods.

3. Results and discussion

The physico-chemical characteristics of the fruit wastewater and mixtures of solid and liquid wastes were analyzed. The pH of the fruit wastewater is observed to vary from 4.02 to 5.9.

The total solid content of the fruit wastewater is found to vary between 1375 and 1625 mg L^{-1} and the volatile solid content varies between 1130 and 1326 mg L^{-1}. The BOD of the fruit wastewater is found to vary between 1250 and 1610 mg L^{-1} and the COD varies between 3000 and 3800 mg L^{-1}. The BOD: COD ratio was determined and it is found to vary between 0.41 and 0.42. The Total Kjeldahl Nitrogen (TKN) is observed to vary from 2.4 to 3.4 mg L^{-1}. The value of TOC varies from 1290 to 1310 mg L^{-1}. The C: N ratio of the waste water is found to vary from 35.2 to 36.4.

3.1 Design of the reactor

The physico – chemical characteristics of the sludge bed play a key role in deciding the biomethanation capacity of the reactor. The amount of daily deposition of sludge depends on the characteristics of raw waste water. The design of the reactor is accomplished as described below,

3.1.1 Total Sludge Production

i) New VSS produced as a result of BOD removal, the yield coefficient assumed as 0.1 g VSS/g BOD removed.

$$\text{New VSS produced in BOD Removal, (mg/L)} = \begin{bmatrix} \text{Influent BOD, (mg/L)} \times \text{BOD} \\ \text{Removal (\%)} \times \text{Yield coefficient,} \\ \text{(g VSS/g BOD removed)} \end{bmatrix}$$

,ii) The non-biodegradable residue of the VSS coming in the inflow is given by

Non-degradable residue, (mg/L) = VSS,(mg/L) ×(1- degradable fraction)

iii) Ash received in the inflow can be calculated as

New Ash received in the inflow, (mg/L) = TSS, (mg/L) – VSS, (mg/L)

The sum of the above three components gives total sludge produced per day

$$\text{Total sludge produced,(kg/day)} = \begin{bmatrix} \text{New VSS produced in BOD removal, (mg/L)} + \\ \text{Non - degradable residue, (mg/L)} + \\ \text{Ash received in the inflow, (mg/L)} \end{bmatrix}$$

3.1.2 Solid Retention Time

The solid retention time of a system also depends on the characteristics of the wastewater

$$\text{Solid retention time, (days)} = \frac{\text{Total quantity of sludge present in the reactor, (kg)}}{\text{Quantity of sludge removed per day, (kg/day)}}$$

$$\text{SRT, (days)} = \frac{\begin{pmatrix} \text{Average Concentration of sludge in the blanket, (kg/m}^3) \\ \text{x Effective depth of the sludge blanket, (m)} \\ \text{x Effectiveness coefficient, (\%)} \\ \text{x Hydraulic Retention time, (h)} \end{pmatrix}}{\text{Total quantity of sludge produced, (mg / L)}}$$

3.1.3 Hydraulic retention time (HRT)

$$\text{Hydraulic retention time} = \frac{\text{Solid retention time} \times \text{Total quantity of sludge produced} \times 24}{\begin{bmatrix} \text{Average concentration of sludge in the blanket} \times \\ \text{Effective depth of the sludge blanket} \times \\ \text{Effectiveness coefficient} \end{bmatrix}}$$

3.1.4 Upflow velocity

$$\text{Upflow Velocity, (m/h)} = \frac{\text{Reactor Height, (m)}}{\text{Hydraulic Retention, Time (h)}}$$

The liquid upflow velocity in the reactor is directly related to reactor height. In a conventional UASB system, the average daily value of liquid upflow velocity for domestic wastewater should not exceed 0.7 m/h (Lettinga and hulshoff Pol, 1991).

3.1.5 Area of Reactor

A cylindrical reactor was considered and the area of the reactor can determined as follows:

$$\text{Cross sectional area of reactor, (m}^2) = \frac{\text{Flow rate, (m}^3\text{/h)}}{\text{Upflow velocity, (m/h)}}$$

3.1.6 Diameter of the reactor

$$\text{Reactor area, (m}^2) = \frac{\pi}{4} \times d^2$$

The designed reactor has the total height of 5.4 m and diameter of 1.6 m. Effective volume and total volume of the reactor are 8.84 m^3 and 10.8 m^3, respectively. Schematic diagram of UASB reactor shown in Fig.1.

The influent with COD load of 5000, 8000 and 11000 mg L^{-1} were tested for each of the hydraulic retention time's viz. 1 day, 3 days and 5 days. The optimum organic loading rate (OLR) observed to be 2.67 kg of COD. m^{-3} day^{-1}, when the reactor was operated at three days HRT. The COD removal efficiency is 70 % and the specific gas production is 0.577 m^3 kg^{-1} of COD removed per day.

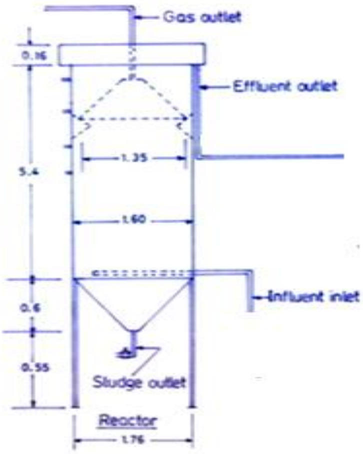

Fig 1. Schematic diagram of UASB reactor

3.2 Cost Economics

The cost economics is the most important consideration of any proposed engineering system. The total cost of the plant (fabrication cost of the reactor, installation of the reactor, slurry pump, pipelines and other accessories) is Rs.80,000. Daily gas production is 10 m^3 day^{-1}, which amounts to a value of Rs. 52,920/ year. The reactor produces 2010 kg of sludge in a year, which gives an income of Rs. 24,120/ year. From the estimation it is seen that the reactor has the payback period of 3 to 4 years.

4. Conclusions

The results obtained on biomethanation of papaya fruit processing wastes reveal that the anaerobic treatment of papaya fruit wastes is technically feasible. The energy generated in the form of methane, when utilized efficiently, not only improves the overall economy of these fruit processing industries, but also provides onsite solutions to waste management problems.

5. References

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