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Production of Biogas from Kitchen Wastes Generated from the Mess of NIT Agartala

Bibhab Kumar Lodh* and Vipin K. Tripathi#
*Department of Chemical Engineering, NIT Agartala
#Department of Mechanical Engineering, NIT Agartala

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Abstract
A review has been done on the formulation of mathematical models for designing anaerobic batch reactor for the producing of biogas from solid wastes. Using material balance analysis, the design parameters, especially biokinetic behavior of solid wastes are studied. Hydrolysis constants and reaction orders at both low total solids concentrations and high total solids concentrations were thoroughly reviewed by initial rate method. Population growth model and first order hydrolysis model are also studied. It has been found that if sufficient reaction time is given, in terms of reaction kinetics, the hydrolysis process in kitchen waste fermentation can be described as a first order reaction**.** An attempt is done by utilizing the biodegradable kitchen waste collected from Aryabhatta hostel, NIT Agartala for generation of biogas and demonstrating the possibilities of energy recovery. A simple anaerobic digester has been fabricated to capture the generated biogas. To produce methane as a clean fuel the use of cow dung as substrate is studied to ferment the kitchen wastes.

Keywords: Anaerobic digester, Biodegradable Kitchen and Food Wastes, Biogas, methane, cow dung

1. Introduction

At present, the demand of energy is increasing rapidly and most of this demand is met by the fossil fuels. Thus, amount of fossil fuels are reducing day by day and more and more use of these fuels leads to higher emission of green house gases (GHGs) into the atmosphere that are harmful for the earth. Therefore, several efforts are given for alternative fuels production from biological resources. A series of experiments were carried out by Alessandro Volta on combustible gases which was taken from marsh sediments and it was seen that a direct correlation can be obtained between degraded biomass and gas produced. [1].

Due to population growth, changing socio-economic characteristics and cultural habits per capita generation of the waste has been increasing steadily. Food waste; vegetable peels, fruit pulp etc, those which are decomposable and can mix with the soil by the action of microorganisms within a short period of time is called biodegradable.

*Corresponding author
Email address: bibhab123@rediffmail.com (Bibhab Kumar Lodh)
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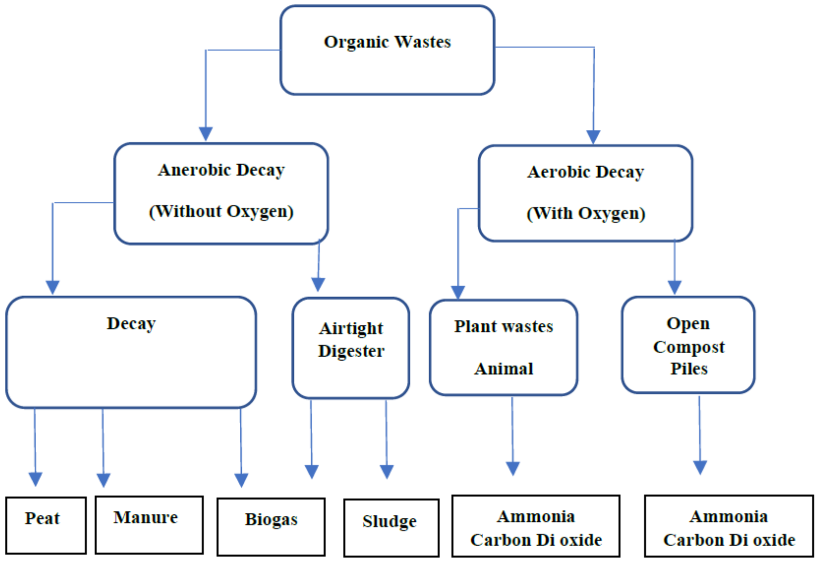


Figure 1: Segregation of organic wastes

Ogunbiyi says that handling and management of solidwaste which is an on-fluid type of waste is relatively difficult, compared to the types of waste that can flow from one place to another, or can vaporize [2]. The process in which the biomass gets converted into biogas by the microorganisms in the absence of oxygen is called anaerobic digestion. Biogas is mainly comprised of methane (55-60%) and carbon dioxide (35-40%) and trace amounts of hydrogen sulphide, ammoniaetc.

Table 1: Composition of biogas

Constituents	% Composition
Methane (CH_4)	55 – 75%
Carbon dioxide (CO_2)	30 – 45%
Hydrogen Sulphide (H_2S)	1 – 2%
Nitrogen (N_2)	0 – 1%
Hydrogen (H_2)	0 – 1%
Carbon Monoxide (CO)	Traces
Oxygen (O_2)	Traces

Carbon dioxide, methane, ammonia and hydrogen sulphide released into the environment contributes to airpollution during decomposition of the waste. These gases released during this process can be captured for the utility of the economy and save the environment. And the solid wastes produced during anaerobic digestion can be used as organic fertilizer.

Itodo and Philips have described biogas as “a methane-rich gas that is produced from the anaerobic digestion of organic materials in a biological–engineering structure called the digester” [3]. According to GEMET, biogas is - Gas rich in methane, which is produced by the fermentation of animal dung, human sewage or crop residues in an air-tight container[4].

2. Anaerobic digestion

Earlier anaerobic digestion was used commonly in the waste water treatment plants for waste management. The management of kitchen waste generated in households has become a social andenvironmentalconcernduetotherapidcontinuousincreaseingeneratedwastesanddueto their improper treatment, which has environmental impacts. By degradation of these organic waste, these wastes can be utilized to produce biogas and the undegraded material can be used as manures. The natural process in which the bacteria breaks down the biomass in the absence of oxygen to produce biogas is called an aerobic digestion. This process is better hanland filling and composting, Anaerobic digestion is also termed as "bio methanogenesis" as the process is rapid and it is a controlled decomposition of biomass to produce methane, carbon dioxide and residue [5].

3. Relevance

Biogas produced from kitchen wastes can be ued for lighting and cooking purpose. Kitchen waste is of high importance if used in proper way and not just dumped in any landfill. It has high calorific value. By increasing the size of the reactor and using higher efficiency, the methane production efficiency can be increased and on large scale biogas generation, the cost of biogas production can be reduced [6]. Everyday almost everywhere from villages, towns, residential areas, hostels, hotels and restaurants, agricultural fields, fruits and vegetable markets, etc large amounts of biodegradable wastes are produced. Dumping of these wastes here and there, causes several health hazards and diseases like typhoid, cholera etc; leads to surface and ground water pollution; promotes breeding of mosquitoes, flies; and alsoemitsfoul odour. Therefore, kitchen waste can be of high utility if used in a proper manner and energy can be generated from these wastes which can be used for various purposes.

Anaerobic digestion is generally composed of 4 main stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis with respect to microbiological, technological and biochemical point of view.

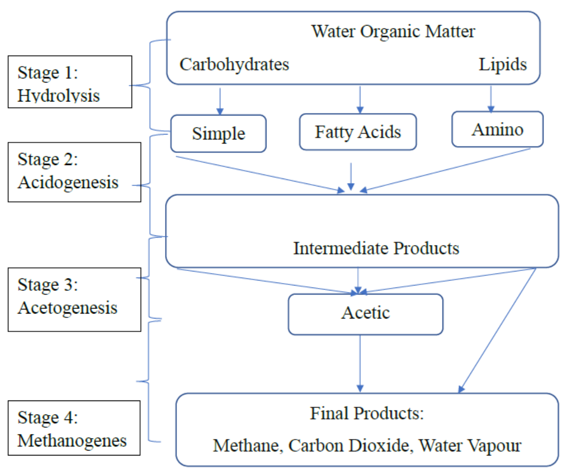


Figure 2: Methodologies for treating wastes

4. Literature review

The reaction order and hydrolysis constants are being studied through anaerobic digestion for production of biogas from kitchen wastes. Lei Feng and Yuan Gao performed the initial rate method to analyze the reaction order and hydrolysis constant at both high and low total solid concentrations. Experimental results show that the hydrolysis in anaerobic digestion of kitchen waste is a first order reaction when sufficient time is given, with respect to reaction kinetics [7]. Material Balance of material is given by –
Rate of accumulation of material in reactor = (rate of material flow in reactor +-rate of appearance or disappearance of material due to reaction - rate of material flow out of reactor) [8].

Asinyetogha H. Igoni gave a relationship between the microbial concentrations and the substrate concentrations at steady state. This relationship is derived from Monod kinetics. A direct relationship between specific rate of solid waste utilization, U and effluent substrate concentration, Se are find out and half saturation constant, Ks was determined. Yield of microbes, Y; lyses coefficient, kd, maximum rate of substrate utilization per unit mass of cells produced, k and specific rate of growth of microorganisms, μ_{max} were also determined [9].

Asinyetogha H. Igoni in the year 2017 gave a general model for anaerobic digestion process from Monod kinetics. Material balance for mass of microbes and material balance for total substrate utilization in a batch process were computed and an equation for finding out the time required for batch digestion process to achieve a given fractional conversion α was obtained [10]. The substrate concentration was determined in terms of chemical oxygen demand and biomass concentration in terms of micro liquor volatile suspended solids using the procedures mentioned in 5220 b.4b and 2540 G of - Standard Methods for the Examination of Water and Waste water.

According to Kiely volume of sludge should be two-third the volume of the digester [11].

It was observed by A. H. Igoni, M.F.N. Abowei that with a marginal increase of percentage total solids (PTS) has resulted in a geometric increase in the volume of biogas produced in a batch reactor [12]. They also investigated the temperature, pH and effectiveness of microorganisms in degradation is also influenced by the total solid concentration of the solid waste.

A biogas system was developed by Dr. Anand Karve in which starchy feedstock is used. He analysed that this system was 800 times more efficient than other conventional biogas plants [13].

Srinivasa Reddy, from his lab experiment for production of biogas from biodegradable kitchen waste, found out that the ratio of the kitchen waste and cow dung that gave more efficient biogas was 75:25 [6].

Tshewang Tenzin, Sanjay Wangdi carried out experiments for the optimization of biogas plant and observed that the waste to water ratio shouldbe1:1.5and the temperature to be maintained around 35^0C for maximum methane gas production. Therefore, temperature plays a vital role and should not be less than 32^0C for optimum methane gas production [14].

An experiment was carried out by S.A.Iqbal in which he prepared 3 separate digesters and individualdegradationrateofcowmanure,kitchenwaste,cowmanureandco-digestedkitchen waste were observed at 25^0C -30^0C (room temperature) and at 37^0C (mesophilic digestion) respectively and found out that the digestion rate of the co-digested kitchen waste and cow manure was higher than that of kitchen waste and cow manure alone. It was also observedthat the rate of degradation was faster at 37^0C than room temperature [15].

Fedailaine M, Moussi K performed mass balances on biomass, organic substrate and biogas produced to study modelling of biokinetics of anaerobic digestion on substrate degradation, microbial activity and methane production. According to their observations, the production of methane is more with the increase in initial concentration of biomass and substrate dose [16].

An effective yet simple design of an anaerobic digester was made by E.O.Ogur and S. Mbatia, to generate biogas using food waste and also an alternative option for saving power cost. After the biogas production process, the leftover slurry was used as organic fertilizer and the excess biogas produced was sold to the neighbors [17].

L.Deressa, S.Libsu, R.B.Chavan, D.Manaye and A. Dabassa produced biogasbyco-digestion of biologically degradable waste with cow manure in different ratios [18].

5. Study of production of biogas from kitchen waste collected from hostel mess, NIT Agartala

An effort has been made to keep a daily record on the amount of kitchen waste generated from hostel mess at NIT Agartala. The data shows that a substantial amount of food waste is produced. For this reason, an attempt has been done to produce biogas with a view to lower the consumption of LPG.

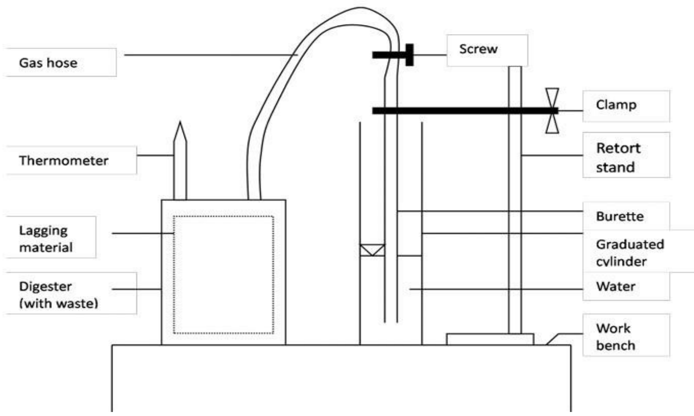


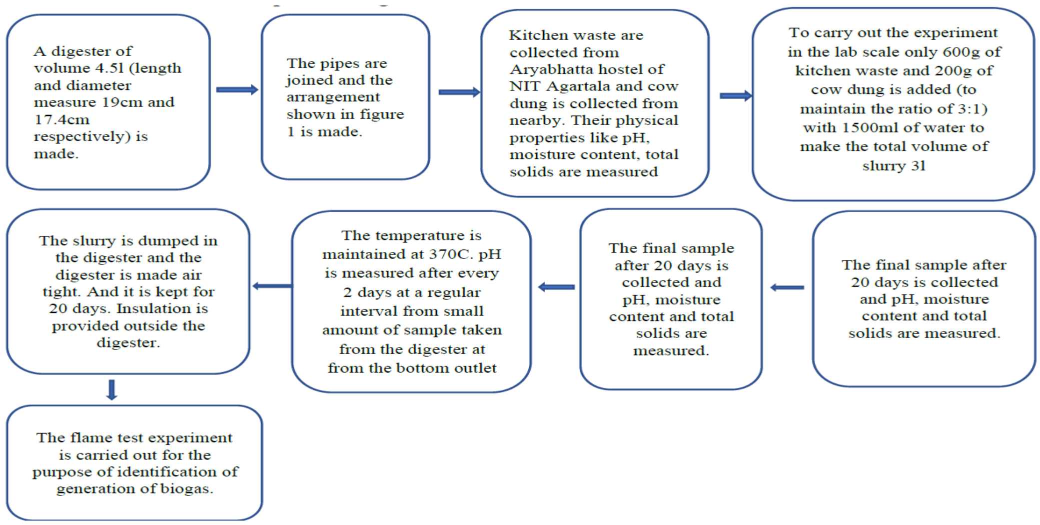
Figure 3: graphical representation of the setup used in the experiment

6. Materials and methods

A small batch digester of volume 4.5 Liters has been made. The sludge comprised of the food waste and cow dung weighing 600g and 200g respectively and the amount of water given is 1.5l. After filling the digester, it is made air tight and kept in the room temperature for 20 days.
Several parameters have been tested.

1. pH -The pH of the sample has been obtained using pHmeter.
2. Moisture content- Drying experiment has been done for initial sample, i.e., at the start of anaerobic digestion. The drying was carried out for 4hours.
3. Total solids- Drying experiment has been done for initial and final samples, i.e., at the start and end of 20 days. The drying was carried out for 4hours.
3. Volume of biogas produced –The water displacement arrangement was performed to determine the amount of biogas generated by anaerobic digestion of kitchen wastes.
4. Verification of biogas production- The flame test experiment serves the purpose for identification of generation of biogas.

The flow sheet of the full process is given here under:



The schematic pictorial diagram of the process is given hereunder:

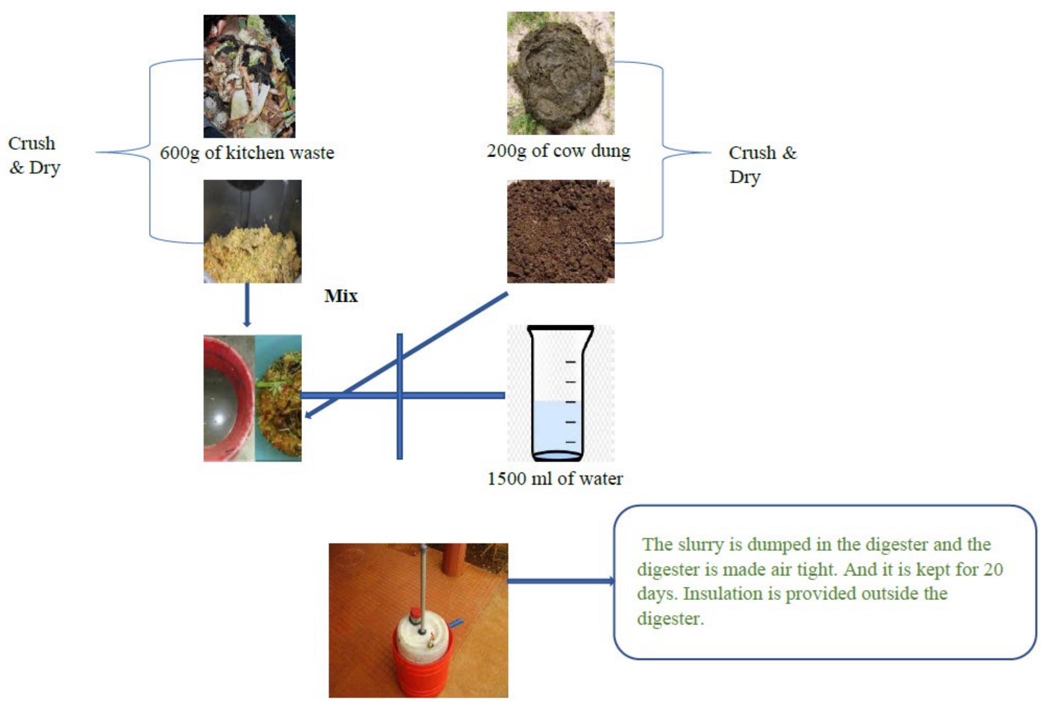


Figure 4: graphical representation of the full process

7. Result and discussion

Table 2: pH results

Before (day 1)	After (day 20)
7.32	5.98

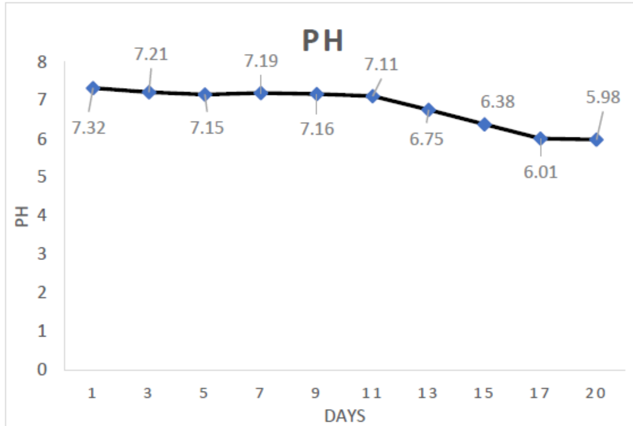


Figure 5: graphical representation of the variation of pH with time (days)

Table 3: Initial moisture content

	Moisture content (g)
Kitchen waste	43.56
Cow dung	21.43

Table 4: Total solids

	Initial weight (g)	Final weight (g)	Moisture content (g)	l solids (g)
Initial	2300	735.01	1564.99	735.01
Final	880.9	262.13	618.77	262.13

Table 5: Volume of gas produced

day	Volume of gas (ml)
20	194

Verification of biogas production: A blue flame was observed.

Total food waste generated in Aryabhatta hostel mess per day is approx. 500kg which has a huge potential to produce biogas. And also there is availability of enormous amount of cow dung nearby. Therefore, a huge amount of biogas can be produced which can be used for different purposes.

7.1. Analysis

Calorific value of biogas (60% Methane) = 30.00
MJ/m3 calorific value of LPG=46.1 MJ/m3
Let us assume we need to boil water sample of 100 ml
We have energy required to boil 100 ml of water=259.59 KJ
Hence, we need biogas to boil 100 ml water= 8.563L
And we need LPG to boil 100 ml of water=5.63L
Assuming density of food waste to be 1.5 gm/cm3, amount of biogas produced per ml of food waste is 0.32 ml of biogas/gm of food waste.
Therefore, amount of water which can be boiled using this much of biogas is 3.7 ml.
As a whole amount of water which can be boiled using the biogas is 1.75 lit/day.
Now amount of LPG required to boil 1.746 Lit of water per day is 98.32 Lit.

Hence we can save up to 3.5 cylinders of LPG per day.

8. Conclusion

There is a fall in pH after anaerobic digestion due to the generation of volatile fatty acids in the acidogenesis stage. For more production of biogas, control of pH is necessary. The amount of total solids was found to decrease with increase in volume of gas produced. Blue flame indicates the presence of biogas. The study reveals that the anaerobic biogas digesters made locally can be used as an alternative for cooking, lightening etc and also the leftover solid residue in the digester can be used as manure.

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