Design of Eco Bin for Household

[1]Kunal A. Shambharkar, [2]Chaitali S. Lipne, [3]Pratiksha D. Deshmukh, [4]Pratiksha P. Deshmukh, [2]Dr. S. B. Warkad

[1,2,3,4]UG Student, [5]Professor, P. R. Pote (Patil) College of Engg., & Mgmt, Amravati, India.

[1]sidshambharkar@gmail.com, [2]chaitali200498@gmail.com, [3]dpratiksha2497@gmail.com, [4]deshmukhpratiksha28@gmail.com, [5]sbwarkad@gmail.com

Abstract: Kitchen waste is the food which is discarded or lost uneaten. Wastage occurs in all stages of food supply chain. Household waste is organic in nature and is mostly composted or can be utilized for better purposes. Biogas production requires anaerobic digestion, this study is to create an organic processing facility to create biogas which will be more cost effective eco-friendly, cut down on landfills waste, generated a high-quality renewable fuel, and reduce carbon dioxide and methane emissions. The process of grinding includes reducing the particle size of kitchen waste which is done automatically and used in waste management for composting. To address this, automatically operated kitchen waste, grinder is developed. The developed grinder was tested using different parameters such as rotational speed and feeding rate. The anaerobic digestion of kitchen waste produced biogas a valuable energy resources anaerobic digestion is a microbial process for production of biogas, which consist of primarily methane and carbon dioxide. In this study we have prepared our Inoculum then we installed batch reactors. In his eco-bin mechanism inoculum of previous cow dung slurry along with the kitchen waste is added to develop for biogas production. The production of biogas and methane is done from the canteen waste and kitchen waste leftovers are determined at laboratory scale using the simple digester. The biogas is further feeded to the gas turbine to produce electricity for lighting purpose.

Keywords — Kitchen Waste, Eco bin, Bio-gas, Grinding, Compost, Electricity generation

I. INTRODUCTION

In this modern era, solid waste management [1] is one of the biggest problems in the world. Around 50% of the waste in the world is organic in nature. This organic waste consists of both organic & inorganic waste. About 78% of the kitchen waste can be recycled. This mixture which consists of both organic and inorganic waste degrades the soil and also produces bad odor. It should be properly treated and segregated. To manage this solid waste, it should be properly segregated at the source (houses).This organic waste can be treated to make compost as well as biogas formation. While inorganic waste can be segregated and taken out for garbage collection. Various other mechanisms segregated this kitchen waste into organic and inorganic waste and use this organic waste for making into nutritive compost as well as biogas [2-3]. Due to scarcity of petroleum and coal it threatens the supply of fuel throughout the world. In order to get access the renewable energy sources such as biogas. It is distinct form of renewable energies because of its characteristics of using, controlling and collecting organic waste and at the same time producing fertilizers and water for use in agricultural purposes. Several literatures are studied as background of research. Shalini singh et al., [4] studied the increased biogas production using microbial stimulants. The result shows that dual addition of aquasan to cattle dung on day 1 and day 15 increased the gas production by 55% over unamend cattle dung and addition of teresan to cattle dung. ART of India, [5] has developed a compact biogas plant which uses the waste food rather than any cow dung as feedstock, to supply biogas for cooking. Debosz et al., [6] studied the effects of sewage sludge and household compost on soil physical, chemical and microbiological properties. The study concluded that the dynamics of growth factors such as nutrient availability, gas exchange, and water retention characteristics can directly influence crop development. Lissens et al., [7] completed a study on a biogas operation to increase the total biogas yield using several treatments. Hilkiah Igoni [8] studied the effect of total solids concentration of Municipal Solid Waste on the biogas produced in an anaerobic continuous digester. A. Malakahmad et al., [9] constructed anaerobic biogas reactor with a unique design and various profiles of microbial communities were developed within the reactor. Peter Wieland [10] reviewed the current state and perspectives of biogas production, including the biochemical parameters and feedstock which influence the efficiency and reliability

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of the microbial conversion and gas yield. Ravi P Agrahari and G N Tiwari [11] compared different ratios of kitchen waste under aluminium made biogas plant. Zhang et al., [12] studied anaerobic co-digestion of kitchen waste and pig manure with different mixing ratios.

The growing urbanization, waste generated at kitchen can be the best alternative for biogas production in a community level biogas plant. It is produced when bacteria degrade organic matter in the absence of air. Biogas contains around 55 - 65% of methane, 30 - 40% of carbon dioxide. The calorific value of biogas is appreciably high (around 4700 kcal or 20 MJ at around 55% methane content).

The biogas can effectively be utilized for generation of power through a biogas based power - generation system after dewatering and cleaning of the gas. In addition, the slurry produced in the process provides valuable organic manure for farming and sustaining the soil fertility. The use of biogas using kitchen waste as feedstock can help solve the problem of energy deficit and at the same time, allow the safe disposal of kitchen waste which is often unscientifically dumped or discarded. [13]. Kitchen waste is organic material in rich in nutritive value to microbes. In order to quick formation of biogas we add some ¼ ratio of cow dung to the slurry. A grinder is helpful for the kitchen waste particles to convert into smallest particles for quick and efficient production of compost and biogas. In this proposed Eco-Bin design, our main motto is to provide solutions to household for kitchen waste and its utility to produce compost for plants, biogas for gas stove and electricity generation for lighting purpose.

II. MATHEMATICAL MODELLING OF ECO-BIN SYSTEM

In this Eco-bin modeling, we describes the procedures employed for collecting mixed types of kitchen waste, determination of physical properties of kitchen waste, constructional or development of kitchen waste grinder and accessing the suitability of grinded waste for composting, biogas and electricity[14].

2.1 Physical Properties

Size: To determine the average size of the kitchen waste, samples of kitchen waste was randomly picked up and there are three major dimensions namely, length (l), width (b) and thickness (t) were measured in (cms) [15].

Dimension (D) = (lbt)^(1/3) ……..(1)

Sphericity of kitchen waste (S) = [(lbt)^(1/3)]/4 ……..(2)

Shape: The shape of kitchen waste is determined through visual observation and by comparing wit standard shapes [16].

Density: The density of kitchen waste can be measured by the following

Density [kg/m^(3)] = Weight of waste (kg)/Volume of waste (m^(3)) ……(3)

The waste were dried in an air ventilated oven at 90 degree Celsius for 48 hrs

Moisture content (% wb) = [(Initial weight of kitchen waste)-(Final weight of kitchen waste)] / Initial Weight of kitchen waste *100 ……(4)

2.2 Grinder Design Details:

Diameter of rotor shaft: The shaft was a rotating member having a circular cross section to which transmitting elements such as cylinder, pegs on the cylinder and bearings, were mounted the materials used for shaft was high carbon steel consist of 9mm diameter for grinder.

Shaft design: The shaft design primarily consist of determination of the optimum shaft diameter to ensure sufficient strength & rigidity .When the shaft was transmitting power under various operating as well as loading conditions. The shaft was subjected to torque and diameter of shaft was obtained by using the equations

$$T=22/7*Fs*d^{(3)} \quad \text{…….(5)}$$

Were Fs=maximum allowable stress for high carbon steel (MPa) taking yield stress=320 Pa; Fs=160 MPa ; d = diameter of shaft required (cm); T=torque developed on the shaft (kg-cm)

2.3 Constructional Features: This section illustrates the constructional details of different machine parts of the grinder

Inner Surface: The surface using fiber of size 92*55*48 cm

Linear speed determined using the formula

$$Ls\{m/min\}=pi*D*N \quad \text{…….(6)}$$

Where, Ls=linear speed (m/min); D=Diameter of the bin surface (m); N=speed of rotations (rpm)

Rotor shaft: It was one of the key components of the machine other parts, were mounted on the shaft. The grinder used 9 mm rotor shaft. The standard size and length of the shaft were selected based on shaft design.

Outlet: The outlet was provided at bottom side of bin. The outlet was wide open in order to have the free fall of the kitchen waste which was separated by the manual door or gap between outer and inner surface bin.

Factors considered for grinding operation: Factors such as feeding rate (kg/h) and rotational speed (rpm) were imposed with main focus to estimate grinding efficiency, grinding capacity and size reduction efficiency of grinding machine. Feeding rate such as a 4kg/h and rotational speed of 1200 rpm were selected. The kitchen waste was separated as mixed food waste.

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Depending variable: Grinding efficiency, Grinding capacity, size reduction efficiency, Initial & final size of kitchen waste grinder are the dependent variables.

Design Factor: The dependent parameters were then computed using the following formulae:

Grinding Capacity (kg/sec) = Mass of kitchen waste grinding (kg)/ Time taken (hr) ……(7)

Grinding efficiency (%) = Output of kitchen waste/ Input of kitchen waste *100 ……....(8)

Size reduction efficiency (%) = [Initial size of kitchen waste (cm)] - [Final size of kitchen waste (cm)] / Initial size of kitchen waste (cm) *100 …….(9)

2.4 Process of composting: First of all organic kitchen waste is taken for the first day, (leaves & food waste and waiting to break down into humus for a certain period) in the basket and spread newspaper sheet or a tissue paper on it to make sure very small food particles like tea or coffee powder do not fall down and clog the outlet. Sprinkle a generous layer of remix powder on it and put a few inches of food waste. The Eco bin has been designed in such a way that its lid is easy to open and close multiple times a day and it also has basket down the bin so that kitchen waste when turned into compost after grinding can make out to fall directly inside the basket easily. Fig.1. shows the compost generated through kitchen waste.

Fig 1: Composted kitchen waste

2.5 Production Process:

(a) Biogas System: A biogas system generally consists of Manure collection, anaerobic digester, Effluent storage, gas handling and use etc. Biogas is a renewable form of energy .Methanogens (methane producing bacteria) is last link in a chain of microorganism which degrades organic material and returns product of decomposition to the environment.

(b) Biogas Production: Organic substances exist in wide variety from living beings to dead organisms. Organic matter are composed of carbon(C),combined with elements such as Hydrogen(H), Oxygen(O), Nitrogen(N), and Sulphur (S), to form variety of organic compounds such as carbohydrates, proteins and lipids. In nature MOs (microorganisms), through digestion process breaks the complex carbon into smaller substances. The digestion process occurring in presence of oxygen is called Aerobic digestion and produces mixtures of gases having carbon dioxide (CO_2), The digestion process occurring without (absence) of oxygen is called Anaerobic digestion[5] which generates mixtures of gases. The gas produced which is mainly methane produces 52005800 KJ/m^(3) which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable).

2.6 Methods and Calculations:

Analytical Methods & Calculations

1) Total Solids (Ts %) - It is the amount of solid present in the sample after the water present in it is evaporised. The sample, approximately 10 gm. is taken and poured in foil plate and dried to a constant weight at about 1050C in furnace.

TS% = (Final weight/Initial weight) * ….. (10)

2) Volatile Solids (Vs %) – Dried residue from Total Solid analysis weighed and heated in crucible for 2hrs at 500 0C in furnace. After cooling crucible residue weighed.

VS % = [100-(V3-V1/V2-V1)] * 100 …….. (11)

Where, V1= Weight of crucible, V2= Weight of dry residue & crucible and V3= Weight of ash & crucible (after cooling)

3) Volatile Fatty Acid (VFA) - Volatile fatty acids (VFA's) is fatty acids with carbon chain of six carbons or fewer. They can be created through fermentation in the intestine. Examples include: acetate, propionate, and butyrate. There are many titration methods for VFA measurement.

Experimental Procedure and results: In this experiment 50 gm of grinded kitchen waste was mixed with 150gm of cow dung and water to make 1 litre slurry which is poured in 1litre bottle. In this experiment gas production occurs with blue flame. Process continues, volatile fatty acids (VFA) are produced which causes the decrease in PH. By using food waste and organic waste from cafeteria and canteens around the campus, this mini biogas digester will digest all the waste to turn it into methane in order to produce electricity.

III. SYSTEM DEVELOPMENT AND ITS DESCRIPTIONS

In proposed system first of all to decide how much kitchen waste is generated at home and at college canteen. We collected nearly 2-3 kg from household and 6-7 kg from canteen kitchen waste. With this we have designed the system which is semi-automatic in which whatever amount of kitchen waste we are getting that is basically 3-4 kg. We 1st grind this kitchen waste in the grinder which has blades

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of rotor 23 cm while its height consists of 19 cm in the bin which has dimension about 28 cm length and 30 cm diameter having a capacity of about 100 litre. The grinding is done at speed of about 1200 rpm while on the jar for biogas in which, we generate biogas of about 40 ml also for steering purpose refixed a DC gear motor of about 30 rpm and then biogas is generated. We further used this pressurised biogas to release on gas turbine in which 40 ml gas and this turbine having length of about 16 cm is rotating for about 7-8 minutes in which we can able to generate electricity at least for lighting LED as prototype. The physical model is shown in Fig. 2 and Fig. 3. Further we can implement this on large scale.

3.1 Components for system: Table 3.1 shows the components used to design Eco-Bin.

Table 3.1: Components for Eco-Bin Design

SN	Product Name	Quantity	Description
1	10 liter gas storage tank	1	-
2	120 liter bin	2	Height-92cm, Width-55cm
3	DC Motor	2	
4	DC Gear Motor	1	Shaft-8mm,Circular area-65mm, height- 12cm, 1200rpm
5	Wiper Motor	1	12V,Torque-100Kg.cm,Speed-30rpm,Circular area-17.898,length-11cm
6	Suction Pump	1	DC 5-12V
7	Rotor Grinder	1	Blades-8 Viser-10
8	Stirrer	1	Length-15cm
7	Turbine	1	Length-16cm; Outer Blades-16 gauge Inner Blades-20 gauge
8	Grinder Bucket	1	Length-28cm; Diameter-30cm
9	Compost Container	1	23cm
10	Gas Pipe	1	1meter

3.2 Proposed Methodology:

First of all considering and keeping all the points in mind all the organic waste which is rich in carbon and nitrogen is selected and collected. The sample for 4 kg of kitchen waste is used in this model. In the first bin as shown in Fig.2 is used for making of compost. In the first bin kitchen waste is grinded with the help of grinder at a speed of about 1200 rpm. When these kitchen wastes are grinded and make it to fall inside the basket which has turned into fine particles. This fine particle is now mixed with magic microbes or kitchen compost remixes powder for 2-3 days and leave it so that it turned into full compost. While the other bin as shown in Fig.3 is for making of biogas. In this bin 4 kg of kitchen waste along with ½ kg of cow dung + water was mixed with it so that it acts as a catalyst for the quick formation of biogas within 3-4 days. This inoculum which is present in the second bin is now stirred with the help of stirrer mechanism or assembly. While the collected gas in the second bin is stored inside the tank which is further used for the production of gas for cooking purpose and for generation of electricity, it can be used for bio-fuels etc. In our design we produce electricity as a prototype model for lighting of one LED by the injection of this collected gas on the turbine which can rotate about 7-8 minutes for 40 ml gas produced out of it. One of the valve is been given for the gas burner for cooking purpose etc.

Fig. 2: Front View of Model-Design of Ecobin for Household

Fig.3: Top View of Compost Bin and Digester

IV. RESULTS & ANALYSIS

The prototype model entitled "Design of eco bin for household purpose" is designed at the Department of Electrical Engineering, P. R. Pote (Patil) College of Engineering & Management, Amravati. The model design and outcomes are presented in this section.

4.1.1 Kitchen wastes in Canteen: Assuming household and canteen works, 12 months per year, amount of waste food generated per year in each mess has been calculated. The major categories of kitchen waste found in hostels are

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vegetable waste, fruit waste, grains waste, rice waste, chapatti, sweets and other waste. During experiment, it was found that rice and vegetable waste was more. In canteen waste production was more because they prepared the food as per customer or consumer requirement and availability. In this experiment, waste food was around 6 to 10 kg per day. Some other wastes like grains, sweet and processed food waste were around 2 to 5kg per day. If Canteen worked around 300 days per year the waste production would be between 2400 kg per year.

4.1.2 Process of composting: First of all organic kitchen waste is taken for the first day, (leaves & food waste and waiting to break down into humus for a certain period) in the basket and spread newspaper sheet or a tissue paper on it to make sure very small food particles like tea or coffee powder do not fall down and clog the outlet. Sprinkle a generous layer of remix powder on it and put a few inches of food waste. The Eco bin has been designed in such a way that its lid is easy to open and close multiple times a day and it also has basket down the bin so that kitchen waste when turned into compost after grinding can make out to fall directly inside the basket easily. In our prototype model we collected fresh cow dung and kitchen waste and poured into 120 litre digester and mixed with water thoroughly. Content of previous experiment was used as inoculum. It contains the required microorganism for anaerobic digestion. After the inoculation digester was kept for some days and gas production was checked. After some days kitchen waste was added for checking gas production. This digester contains the composition i.e. 120 liters digester, Cow dung + waste + water added, Cow dung – ½ kg, waste – 4kg, Water – 5lit and PH – 5.02.

4.1.3 Numerical Results: Following results as shown in Table 4.1.3 are drawn from proposed model.

Table 4.1.3: Results of Eco-Bin for production of compost, Biogas and electricity based on model implemented.

Kitchen Waste (Input)	**Added (Input)**	**Compost Production (output)**
4-5 kg kitchen waste which is organic in nature feed to Eco-bin daily	Total 8 litres slurry generated in Eco Bin which includes 4-5 kg kitchen waste + ½ kg cow dung + 3.5 litre water	Minimum of 2-3 kg of compost is formed when this kitchen waste is grinded and mixed with some remix powder to completely turn into compost.
Bio-Gas Production (output)	**Electricity Generation (output)**	
About 2kg of gas is produced by the natural process while this process requires about 3-4 days for quick formation of biogas in which we have to feed our stuffs daily	When this bio-gas is been injected then it leads to the glowing of at least one LED for 40 ml gas it rotates this turbine for 7-8 minutes and light also glows by the time.	

Recommendations for Generation of Electricity: In order to generate sufficient electricity for household, it is recommended to use biogas mini power plant at remote areas because it does not cost a lot and generates electricity easier without causing any problem. Furthermore, this system can be installed easily due to it being modular which means it is portable and can be transferred and installed anywhere. The biogas mini power plant only needs food and organic waste to generate electricity energy and the generator is guaranteed to work 24 hours a day regardless of the weather. The supply of wastes is continuous as long as there are people that lives in the vicinity; ensuring that this system will work well. If solar system is used, it may cause a problem during rainy day because the system will not be able to receive any sunlight and needs battery for backup. The battery will cost a lot and the place needed to store the battery is also high in cost. The price needed is too high to be used in remote areas. The proposed biogas generator has a rated power for 15 KVA on large scale while its gas consumption will be 7-9 scum per hour whose engine model is PNG-2-BG. The recommended model is shown in Figure 4.

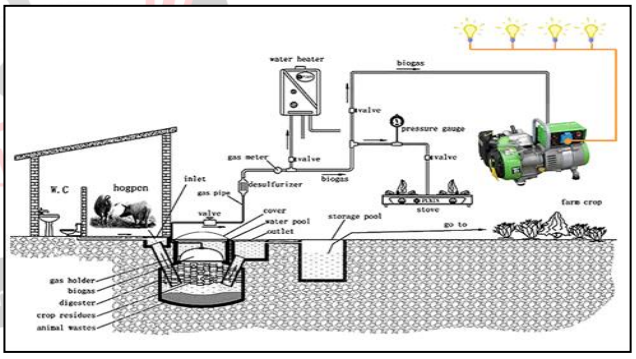

Fig. 4: Biogas to electricity generation

Recommendation for Biogas generation: Biogas is one of the energy provides in rural areas for cooking purposes. This paper attempted to produce electricity, biogas and compost. There are two bins we use one for compost bin and second for digester. Digester having some kitchen waste plus cow dung as well as water at mesospheric temperature has high rate of biogas production and we also use some magic microbes powder for the production of biogas and electricity. Cow dung is best for input to digesters which are at room temperature. Also, occasional stirring of digesters would increase the rate of biogas production. For future studies in biogas, it is recommended that effluent from existing digesters be introduced in the beginning to observe the rate of biogas production. The effect of removing H2S from biogas before burning can also be studied.

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V. CONCLUSIONS

Proposed Compost Bin can play a major role in solid waste management in India in the future by eliminating the organic waste dumping at the source and instead only dumping inorganic waste. As the compost bin is easy to use and is cost effective, many people can buy and use it. It is easy to use and is simple. This study demonstrates the design of Eco bin for household. In this study calculations and mathematical modeling is demonstrated. This study demonstrates kitchen waste as well as how much amount of feed stoke which is been required to make this mixed kitchen waste into compost by adding some compost remix powder to convert this organic waste into compost. It also demonstrates generated biogas for 4kg of feed stoke of kitchen waste as well generated electricity by rotating the turbine for 40ml gas the gas turbine rotates for about 7-8minutes in order to glow one LED for nearly 7-8 minutes.

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