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Biogas Production from Kitchen Waste Water using USAB Reactor

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Abstract: The appropriate management of available water resources is becoming more important due to the scarcity of water as the population increases. Therefore implementations of these concepts a waste stream such as domestic waste water become an important source of re-usable water. Considering a presence scenario there is a peak demand for energy in our country. Energy from the waste is one of the best methods to overcome this problem. Biogas production from the kitchen wastewater by anaerobic digestion was investigated. The waste water has been taken from the college canteen. The mathematical model has been developed for batch process to determine the biogas production. The experimental work has been done in 1 liter anaerobic digestion tank. The biogas yield from the experimental work has been compared with mathematical model. For the hydraulic retention time of 10 days at 30^{o}C and the organic loading rate of 1500 mg/l, it was found that biogas production of 2ml/day. pH and TSS has been monitored in the process. The potential of biogas generation has been calculated for the college canteen waste water. Cost reduction has been calculated based on the replacement of LPG.
Keywords: Anaerobic digestion, biogas yield, kitchen waste water, organic loading, LPG.

Introduction

India is world's eleventh largest energy producer currently and accounts for nearly 2.4% of the world's total energy production and 3.7% of the world's total annual energy consumption which makes it the sixth largest energy consumer. Due to scarcity of petroleum and coal it threatens supply of fuel throughout the world also problem of their combustion leads to research in different corners to get access the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal, hydro sources of energy and biogas are all renewable energy resources. But, biogas is distinct from other renewable energies because of its characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply[1-5].

The origin of biogas starts from l0th century in Assyria for heating bath water. In 17th century that flammable gases could evolve from decaying organic matter. Count Alessandro Volta concluded in 1776 that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced. In 1808, Sir Humphry Davy determined that methane was present in the gases produced during the AD of cattle manure. The first digestion plant was built at a leper colony in Bombay, India in 1859. AD reached England in 1895 when biogas was recovered from a "carefully designed" sewage treatment facility and used to fuel street lamps in Exeter. The development of microbiology as a science led to research by Buswell and others in the 1930s to identify anaerobic bacteria and the conditions that promote methane production. There are two types treatment is done for effluents i.e. aerobic treatment and anaerobic treatment, but in aerobic treatment external energy is needed for aeration also there is excess sludge production in aerobic treatment. Anaerobic treatment is widely applicable for treating high strength waste water. It does not require external energy and itself produces energy in the form of methane gas [6-12].

Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several order of magnitude as said earlier. It means higher efficiency and size of reactor and cost of biogas production is reduced. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences: It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming. Mankind can tackle this problem(threat) successfully with the help of methane , however till now we have not been benefited, because of ignorance of basic sciences – like output of work is dependent on energy available for doing that work. This fact can be seen in current practices of 9 using low calorific inputs like cattle dung, distillery effluent, municipal solid waste (MSW) or sewage, in biogas plants, making methane generation highly inefficient. We can make this system extremely efficient by using kitchen waste/food wastes[9,13].

USAB is one of the anaerobic treatment converts the waste water organic pollutants into small amount of sludge and large amount of biogas as a source of energy. Anaerobic treatment converts the waste water organic pollutants into small amount small amount of sludge and large amount of biogas as source of energy for aeration. The upflow anaerobic sludge blanket (USAB) reactor is by far most widely used high rate of anaerobic treatment system for verity of wastewater. However the anaerobic digestion of solid organic materials such as biomass takes place a long time using currently available methods. The degradation of particles into soluble substrates is the rate-limiting step during anaerobic digestion; thus, liquidization pretreatment with subsequent anaerobic digestion of the liquid phase could be enable faster digestion of solid organics [5,6,14-20].

In this project we are going to produce biogas from kitchen waste and to reuse the waste water. Theoretical calculation has been made for the batch reactor and experimental work has been done for the batch reactor to study the various factor involving in the biogas production.

Methods and Materials Collected

Raw Materials Collection

The kitchen waste is collected from our college canteen to produce Biogas for our kitchen purpose. It is collected as slurry form is shown in (Figure- 1).

Figure 1: Sources of Kitchen Waste

Digester has designed for the capacity of 1L. In this method the inlet pipe is fixed at the bottom of the digester and the biogas outlet is designed at top if the bottle. Here final waste collection outlet is fed at top of the bio digester for collection as a Biofertilizer to agriculture lands The gas will be collected on the bio digesters and then they collected at the separate collector. The gas was measured by water displacement method. The final unit has a measuring jar to collect the water.

Methods

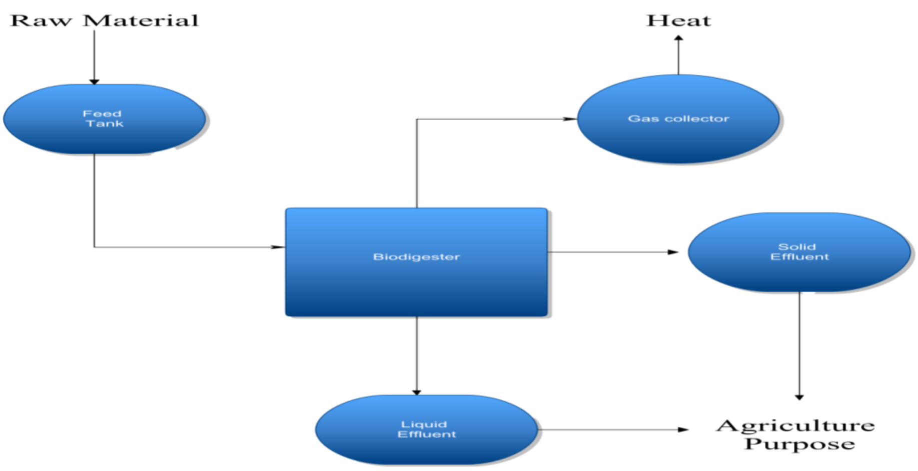
The kitchen waste water has been treated using the batch anaerobic digestion. The digesters are loaded with substrate completely and after some determined digestion time are fully unloaded. For this loading method any design of biogas plant and any type of substrate can be used, but such plants are distinguished by unstable biogas production.

In the batch process the feeds are sending as in liquid form. The kitchen waste is diluted with the warm water and nutrients are added to the feed tank. The anaerobic digester is charged and the process will be stabilized at 10 days at normal temperature. The anaerobes are naturally colloidal substance because of the formation of the gas bubbles within the liquid presented in the digester. Anaerobic digestion is carried out in an oxygen free environment. Anaerobic fermentation involving the degrading of the waste by the action of various microbes of different size and functions, leading to the production of biogas in the absence of oxygen was achieved.

Figure 2: Experimental setup of batch digester

Anaerobic decomposition is a two stage process as specific bacteria feed on contains organic materials. In the first stage, bacteria are converting the complex organic molecules into peptides, glycerol, alcohol and the simpler sugars. In second type bacteria are starts to convert these simpler compounds into methane. These methane producing bacteria are particularly influenced by the ambient condition. The Methanogenesis process is always slow growth processes the organisms of the Methanogen bacteria can be produce biogas. The 33% of total biogas will be produced in the first 5 days; another 25% in the second 3 days and the remainder of the biogas production will be spread over the remaining days. The main part of the biogas (methane) being produced in the first stage and the second stage is collection of Bio fertilizer, but still producing 90% of the total biogas. The collection of biogas is monitored by water displacement method. The effluent will be collected on separately. And this will also preserve the nitrogen level in the slurry for use as fertilizer. Flow chart for the batch digestion process given in the (Figure- 3).

Figure 3: Flow chart for batch process



Substrate Preparation and Stabilization

The nutrient medium was prepared at the proper concentration as given the (Table- 1). Then nutrient medium was used as inoculums. Initially, the cow dung mixed kitchen waste water is feed to the digester.

Table 1: Substrate Concentration

S. No	Parameters	Concentration (mg/L)
1	Glucose	5000
2	Urea	600
3	Magnesium sulfate	500
4	Ferric Chloride	2.5
5	Calcium chloride	3.5

Table 2: Anaerobic Process Stabilization Schedule

S. no	Organic Load to UASB (%)	Periods of Loads (day)
1	5	2
2	10	3
3	20	4
4	30	5
5	40	6
6	50	7
7	60	8
8	70	9
9	80	10
10	90	12
11	100	Continous

The reactor is started with cow dung and food wastes then we are getting result of biogas yield from this organic waste after 8 days. Based on the (Table- 2), organic loading the rate is increasing slowing to stabilize the digester. Once the system gets stabilized, we can load the kitchen waste to produce the biogas. Fresh kitchen waste was collected from the canteen. 1L of canteen waste was screened through a sieve 100 mesh size. Then, the prepared substrate was used as inoculums. The working volume of the bioreactor was maintained at 1L and run under uncontrolled pH, which is without acid or base addition. Experiment was carried out at mesophilic temperature of 30 to 35. The system was started up as batch to achieve an active acidifying culture by loading the substrates. The Hydraulic Retention Time (HRT) was maintained at the 15 days in the bioreactor. The design parameter of batch reactor discussed in (Table- 3)

Table 3: Design Parameters

Composition / Parameters	Unit	Quanitity
pH	mg/L	7.5
COD	mg/L	1500
BOD	mg/L	800
TSS	mg/L	0.4
TEMPERTURE	^{o} C	30-40
TANK CAPACITY	L	1

Design Calculation Solid Retention Time (Q)

Q_c (min) = 1/YK ×Ks + So/So

Where,

Y = Bio gas yield coefficient
K = constant (4.6) maximum substrate utilization.
K_s = substrate concentration at one half, specific substrate utilization S_o = COD of sludge
Q_c (max) = safety factor X minimum SRT
Qc =solid retention time, QC

Biomass Produced Per Day (Px)

$Y_{obs} = Y_T/1+K_d\theta c$
Vss Reduction
VSS = Q (S_o-S)

Methane Production

CH_4 generated = methane production at 0.40m3/Kg of COD Stabilized at 35c*VSS reduction. Methane production from Biomass in given in (Table- 4)

Table 4: Methane Production

Solid Retention Time	**Biomass Produced Per Day**	**Vss Reduction**	**Methane Production**
15days	**0.**47 Kg/dl	1.43 Kg/d	0.084 L/d

Result and Discussion for Batch Process

The digestion performance of cow dung was investigated based on the results obtained from the process monitoring for: VS reduction, TS reduction, VS/TS ratio, pH, alkalinity, acidity and biogas production with its methane content. Although, variations in reactor performance were observed in the period of digestion, the observed pH of 6.6 to 7.8 were primarily within the acceptable range for anaerobic digestion for the entire operation. This implies average buffering capacity of the mixed substrate. Generally, degradation of substrate starts between day one today three before it commences the production of biogas in the batch operation and the batch process values are given in (Table- 5).

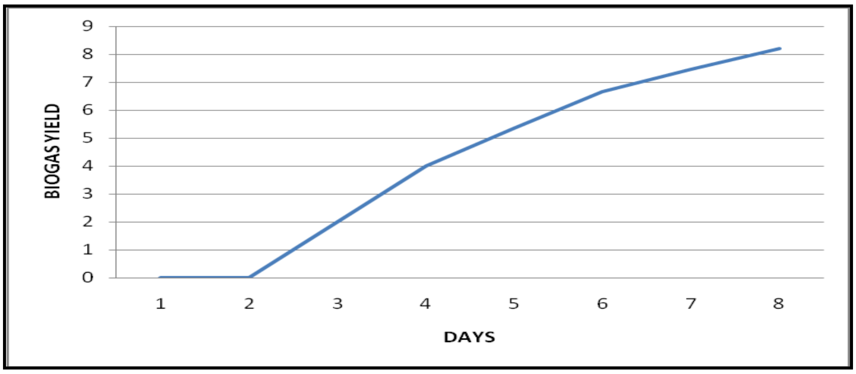
Table 5: Batch Process Values

DAY	**p^H**	**T^oC**	**COD (mg/l)**	**BOD (mg/l)**	**TSS (g)**	**Biogas Yield (ml)**	**Cumulative Biogas Yield (ml)**
1	7.9	36	1500	600	0.4	0	0
2	7.8	36	1500	600	0.4	0	0
3	7.5	36	1200	500	0.3	2	2
4	7.4	37	1200	500	0.3	2	4
5	7.2	35	900	450	0.2	1.33	5.33
6	7.01	34	700	370	0.2	1.33	6.66
7	6.8	36	500	210	0.12	0.8	7.46
8	6.6	35	380	180	0.11	0.73	8.19

Biogas Production

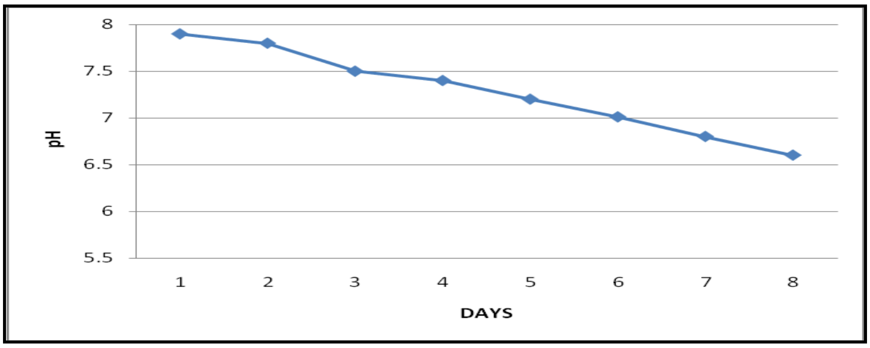
The cumulative biogas production during the study period was observed that biogas production was actually slow at starting and the end of observation. This is predicted because biogas production rate in batch condition is directly equal to specific growth of Methanogenic bacteria. During the first 5 days of observation, there was less biogas production and mainly due to the lag of microbial growth. Whereas, in the range of 8 to10 days of observation; biogas production increases substantially due to exponential growth of methanogens. Highest biogas production rate of 135ml was measured on day 10. The methane content of the biogas generated during the entire operation was on average 42.06%. This result implies that all the operation are most likely in balanced and stable operation.

Figure 4: Days Vs Cumulative Biogas Yield



Change of pH

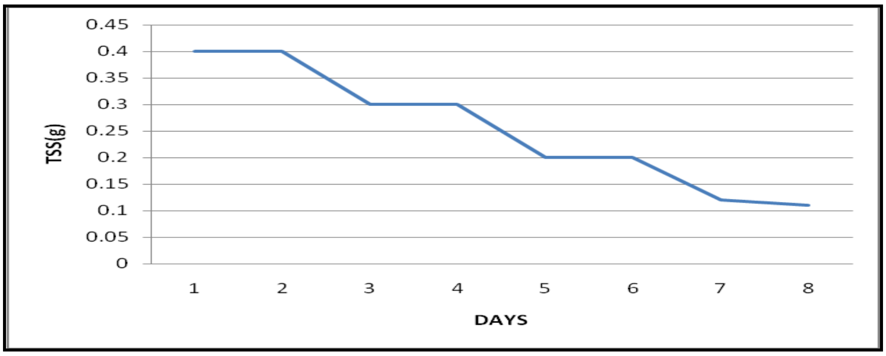
Figure 5: Days Vs. pH



The pattern of pH was typical of a digester operation under stable condition (Figure- 5). A decrease in the processes pH was observed in the first few days of the digestion and this is due to high volatile fatty acid (VFA) formation. The pH increased to its normal operating value after VFAs metabolism. The pH was observed to increase substantially with little variation on the commencement of the batch operation, leading to lower biogas yield. This explains the observed ability of the operation to stabilize even with pH and with lower, but stable biogas production.

Total Suspended Solid in Batch Reactor

Figure 6: Day Vs. TSS



(Figure- 6) shows the Time (days) Vs. TSS profile of the bioreactor content during the experiment. TSS destruction is a vital aspect in evaluating anaerobic digestion performance. The most effective performance in terms of TS degradation was observed during batch digestion, probably through efficient hydrolysis in the acid phase. The TSS reduction is stably achieved during the operation.

Energy and Cost Saving Pattern

Around 570 Engineering colleges, only 10% of biogas have been produced. Especially in our college student list (Table- 6).

Table 6: Number of Students

DEPARTMENT	1st year	2nd year	3rd year	4th year	Total
Mechanical	140	141	140	138	559
Civil	68	70	68	67	273
EEE	60	61	65	64	250
ECE	120	129	131	131	511
CSE	90	100	122	130	442
IT	90	92	104	110	396
Chemical	38	34	32	41	145
Total					2576

In our college, the canteen waste is 5000 lit / day. Through our college canteen the usage of cylinder is minimum 3/ day. In that cylinder the presence of gas is 14.2 kg /cylinder. So totally 42.69 kg have been used per day. The price per cylinder is Rs 490.

We are preparing the renewable source of biogas production. We are taken 1.6 lit / hr of canteen waste, then the production of biogas around 15 ml / hr. For 5000 liter per day, can produce a 47000 ml / day.

So the production of biogas is around 47 L. By analyzing this, the canteen waste to production of biogas is more useful. We can reduce the cost with this, we can reduce non-renewable energy by the production of renewable gas energy.

Cost Reduction using Biogas

By using biogas we have reduced Rs.5, 47,500 per year. We have taken the survey that in college canteen they are using 3 cylinders per day and canteen waste water is 5000liter per day. We can produce 47liter of biogas from the canteen waste from a day and it is equal to 2cylinders per day so that we can save 730 cylinders per year and cost reduced is 5, 47,500 per year and the (Table- 7 & 8) shows the cost reduction before and after using Biogas.

Table 7: Before Using Biogas

Canteen waste (L)	Usage of cylinder per day	Usage of cylinder per year	Cost per year (Rs.)
5000	3	1095	16,42,500

Table 8: After Using Biogas

Biogas production per day (L)	Usage of cylinder per day	Usage of cylinder per year	Cost in year (Rs.)	Saving cylinder per year	Cost saving per year (Rs.)
47	2	730	1,095,000	365	547,500

If they are using biogas can save 365 cylinder per year .The cost is 547500 Rs per year.

Conclusion

This study investigated the effectiveness of kitchen waste for biogas production and presented the performance characteristics of the anaerobic digestion in batch operation. Under these conditions. In batch process the COD conversion is occur (1500-90) and digestion reaches reduction with biogas yield of 0.0083 L biogas per 1 L of kitchen waste. Even the pH effect also reducing step by step. So the canteen waste, they producing 5000 L/day. The 47 L of biogas is produced and it is equal to production is can equal to 1 cylinder of LPG and per year 365 cylinder. In cost wise one cylinder is 1500 can able to save this amount and even cost of saving amount per year Rs.547500. And the by-product of bio fertilize is used to agriculture purpose as liquid and solid form fertilizer.

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