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Research Article

Solid Waste Management using Biogas Technology

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Abstract

The critical reason for extensive climate change, resource exploitation, and limiting living standards of humans in developing countries like India is the increasing energy demand. The per-capita energy consumption is a great determinant cum indicator of economical development, economic prosperity and quality of life in most countries. Thus, finding alternative, clean and economical sources of energy has nowadays become a major concern due to the increasing prices of fossil fuels and taxes on energy sources. The present studies had focused on Biogas technology that can be adopted as a substitute for firewood and cattle dung for energy requirements. Biogas has potential to meet the energy needs of the rural population, is based on renewable energy and can be utilized as an alternative for natural gas or liquefied petroleum gas. Anaerobic digestion of organic compounds can yield to value-added Biogas and is highly inflammable. Biogas is a mixture of methane (CH_4) and carbon dioxide (CO_2) and the heating value is straightly linked to its methane content. Biogas digesters like floating drum type are cheap, easy to handle and can reduce the amount of organic domestic solid wastes. These digesters can be handy for effective solid waste management. Moreover, after anaerobic digestion the end products has high potential to be used for agricultural purposes. Both, Biogas and fertilizer obtained at the end of anaerobic digestion can be utilized for cooking, lighting and electricity. Thus, the technology can serve the dual purpose of generation of energy resources and also its residue utilization as soil amendments. In lieu of these advantages, present studies had focused to develop In-house Biogas digester that can process domestic food wastes into biogas. The model was based on the floating drum digester type. The entire experiments of biogas generation in developed model were carried out for a period of 12 months and it was concluded that at average ambient temperature of 30.56°C, the average digester temperature remains consistent at 34.63°C and at this point of time, the average pH value will remain at 7.09 in the digester and the peak volume of biogas i.e., 64.16 liters will be generated in the developed In-House Biogas Digester, wherein the average amount of generated Methane gas will be 54.56%. Therefore, the results indicate that about 128.32 liters Biogas can be generated by only one kg of food refuse as raw materials when it is fed in the built model. Moreover, cost analysis done suggests that the digester is cost effective i.e., Rs 842/- only, has high uptake capacity and requires less technical expertise. Moreover, it requires less space and maintenance so can be adopted for household applications. Thus, the model can be readily acceptable and affordable at rural-scale and is environment friendly technology.

Keywords: *Solid Waste Management, Food Wastes, Biogas, Anaerobic digestion.*

Introduction

The demand for fuel is increasing tremendously and also taxes are high on the various sources of energy. Therefore, the major concerns for households and nation's economies are finding alternative clean and economical energy resources. In most of the countries, quality of life and economic prosperity are correlated to per-capita consumption of energy and that is a vital sign of economic development (Amigun B. *et al.*, 2008; Pagar Savita D. *et al.*, 2008; Zhou Z. *et al.*,2008). The living standards of humans are mainly restricted by excess resource exploitation and climate change (Li G.Z. *et al.*, 2007; Li G. *et al.*, 2009). Also, problems like global warming arising as energy is not consumed in a sustainable manner is a burning issue.

The applications of In-house Biogas digesters can help to tackle these menace. These digesters can prevent soil erosion, loss of agriculture lands, greenhouse gas emissions (GHG) and deforestation thus result in lower environment pollution. The GHG generated from burning fossil fuels like natural gas, oil and coal are the major responsible factors for global warming.

Thus, approach of Biogas technology that is environment friendly can reduce global warming issues. At rural scale they can improve socio-economic status and ensure environment protection. As compared to carbon dioxide the potential of methane

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to cause greenhouse effect is twenty one times higher. Therefore, as reduction of wastes as well as energy can be recovered from anaerobic digestion of solid wastes they can be termed as environment friendly techniques. Researchers have indicated that for 2.5 million population in Asia, the common traditional energy source was wood (Starke L. *et al.*, 2004) and in most developing countries the rural communities are bound to depend on dung, paraffin, firewood and crop residues etc., inspite of the fact that sometimes they can be time-consuming and expensive (Ravindranath N.H. *et al.*, 2000). This is so as 90% of consumption of energy is required for cooking in most developing countries (Bioenergylists 2012) even after the access to electricity is relatively scarce in their rural areas. In rural areas mainly firewood and cattle dung are used as energy source and biogas has the potential to substitute these energy resources (Bhattacharya S.C. *et al.*, 2000; Xiaohua W. *et al.*, 2005). Energy resources like liquefied petroleum gas and natural gas can be replaced by biogas and it is renewable energy resource. Thus, the scope of biogas technology is high in developing countries; however there is a challenge for scientists and engineers to device efficient domestic digesters with the materials available and simultaneously taking into account the economical and local considerations. Thus, there is a need of additional research and awareness to meet the changing energy needs.

The process of anaerobic digestion results in breakdown of organic wastes by the action of bacterias in an oxygen-free environment. The generated biogas is renewable energy CO_2 neutral. Mainly, there are four basic steps of methane formation in anaerobic digestion process. These steps are hydrolysis followed by acidogenesis, acetogenesis and the final step is of methanogenesis. There are varieties of bacterias that act in a syntrophic relationship with each other to form methane. During the hydrolysis process complex carbohydrates, proteins and fats are first hydrolyzed to their monomeric forms. This hydrolysis is mainly carried out by bacterial cellulosome and exoenzymes. During the second step of acidogenesis the generated monomers are further degraded into short-chain acids like propionic acid, acetic acid, isovaleric acid, butyric acid, isobutyric acid, valeric acid, alcohols, hydrogen and carbon dioxide. The third phase involves acetogenesis wherein short-chain acids conversion into acetate, hydrogen and carbon dioxide occurs. During the final step, conversion of produced intermediates into methane and carbon dioxide takes place by methanogens and approximately one-third of methane formation occurs mainly due to reduction of carbon dioxide by hydrogen (Deublein D. *et al.*, 2008). The production of biogas depends on various parameters like temperature, loading rate, C/N ratio, mixing, pH, substrate and hydraulic retention time (HRT). Biogas is highly inflammable and is produced during the organic matter digestion under anaerobic conditions. Biogas and digestate are the main produce from the digesters. Biogas varies in composition of methane percentage ranging from 50-80% methane and rest as carbon dioxide, water and hydrogen sulfide. This chemical energy can in turn be converted into electrical energy and thus production of electricity is feasible. This biogas as fuel can result in a drastic decrease of regional emissions of methane and does not only produce less CO_2 emissions per produced kWh but it also has been proven that it is environment friendly (Soren Tafdrup *et al.*, 1994). The generated electricity from Biomass energy is often referred to as 'Biopower' (US DRAFT Factsheet 2005). The type of biomass materials available and the scale of power generation decide the method for generating electricity for instance cattle manure can be best converted into biogas in an anaerobic digester. The generated biogas can be used to fuel an engine to generate electricity. There has been enormous increase in cost of carbon-based fuel and people in rural areas across world are experiencing financial crisis. Thus adoption of renewable energy is only remedy and most of under developed countries too face worst energy crisis. These countries should invest in renewable energy resources and take initiative to solve their energy issues (Botero R. *et al.*, 1986).

Global Scenario: Biogas technology and practices

Since long worldwide research efforts have targeted to design and implement more effective Biogas technology for efficient solid waste management. It is well known fact that among renewable energy sources, waste is all the more attractive as its valorization enables us to both produce energy and dispose of waste streams. Globally, Biogas technology is a fast growing technology that transforms organic wastes into biogas through a biological fermentation. The technology splits organic substances into an oxidized form carbon dioxide and reduced form methane. Researchers had studied on the aspects of centralized biogas plants and had suggested that they have potential to generate energy as well as manage wastes. They had recommended that lowering temperature in later stages of the process can be handy. Thus, it was envisaged that these technologies can result in socio-economic development of society (Soren Tafdrup *et al.*, 1994). A group had studied the Biogas opportunities and its potential in New Zealand and had emphasized on their usefulness as potential tool to treat dairy farms wastes. However, the feedstock collection and conditioning, feedstock availability can be issues and constraints for the technology advancement (Brian Cox *et al.*, 2004). Another group of researchers had studied on generation of biogas from wastes of food materials and had shown sound results (S. Sedlacek *et. al.*, 2010). Subsequently, a model for biogas generation was designed for electricity generation using biogas by dry process that can fulfill the energy demands of society. Reactor by-products were used as a fertilizer and compost. Finally the excess CO_2 produced with CH_4 for the beverages industry and making of dry ice was made highly profitable (Moinuddin Ghauri *et. al.,* 2011). The same year, scientists had studied on the developments of Biomass and biogas for energy generation, its perspectives and had suggested that development of the rural areas is mainly dependent on cost effective energy solutions like the technology of Biogas. Their review recommended Biogas technology as important tool for management of a wide variety of wastes (Abdeen *et al.*, 2011). The studies on optimization of biogas generation process had suggested that in spite of a heterogeneous composition of solid wastes, a majority of the solid wastes fractions is organic and can generate significant amount of biogas. Furthermore, the ANOVA procedure can be performed to know the influence of composition, biodegradability and time of confinement of solid wastes and methane production (Carlos Gonzalez *et. al.* 2011).

Recently, researchers had studied the anaerobic microbial hydrolysis of agriculture wastes for biogas production and had suggested that the gas production can be enhanced by inoculating isolated hydrolytic microorganism to agriculture wastes with decrease in detention time and the pre-treatment of agriculture wastes with white rot fungus to maximize the accessibility of hydrolytic enzymes to its organic matter like hemi-cellulose and cellulose by lignin degradation (Sneha *et al.*, 2012). The studies on Biogas production from kitchen wastes had concluded that food wastes or peelings can serve as a significant energy resource and can result in excellent residues that can retain the fertilizer value of the original wastes products. Therefore, biogas technologies must be intensified so that ecological disasters like deforestation, desertification, and erosion can be arrested (Joaquin Perez Diaz *et. al.,* 2012). During the same year, green wastes were utilized and processed into Biogas and these experiments had suggested that a very high percentage of the theoretical residual biomass potential may be difficult to access as there can be various technical, legal, ecological or management constraints and only the municipal lawns and green spaces may provide suitable substrates (Daniel Pick *et. al.,* 2012). Moreover, a review on household Biogas digesters had indicated that the production of biogas relies on various parameters like ratio of carbon to nitrogen, levels of raw materials fed, its temperature and pH to name a few and that the technology is highly cost effective (Karthik *et al.,* 2012). However, the design of model must be based on the socio-economic requirement of the locality wherein the technology needs to be installed (Dr. Akhilesh Kumar *et al.*, 2012). Another group of researchers, had studied on processing wastes of domestic origin to Biogas and had concluded that the technology resulted in high energy generation and the said raw materials can be ideal source for generation of Biogas. Moreover, the technology has potential to solve disposal problems of wastes alongside energy generation (Usman M. A. *et. al.,* 2012). Also, studies on production of biogas from kitchen wastes had indicated that the average daily gas production per Kg of dry kitchen wastes was 35 L, thus, by storing the 2-3 days' gas it will be equivalent to consumption of 1 days LPG gas. They had recommended that the concept of kitchen wastes utilization using a modified ARTI compact plant can be handy (Laxman Lama *et al.*, 2012). During next year, a group of researchers had worked on biogas production from domestic wastes and its purification with charcoal and had suggested that the charcoal can be used to upgrade biogas by reducing the CO_2 content and increasing the quantity of CH_4 thereby enhancing the caloric value of gas (Felix *et al.,* 2013). Thus, as per the prior art search done, there was a need of further research on Biogas technology development for effective solid waste management and that had resulted the present studies to investigate the same.

2. Materials and Methods

The present studies had focused on to generate Biogas and its measurement. In-house Biogas digester was designed to process domestic food wastes into biogas. The model was based on the floating drum digester type model. A digester was taken for designing the biogas model wherein inverted drum was adjusted so that it can move whenever required. The digester supports a drum made of steel on its upper side that works as a storage tank and that too is moveable in accordance to accumulated gas at the top of the digester. The pressure required by the gas to flow through pipeline is obtained from weight of this inverted drum. The position of this drum indicates the level of accumulated biogas. The drum that is floating can be coated by paint so that it will not rust. The developed In-house biogas digester model is as represented in figure 1. This model was used in the experiments and results were recorded. Biogas was analyzed on daily basis. The main digester tanks were made from 200 liters capacity plastic drums. Gas holders were also plastic drums of smaller capacity. Gas holders had a valve on top to discharge the product gas. The units had facility to feed bio degradable material at the bottom through a feed pipe. Small quantities of feeds were introduced every day in control unit and the generated gas was studied. The volume of gas generated in each of the units was measured from lift of the floating dome. Quality of gas was analyzed using Orsat apparatus for carbon dioxide content and methane content by volume. The principle of Orsat method is absorption of gases into chemical solutions in absorption pipettes that has calibrated water or air jacketed gas burette. This is attached to glass capillary tubing. The apparatus is embedded in a wooden box for its safe and portable use as represented in figure 2. Absorbents used comprisesed of Potassium Hydroxide (Caustic Potash) or Sodium Hydroxide for estimation of CO_2, Alkaline Pyrogallol for the estimation of O_2, Ammoniacal Cuprous Chloride for the estimation of CO and Potassium Permanganate for the estimation of any reducing agent like Hydrogen. The gas can be transferred to and from the absorption media as the gas burette base is attached to a leveling bottle that will allow taking readings at constant pressure. The burette will possess traces of methyl orange or methyl red as indicator for coloured appearance and also water.

Figure 1: Developed In-house Biogas digester

Figure 2: The ORSAT Apparatus

Biogas analysis: Methods adopted

The analysis of gas was done by drawing it into burette by flushing many times via arrangement of rubber tubing at a rate of 100 ml gas to facilitate the necessary calculations. Thereafter, the burette was adjusted to zero via stopcocks separating absorption burettes, and thus gas was leveled. The remaining gas was isolated after passing through caustic potash burette for 2 minutes and then withdrawal of the same with the help of stopcock arrangements. These steps were followed till all the gas was absorbed. The remained gas in burette after bottle liquid and burette have reached the same level indicates the absorbed CO_2 percentage. Also, using Ammonical cuprous chloride or any other gas the same process can be used for oxygen with the help of CO and Pyrogallol. Thus, it can be envisaged that analysis of biogas with the help of Orsat apparatus is fairly easy and economical approach.

Food waste analysis: Methods adopted

The analysis of the food wastes fed into to the biogas model was done in order to detect mainly the starch, sucrose and glucose contents. Moreover, food waste analysis for various contents estimation like moisture, carbohydrates, vitamin, minerals, protein and lipids was also carried out. Tests were also performed in order to detect any presence of preservatives or additives in the food wastes samples. Mainly the detection tests were carried out for urea, carbonates, salicylic acid, hydrogen peroxide, formalin, boric acid, β-Napthol and benzoic acid.

A) Detection of Starch

Addition of starch increases the solids not fat (SNF) content of sample. Wheat flour, arrowroot, rice flour, etc., can be added for increasing the SNF content; **Requirements**: Boiling water bath, 1% iodine solution; **Procedure**: Take 3 ml sample in a test tube and boil it thoroughly, allow to reach normal temperature, mix iodine solution i.e., only few drops, change of color to blue indicates that the sample is adulterated with starch.

B) Detection of Sucrose by Saliwanhoff's test

Requirements: Saliwanhoff reagent (Dissolve 0.5 gm resorcinol in 10 ml of 3N HCL); **Procedure:** Mix reagent of Saliwanhoff, volume 2 ml with sample of volume 3 ml, Keep in boiling water bath for 5 minutes, development of red color indicates presence of cane sugar.

C) Determination of Total Carbohydrate by Ferricyanide approach

The basis of this approach is that sugars are oxidized by alkaline potassium ferricyanide and the amount of ferricyanide produced is then measured either photometrically or volumetrically. Thus, amount of the total sugars can be determined calorimetrically; **Requirements:** Colorimeter, table centrifuge, saturated natural lead acetate solution, sodium oxalate, sodium carbonate**,** concentrated HCL**,** Potassium ferricynaide solution: Dissolve 0.5 g potassium ferricyanide in 1 liter of distilled water (D/W), keep it safe in brown bottle, Carbonate-Cyanide reagent: Mix potassium cyanide of quantity 0.65 g and sodium carbonate of quantity 5.3 g in D/W of volume one liter, Solution of Ferric Ammonium Sulphate: Mix Ferric

Ammonium Sulphate of quantity 1.5 g in one liter 0.05 M H_2SO_4, Tungstate solution: Prepare 10% Sodium Tungstate in D/W, Standard Glucose solution: In D/W mix glucose of quantity hundred mg and prepare a 100 ml final volume, H_2SO_4 Solution: Prepare one liter final volume worth to D/W by adding concentrated sulphuric acid of volume 2.26 ml; **Procedure:** For extracting the sugars, suspend 1 g of finely powdered oven dried sample in 40 ml of D/W, heat in boiling water bath for 30 minutes, now for twenty minutes at three thousand rpm perform centrifugation and collect the left supernatant, again suspend pellet in 20 ml of water and repeat this extraction step 6-8 times till the supernatant is free of sugars, combine all supernatants, in the supernatant, mix lead acetate of volume 2 ml thoroughly for fifteen minutes, thereafter filter it by Whatman filter paper and with the help of D/W, prepare final volume upto 250 ml, solid Sodium Oxalate will precipitate out additional lead acetate, for reducing sugar determination the above extract is used directly. However, for estimating the amount of the total sugar, take 25 ml of the above extract and hydrolyze it with 5 ml concentrated HCL for 8 minutes at 68ºC, after cooling neutralize the hydrolysate with solid sodium carbonate and prepare with D/W a final volume of hundred ml, now add H_2SO_4 in reducing sugar preparation and that obtained in the step 3 in D/W of volume 9 ml, add Sodium Tungstate of quantity 0.02 ml and after shaking the contents allow to stand for 10 minutes, centrifuge it at 3000 rpm for 20 minutes, add 1 ml of Ferricyanide solution to 1 ml of cyanide-carbonate solution, heat this mixture for 15 minutes in a boiling waterbath and cool immediately under running tap water, now add 5 ml of ferric ammonium sulphate, mix the solution and after 10 minutes, record its Optical Density (O.D.) at 690 nm on spectrophotometer, prepare a reference curve of glucose over a range of 0-100 microgram as standard.

D) Detection of Glucose

Requirements: Fehling A solutions and Fehling B solutions; **Procedure:** Mix Fehling A solution of volume one ml with sample of volume one ml, thereafter add Fehling B solution, now for few minutes in a boiling water bath heat it, presence of yellow or red colour precipitates indicates presence of glucose in the sample.

E) Determination the Total Protein by Lowry's method

Requirements: Stock solution of Bovine Serum Albumin (1 mg/ml), prepare analytical reagents: Mix NaOH solution of volume fifty ml and strength 0.01 N with Sodium Carbonate of strength two percent, mix titrate solution of Sodium Potassium of quantity 10 ml with Copper Sulphate solution of strength 2 %, mix NaOH solution of quantity 50 ml and strength 0.01 N with Copper Sulphate solution of volume 2 ml and Sodium Carbonate of volume 50 ml; Reagent solution of Folin Ciocalteau that has strength 1 N: Prepare a mixture of equal volume two ml of water and commercial reagent, acetone, buffer of Phosphate having pH 7.6 and strength of 0.1 M., 20% (w/v) TCA; **Procedure**: For sample extract: Weigh 1 g sample, macerate the sample in the pestle mortar in 5 ml phosphate buffer and transfer the material to centrifuge tube at at 8000 rpm for 20 minutes, collect the supernatant and repeat the extraction 4-5 times, combine the supernatants, make the volume to 50 ml with phosphate buffer, mix TCA of strength 1% and volume 1 ml with equal volume of this extract, keep it for half an hour and centrifuge at 8000 rpm for 20 minutes, wash the pellet with Acetone twice and again centrifuge it, discard the supernatants, dissolve the pellet 5 ml of 0.1 N NaOH and mix well till it gets dissolved, take suitable aliquot (1 ml) of above solution and add to it 5 ml of freshly prepared alkaline Copper Sulphate reagent, mix reagent of Folins that has volume of 0.5 ml after ten minutes, add the contents instaneously, allow the colour to develop for 30 minutes, record the absorbance at 660 nm after setting the instrument with reagent blank which contains 1 ml of 0.1 N NaOH instead of the sample aliquot, in another set of tubes take suitable aliquot of BSA solution make the total volume to 1 ml with 0.1 N NaOH and develop the colour as described in step 4 and 5., draw a standard curve to determine the amount of protein in the sample tube, calculate the amount of protein per g of the sample.

F) Determination of Moisture

Requirements: Samples of food wastes, water, oven, watch and calculator; **Procedure:** There are various methods to determine the moisture percentage in the food samples like vacuum oven, microwave oven, infrared drying and forced oven drying, the vacuum oven drying method was adopted for the present studies; **Process of Oven:** The level of volatiles and H_2O that can be eliminated without degradation in just three to six hour time is possible by placing it in a reduced pressure condition at 25-100 mm and this process is termed as 'Drying' that forms the basis of this oven method,

% Moisture = (m water/m sample)×Hundred (Note: Water (m) = Water mass and sample (m) = Sample mass)

G) Detection of Urea

Requirements: 0.1 N Acetate buffer (pH 4.75), 1 N NaOH, Sodium Hypochlorite solution and concentrated Phenol solution; **Procedure:** Keep ready a conical flask and place sample in it of quantity 5 ml, place Acetate buffer of volume five ml and heat the flask in boiling water bath for 3 minutes, thus, filtrate of volume one ml can be obtained in test tube after filtration, mix solution of Sodium Hypochlorite of volume 0.5 ml and NaOH of quantity 1 ml, after mixing add solution of

Phenol of quantity 0.5 ml, appearance of yellow colour indicates presence of urea.

H) Determination of Minerals

Requirements: Silica crucible, bunsen burner, boiling water bath, volumetric flask, whatman filter paper, dilute HCL, muffle furnace; **Procedure:** Take a known weight (5-10 g) of an oven dried sample in a tared silica crucible and heat it first on a bunsen burner on a low flame till the contents get charred, now transfer the crucible to a muffle furnace and wait till white ash is obtained after allowing the temperature to rise till five hundred degree Celsius, then remove it and place it in desiccators till its cools down, weight the crucible and calculate weight of the ash obtained, express the results in terms of g of ash per 100 g of dry weight of the sample, moisten the ash with small amount of glass D/W (0.5-1.0 ml) and add 5 ml of diluted HCL to it, then on a boiling water bath allow it to completely dry via evaporation and then add another 5 ml of HCL and evaporate this solution to dryness again, now add 4 ml of HCL and a few ml of water and warm the solution in boiling water bath, filter the extract into a 100 ml volumetric flask using Whatmman no. 40 filter paper, allow it to cool and make the volume up to 100 ml., suitable aliquots of this extract can be than used for the estimation of minerals.

I) Boric acid estimation

Procedure: Keep ready a test tube and take sample in it of volume 5 ml, mix concentrated HCL of quantity one ml, place a paper strip of turmeric in it, we can observe change of colour when the fliter paper is dried, if borax is present the turmeric paper will appear red.

J) Bicarbonates or Carbonates estimation

Procedure: Keep ready a test tube and place sample in it of quantity 10 ml, shake it after addition of alcohol of quantity 10 ml, mix rosalic acid solution of strength one percent by adding only few drops, take observations of colour change, sample Bicaronate presence can be confirmed by red colour and absence can be confirmed by brown colour appearance.

K) Estimating β-Napthol

Procedure: Fow few minutes heat the sample with potassium hydroxide and also extract it with chloroform, β –naphthol can be confirmed if blue colour appears.

L) Detection of Formalin

L.1 - Hehnes Test

Procedure: Keep ready a test tube and place sample in it of volume 10 ml, mix solution of ferric chloride in it of volume 0.5 ml, now without mixing the sample mix concentrated H_2SO_4 of volume five ml in a manner that is generates a bottom separate layer, note the appearance of ring at junction formed between these liquids.

L.2 - Leech Test

Procedure: Keep ready a test tube and place sample in it of volume 5 ml, mix 1 ml of concentrated HCL and solution of ferric chloride of volume 1 ml to both acids of volume 500 ml, place it for few minutes on a flame, observe appearance after rotating it, the presence of formalydhyde can be confirmed by violet colour appearance

M) Hydrogen Peroxide estimation

Procedure: Keep ready a test tube and place sample in it of volume 10 ml, mix solution of Paraphenylene Diamine Hydrochloride only a few drops, take observations after mixing it, the presence of Hydrogen Peroxide can be confirmed by appearance of blue colour.

N) Estimating Salicylic acid

Procedure: Keep ready the sample and mix Mercuric Nitrate in it, perform sample filtration, red colour will appear after few minutes if there will be a presence of Salicylic acid.

O) Estimating Benzoic acid

Procedure: Dissolve 20 g sample by mixing concentrated HCL and then allow it to cool, shake this mixture by addition of equal volume of petroleum Ether and Ether, the volume added must be 25 ml, now as Benzoic acid is present when a drop of Ammonium hydroxide is added, there will be separation of Ether layer.

3. Results and Discussion

Solid wastes analysis was carried out monthly for a period of 12 months and for each batch mainly detection of additives and preservatives, prior to accepting it in the developed In-house Biogas digester was performed. After performing the detection tests the waste samples were accepted in the biogas generator. The results of these estimations are as shown in table 1.

Table 1: Test results for Additives/Preservatives

Sr. No.	Names	Detection Results
Additives		
1	Urea	No Detection
2	Boric Acid	
3	β – Naphthol	

Preservatives		
4	Benzoic Acid	No Detection
5	Sailicylic Acid	
6	Hydrogen Peroxide	
7	Formalin	
8	Carbonates	

Furthermore, solid wastes analysis was done for the estimation of total carbohydrates, total fats, minerals, total proteins and calories. The result obtained for composition analysis of solid wastes that was used as intake materials in biogas digester and recorded observations is represented in table 2 and table 3 respectively.

Table 2: Test Results for waste composition

Sr. No.	Tests/Parameter	Unit	Results
1	Moisture	g/100g	75.2
2	Total Protein	g/100g	1.85
3	Total Fat	g/100g	3.2
4	Total Carbohydrate	g/100g	18.01
5	Calories	g/100g	110
6	Minerals	g/100g	1

It can be envisaged from the table 3 that when 500 g material is fed, average ambient temperature remained at 30.56°C, the average digester temperature was consistent at 34.63°C. At this point of time, the average pH value remained at 7.09 in the digester and the peak volume of biogas i.e., 64.16 liters will be generated in the developed In-house Biogas digester, wherein the average amount of generated methane gas will be 54.56%. Therefore, it can be estimated that about 128.32 liters Biogas can be generated from one kilogram of wastes when it is fed into the biogas digester.

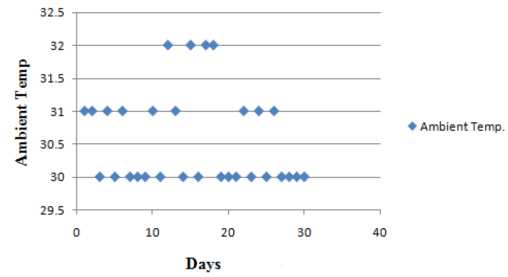

Figure 3(A): Average Ambient Temp. during trials

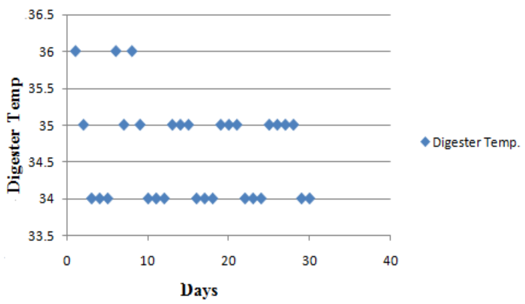

Figure 3(B): Average Digester Temp. during Trials

Following figure 3 (A) and figure 3 (B) depicts the average ambient and digester temperatures respectively during the trial period.

Table 3: Generated Biogas during trials

Days	Ambient Temp.	Digester Temp.	pH	Generated Gas Vol. (Lit.)	Generated Methane Gas (%)
1	31	36	7	63	56
2	31	35	7	62	50
3	30	34	7	62	52
4	31	34	7	63	57
5	30	34	7	68	54
6	31	36	7	63	57
7	30	35	7	62	53
8	30	36	7	68	56
9	30	35	7	63	56
10	31	34	7	62	52
11	30	34	7	68	54
12	32	34	7	62	52
13	31	35	7	63	56
14	30	35	7	68	56
15	32	35	7	63	56
16	30	34	7	63	56
17	32	34	7	68	54
18	32	34	7	68	56
19	30	35	7	68	56
20	30	35	7	62	52
21	30	35	7	63	54
22	31	34	7	68	56
23	30	34	7	62	54
24	31	34	7	63	56
25	30	35	7	68	56
26	31	35	7	63	56
27	30	35	7	68	56
28	30	35	7	62	52
29	30	34	7	62	54
30	30	34	7	62	52
Avg	30.56	34.63	7	64.16	56

The pH Value that prevailed in the In-house Biogas digester was measured on daily basis during the trial period. The average pH value of 7.09 was inferred from this observation and the same is represented in figure 4 that indicates a consistent range of pH value during the entire trial period i.e., 7.0 – 7.3.

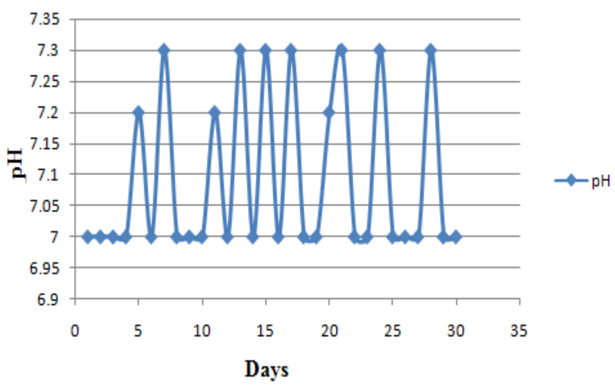

Figure 4: Average pH value during trials

The range of Biogas generated (Volume in liters) and range of methane % obtained in Biogas during the trials is depicted in figure 5. The range of volume of biogas generated remained consistent between 60-70 liters as shown in series 1 of figure 5, and the methane % was observed in the range of 50%-60% as shown in series 2 of figure 5.

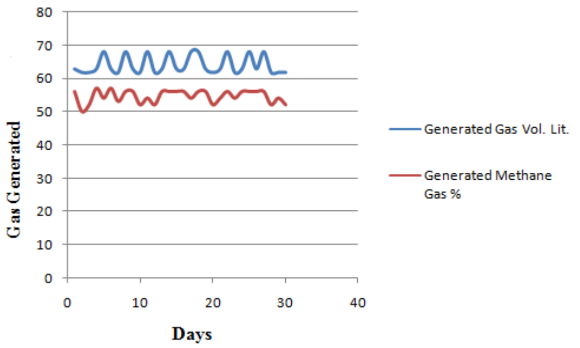

Figure 5: Biogas generated during trials

The developed Biogas technology can serve as attractive opportunity to produce biogas in rural India as a possible alternative to conventional energy resources. Biogas technology adaption can facilitate to achieve the goals like cost minimization, employment generation, efficiency maximization, system reliability, maximum use of local resources, minimum use of petroleum products and allows low emissions. The biogas digesters can be incorporated with public toilets that can improve its sanitary conditions, reduce waste problems and the residue can be used as fertilizers. At rural scale, adoption of biogas technology result in socio-economic upliftment, improve health and increase the overall standard of living of people as use of conventional energy sources like wood results in air pollution as they generate high smoke and cause health problems like respiratory disorders that is the main reason for infant mortality in developing nations. In comparison to coal, the biogas technology can provide clean energy solution like when it is used for cooking the vessels will not turn black from bottom. The problems of vomiting, dizziness, nausea and headaches increase if the levels of hydrogen sulphide increase and even problems like sneezes and choking can result due to the increased levels of sulfur dioxide. These problems can be eliminated as only low levels of these larger hydrocarbons are emitted by Biogas technology and will result in less air pollution because they have few larger hydrocarbons. Also, parasitic disease can be controlled by proper sanitation and production of energy in a sustainable manner. Thus, the Biogas technology can be strategic in strengthening a nations' economy.

Conclusion

The In-house Biogas digester developed during the present studies can process domestic food wastes into biogas. The model was based on the floating drum digester type model. The entire experiments of biogas generation in developed model were carried out for a period of 12 months. During each month initially the solid waste analysis was carried out that had to be fed in the developed In-house Biogas digester. Analysis was done to detect the presence of additives and preservatives. The waste composition analysis was done and month-wise measurement of Biogas in the developed In-house biogas model was carried out. The month-wise analysis of additives and preservatives suggest that there was no detection of preservatives and additives in food wastes fed as raw materials into developed In-house Biogas model during each month. The monthly tests were performed in order to detect additives and preservatives like Urea, Boric acid, β-Naphthol, Benzoic acid, Salicylic acid, Hydrogen peroxide, Formalin and Carbonates. Furthermore, the month-wise composition analysis of solid wastes that was used as intake materials in biogas digester was performed. The results obtained for Moisture, Total Protein, Total Fat, Total Carbohydrate, Calories and Minerals were 75.2, 1.85, 3.2, 18.01, 110.0 and 1.0 (g/100g) respectively. The generated biogas in the developed model was measured on a daily basis and it is concluded that at average ambient temperature of 30.56°C, the average digester temperature remains consistent at 34.63°C and at this point of time, the average pH value will remain at 7.09 in the digester and the peak volume of biogas i.e., 64.16 liters will be generated in the developed In-House Biogas Digester, wherein the average amount of generated Methane gas will be 54.56%. Therefore, the results indicate that about 128.32 liters Biogas can be generated by only one kg of food refuse as raw material when it is fed in the built biogas reactor. Thus, it is recommended that more and more development of such eco-friendly Biogas technology must be encouraged for effective solid waste management. Thus, trials conducted indicate that the developed In-house Biogas model was efficient for the generation of Biogas and can be adopted as economically viable option for effective management of solid wastes with wide acceptance. The model is very cheap, small capacity biogas generator that can be easily installed at our House. It costs merely Rs.842/- only with high uptake capacity of our domestic wastes and technical expertise is not mandatory. Moreover, it requires less space and maintenance. Thus, it is a model that can be readily acceptable and affordable at rural-scale and is environment friendly technology.

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Conflict of Interest

None Declared.

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