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Design of biogas digester for effective utilization of kitchen waste from hostel mess

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Abstract
The uses of renewable energy sources are becoming very essential due to the limited reserves of fossil fuels. Biogas is a valuable renewable energy source containing 55% methane and a sustainable mode of waste disposal. This research work focusses on the biogas production from the food waste collected from a hostel mess. Kitchen waste is one of the wastes having high calorific value and can be used for solving the problem of increased demand of fuel and waste disposal. The use of biogas using kitchen waste as feedstock can help solving the problem of energy scarcity and at the same time; allow safe disposal of kitchen waste which is often unscientifically dumped or discarded. It maximizes the reduction of food waste to the ground. This biogas plant will provide biogas for cooking purpose and also manure for vegetation purpose. The kitchen waste is obtained up to 27.5 per kg/day may be produce gas up to 6.54 m3/day within 30 days of retention period.

Keywords: Renewable energy, biomass, solar power, kitchen food waste

Introduction
Rapid growth of population, uncontrolled and unmonitored urbanization has created serious problems of energy requirement and solid waste disposal. 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 orders of magnitude. The purpose of this project is to find out how the hostel mess kitchen waste could be converted into biogas and to design an anaerobic digester which uses kitchen waste to generate the biogas. The purpose of this project is to find out how the hostel mess kitchen waste could be converted into biogas and to design an anaerobic digester which uses kitchen waste to generate the biogas. Proper design & efficient operation of biogas plant can be considered as cost effective & efficient method for energy generation & waste minimization.

Methodology
Estimation of kitchen waste: The kitchen waste was collected from K.K. Wagh Agriculture Boys Hostel Mess. Kitchen waste which include cooked rice, cooked vegetable, chapatti, etc. The kitchen waste estimated on per day basis after meals from hostel mess. The daily kitchen waste was measured by using 10 liter bucket.

Evaluation of parameter of Kitchen Waste
The Kitchen Waste utilized for Biogas generation was tested in laboratory for various chemical parameters in order to determine whether its chemically fit for anaerobic digestion or not. The various test are as follows.

1. Moisture Content
To determine the amount of moisture present in the known sample of feed material was kept in Electric Hot Air Oven at 130 ºC until constant weight was obtained. It is given by,

$$\text{M.C. } (\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,
W_1 = weight of empty crucible, g
W_2 = weight of crucible with sample before drying, g
W_3 = weight of crucible with sample after drying, g

2. Volatile Matter
Volatile Matter present in feed material was determined by keeping oven dried material with lid inside Muffle Furnace at 925 ºC for 7 min. The loss in weight represents volatile matter. It is given by,

$$V.M. (\%) = \frac{W_4 - W_5}{W_2 - W_1} \times 100$$

Where,
$W_4 = W_3$ + weight of lid, g
W_5= weight of crucible with sample from Muffle Furnace + weight of lid, g

3. Ash Content
Ash Content is determined by keeping the wet sample in Muffle Furnace for 2 hour at 600 ºC. The procedure was repeated until no variation in weight was observed. It is given by,

$$A.C. (\%) = \frac{W_8 - W_6}{W_7 - W_6} \times 100$$

Where,
W_6 = weight of empty crucible, g
W_7 = weight of wet sample with crucible, g
W_8 = weight of ash of sample with crucible, g

4. Fixed Carbon Content
The percentage of fixed carbon was estimated by deducting the moisture content, volatile matter and ash content from hundred. It is given by,

$$F.C. (\%) = 100 - (M.C. + V.M. + A.C.)$$

5. C: N Ratio
It is one of important chemical parameters for methane production. The value of C: N ratio must lie in range of 20:1 to 30:1. The various empirical formulae for determining C: N Ratio are as follows:

% Carbon = 0.9F.C. + 0.7 (V.M. - 0.1A.C.) - M.C. (0.6 - 0.01M.C.)
% Nitrogen = 2.1 - 0.02V.M.

$$C: N\ Ratio = \frac{\%\ Carbon}{\%\ Nitrogen}$$

Design and Consideration
1. Gas production rate (G): One kg of kitchen waste if digested well yields about 0.24m3 of gas. The gas production rate G for the available waste thus given as (K.M. Akkoli 2015) [2].

$$G = 0.24W$$

Where,
W = 27.25 kg/day.
G = 0.24 × 27.25
G = 6.54 m^3/day

2. Active slurry volume (Vs): The active slurry volume in the digester is directly related to the HRT chosen and is given by

$$Vs = HRT \times \frac{2W}{1000}$$

Where,
HRT = Hydraulic Retention Time it is 30 days.

$$Vs = 30 \times \frac{2(27.25)}{1000}$$
$$Vs = 1.6\ m^3$$

3. Calculation of height (H) & diameter (D) of digester: There is no strict rule for the relative values of H and D, but usually a D/H ratio 2.0 is used in practice. Knowing the active slurry volume from above calculation, H can be calculated from equations.

$$Vs = \frac{\pi}{4} D^2 H$$

But D =2H,

$$1.635 = \frac{\pi}{4} \times 4H^3$$

$$H = \left(\frac{1.63}{\pi}\right)^{\frac{1}{3}}$$

H = 0.804 m, D = 2 × 0.80, D = 1.6 m

4. Slurry displacement inside digester (d): The selection of a suitable value of d depends upon gas usage pattern. If the total cooking time is about 3 hours, the variable gas storage volume Vsd is obtained from equation

$$Vsd = (0.375\ G) = 0.375 \times 6.54,\ Vsd = 2.6\ m^3$$

D is obtained from equation,

$$Vsd = \frac{\pi}{4} D^2 d,\ Vsd = \frac{\pi}{4} 1.6^2 d$$
2.6 = 2.03d
d = 1.2 m

5. Slurry displacement height (h) in Inlet & Outlet tanks: The maximum pressure attained by the gas is equal to the pressure of the water (slurry) column above the lowest slurry level in the inlet/outlet tanks. The pressure usually selected to be 0.85 m water gauge as a safe limit for brick

h + d = 0.85, h = 0.85 – 1.2, h = - 0.35 m

(Negative sign means the height is below the tank level)

6. Length (l) & breadth (b) of inlet & outlet tank: Usually a rectangular shape with l=1.5b is selected. If the inlet and outlet cross sectional areas are selected to be identical we get

2 × l × b × h = Vsd
$2 \times 1.5b^2 \times 0.35 = 2.6$
b = 1.57 m, l = 2.3 m

Result & Discussion
Estimation of Kitchen waste: The kitchen waste was collected from K.K. Wagh Agriculture Boys Hostel Mess. The kitchen waste estimated on per day basis after meals from hostel mess. as given in table No.1

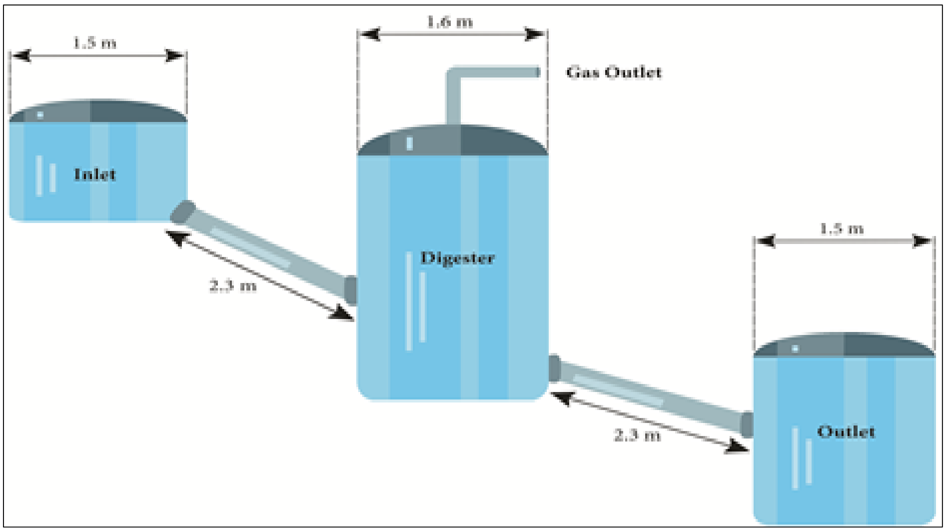

Plate 1: Design of Digester

Table 1: Estimation per day kitchen waste

No. of Days	Days	date	Total Student	Per Day Kitchen Waste In, Kg
1.	Thursday	14/09/2017	90	31
2.	Friday	15/09/2017	75	38
3.	Saturday	16/09/2017	40	24
4.	Sunday	17/09/2017	38	28
5.	Monday	18/09/2017	85	30
6.	Tuesday	19/09/2017	82	34
7.	Monday	25/09/2017	70	33
8.	Tuesday	26/09/2017	64	36
9.	Wednesday	27/09/2017	68	33
10.	Thursday	28/09/2017	65	23
11.	Friday	29/09/2017	38	19
12.	Saturday	30/09/2017	30	20
13.	Sunday	01/10/2017	28	25
14.	Tuesday	03/10/2017	40	18
15.	Wednesday	04/10/2017	48	23
16.	Thursday	05/10/2017	60	17
Total				W = 436

$$\text{Average} = \frac{\text{TOTAL WASTE}}{\text{NO.OF DAYS}} = \frac{436}{16}$$

Average = 27.25 Kg/Day.

Average per day kitchen waste is 27.25 kg/day.

As per the information, hostel is equipped with the mess facility to fulfill student's food demand. In order to fulfill the food demand of hostel students, lots of food waste is also generated which needs a proper disposal. The daily kitchen waste was measured by using 10 liter bucket.

Proximate analysis of selected kitchen waste

The sample of Kitchen Waste generated after lunch and dinner were collected. They were characterized and composition was found out in laboratory. As per observation and by characterization it was found that C: N ratio is calculated as 21.8% can be used as biogas.

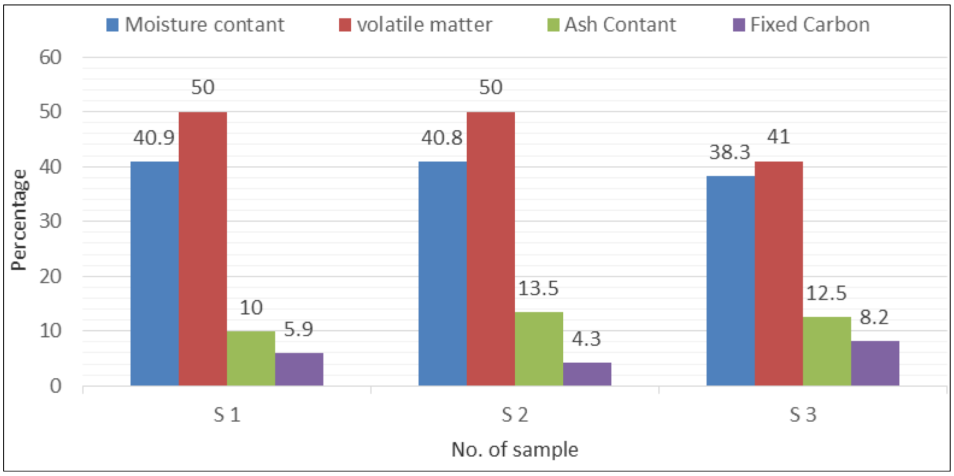

Plate 2: Proximate Analysis of Kitchen Waste

Conclusions

- By utilizing the hostels kitchen waste and other biomass residues can be utilized for better purposes in college campuses. Biogas production requires anaerobic digestion. This study has analyzed a biogas process and how it can be replace the LPG.
- From design we obtained that the estimation of kitchen waste up to 27.5 per kg/day may be produce gas up to 6.54 m^3/day within 30 days of retention period.

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