Design of Biogas Plant for Food Waste and Evaluation of Biogas Generation from Co-Digester Mixtures

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Abstract - *Due to over utilization of fossil fuels and global depletion of energy supply, Biogas is a sustainable energy source because of the major environmental and socio-economic benefits. Anaerobic decomposition of different wastes which biodegradable in nature that can produce biogas. It can be used as healthy cooking alternative.The main objectives of the study are to design a biogas plant for food waste generated in our college and evaluate the efficiency enhancement of biogas by adding various co-digester mixtures such as water hyacinth, algae, cow dung and sugar cane with food waste. An attempt has been made to find the different ways to improve the overall performance of biogas plant. In survey, it is obtained that average total food waste of 100 kg per day is generated from UKF college canteen, cafeteria and all the departments. The fixed dome biogas plant was designed according to the obtained value. Generation of biogas is enhanced by combination of co-digester mixture water hyacinth, algae, and cow dung with proportion of 1:1 among the four batch experiment carried out. The study emphasis to find that, water hyacinth improves the overall efficiency of biogas plant. Biogas having higher cost benefits than LPG. We can safe rupees 66315 per year. So use of biogas plant with the co-digester of water hyacinth is a better alternative one.*

Key Words: **Biogas Production, Food waste, Co-digester mixtures, Anaerobic Decomposition, Fixed Dome Biogas Plant.**

1. INTRODUCTION

In evaluating national development and the standard of living of any nation, the supply and consumption of energy are very important. The overdependence on fossil fuels as primary energy source has led to global climate change, environmental pollution and degradation, thus leading to human health problems. According to current research and future predictions, the crude oil will run out within 40 to 70 years, and natural gas will be finished within 50 years[1)]

Biogas is generated from organic materials under anaerobic conditions. Feed stocks for biogas generation include cow dung, poultry droppings, pig manure, kitchen waste, grass fecal matter and algae. Countries where agriculture sector is an important component to the growth of economy, have found biogas as a useful replacement for wood fuel and dung as fuel for cooking, and heating. Biogas technology even though is a well known technology is relatively new in some parts of the world and can be used as a potent tool to address issues of Indoor Air Pollution (IAP), deforestation and Climate Change. Biogas is a clean fuel because it burns without leaving soot or particulate matter and also since it is lighter in terms of carbon chain length, less amount of carbon dioxide is released into the atmosphere during combustion. Biogas technology has helped some countries in many ways through income generation, life-style improvements and cost saving. Particularly, the paper presents the historical background and current status of the biogas technology and attempts to reveal the future potential and challenges in the dissemination of the technology.[2]

As the biomass extraction technologies are the basically renewable one and which decreases the dependence on the fossil fuels ones the proper technology is adopted for extraction of the energy efficiently and economically. The typical biogas is having the highest composition of Methane (50-70%) and remaining Carbon dioxide (30-50%), also small traces of some other gases, having the calorific value ranging from 21-24MJ/m3[3].

The main advantage of this process is that the product can be used as a cooking, vehicle fuel or for co-generation of electricity and heat, and also leads to reductions in greenhouse gas emissions. The potential can be translated to an aggregated estimated capacity of approximately 48383 million m3 of biogas generation annually.[4]

Even in smaller firms, significant investment costs cannot be addressed without having a clear framework of their profitability and changes that such technology determines in a productive and managerial identity[5].

Energy availability is decreasing day by day; so we need to produce a renewable option of energy; biogas is a better alternative one.

The work is to create an organic processing to generate biogas which will be more cost effective, ecofriendly, reduce landfill waste, generate a quality renewable fuel and reduce carbon dioxide and methane emissions. The installation of biogas plant in the developing countries like India and china are started in 1970.Currently there are 4 and 22 million biogas plants are installed in India and china respectively.

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions .Natural generation of biogas is an important part of bio-geochemical carbon cycle. The major bio chemical reactions involved in biogas production are hydrolysis, acidogenesis, acetogenesis and methanogenesis. Hydrolysis is the process by which complex molecules of carbohydrates like proteins and lipids that are converted into simple compounds like sugar, fatty acid and amino acids.

1.2 OBJECTIVES OF THE STUDY

- To design a biogas plant for food waste generated in our college
- To evaluate the efficiency enhancement of biogas by adding various co- digester mixtures such as water hyacinth, algae, cow dung and sugar cane with food waste
- To determine the cost-benefit analysis

2 MATERIALS AND METHODS

2.1 SOURCES AND GENERATION OF FOOD WASTE

A quantity field survey had taken to determine the total waste generation of food waste from all the departments, canteen and cafeteria in UKF College.

Table.1 Quantity Field Survey

Survey date	Waste Generation per day in kg			Total waste generation per day in kg
	Canteen	Cafeteria	All department	
11/3/19	40	5	50	95
12/3/19	45	5	45	95
13/3/19	50	8	40	98
14/3/19	52	10	35	95
Grand Total = 495kg Average food waste generated per day = 100kg				

2.2 CO-DIGESTOR MIXTURES

Various co- digester mixtures such as algae water hyacinth, sugar cane and cow dung is added to the raw food waste for efficiency analysis.

2.2.1 ALGAE

Algae are a diverse group of aquatic organisms that have the ability to conduct photosynthesis. Certain algae are familiar to most people; for instance, seaweeds (such as kelp or phytoplankton), pond scum or the algal blooms in lakes. From this study Algae is obtained from Thanny; which is an important co digester for the bio gas production.

2.2.2 WATER HYACINTH

Water Hyacinth (Eicchornia crassipes) is obtained from Umayanallor field; has the potential to produce biomethane which can be used to ease the dependency of fossil fuels. Eichhornia crassipes, commonly known as common water hyacinth, is an aquatic plant native to the Amazon basin, and is often a highly problematic invasive species outside its native range.

2.2.3 SUGAR CANE

Sugarcane is a powerful co-digester mixture obtained from alamcode (Attingal, Thiruvanathapuram). Bagasse is the dry pulpy fibrous residue that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a bio fuel for the production of heat, energy, and electricity, and in the manufacture of pulp and building materials.

2.2.4 COW DUNG

Cow dung, also known as cow pats, cow pies or cow manure, is the waste product of bovine animal species. These species include domestic cattle, bison, yak, and water buffalo. Cow dung is the undigested residue of plant matter which has passed through the animal's gut. The resultant fecal matter is rich in minerals.

2.3 DESIGN OF A BIOGAS PLANT

The experimental study aims at, design of fixed dome biogas plant for total food waste generated from our college. The biogas plant designed based on the result of quantity field survey. The average food waste generated per day is 100 kg.

Design a biogas plant based on the following parameters.

2.3.1. Gas production rate (G)

1 kg of food waste produce 0.24m3 of biogas

G = 0.24 W

Where W = 100 kg

G = 0.24* 100 = 24 m3/ day

2.3.2. Active slurry volume (VS)

HRT – 10 days

VS = HRT * (2W/1000)

= 10*((2*100)/1000 = $2m^3$

2.3.3. Height and Depth of digester (H& D)

Usually D/H Ratio in practice is 2

D = 2H

VS = (Π /4) * (2H) 2*H

VS = (Π/4)*4H3

H3 = 4VS/4Π

H = 0.86m

Therefore,

D = 2*0.8 = 1.72m

2.3.4. Slurry displacement inside digester (d)

If total cooking hours is 5

(5G/24) + VSd = 0.5 G

From this we obtained Vsd in terms of G

Therefore, Vsd = (Π/4) * D2 d

d = (0.3*G*4)/ (D2Π)

= (0.3*24*4)/ (1.722*Π) = 3.1m

2.3.5 Slurry displacement in the inlet and outlet tank

Water pressure usually selected is 2.1 m

h + d = 2.1

h = 1m

2.3.6 Length and Breadth of inlet and outlet tank

Length = 1.5 * Breadth

Vsd = 2*l*b*h

VSd = 2*1.5b*b*1

VSd = 2*1.5b2*1

B = 1.55 m

Therefore,

L = 1.55*2

= 2.32 m

2.3.7. Calculation of dome height (dh)

Vd = (/4 * dh) * (3* (D/2)2 + (dh) 2)

Where, Vd = G – Vsd = G – 0.3G

dh = 2.51m

2.3.8. Radius of dome (r)

r = ((D/2)2 + (dh) 2 / 2 dh)

r = ((1.72/2)2 + (2.512)/2*2.51 = 1.4m

Table.2 Design of Biogas plant

Parameters	Obtained value	Parameters	Obtained values
G	$24m^3$/day	d	3.1m
Vs	$2m^3$	L	1.55m
H	0.86m	B	2.32m
D	1.72m	h	1m
dh	2.51m	r	1.4m

2.4 Batch Experiments

The batch experiment consists of mainly three container units as digesters. The mouth of each container is connected to separate tire tubes through PVC pipe and valve.

The various co-digester mixtures used for the biogas production are water hyacinth, sugar cane, algae, cow dung along with food waste. The algae and water hyacinth were collected from thanny and umayanalloor field respectively. The collected algae and water hyacinth is made to a smaller size by hand. The prepared algae and water hyacinth is kept in a temperature of 4^0 C for 48 hrs separately. The three containers were filled with 5 kg food waste. In the first container, co-digesters of 5 kg of algae and 5 kg of cowdung were added to the food waste with mix proportion of 1:1. In the second container, co-digesters of 5 kg of water hyacinth and 5 kg of cowdung were added to the food waste with mix proportion of 1:1. In the third container, 5 kg of sugarcane and 5 kg of cowdung were added to the food waste with mix proportion of 1:1.

The valve is kept open for 28days of anaerobic digestion process. The digesters are kept at 37 degree celcious. Leakage is prevented through necessary valves and fittings.

The experimental study found that water hyacinth playing an integral role in biogas production.

Table.3 Co-digester Mixtures for Phase-1

Sl. no	Food waste (kg)	Co-digester			Biogas Obtained (Kg)
		Mixture	Quantity (kg)	Proportion	
1	5	Algae+ cow dung	5+5	1:1	2.26
2	5	Water hyacinth+ cow dung	5+5	1:1	5.24
3	5	Sugar cane+ cow dung	5+5	1:1	2.63

Again the five experimental studies were contacted to find the effectiveness of biogas production from water hyacinth and cow dung with different mix proportions shown in Table.4.

Table.4 Co-digester Mixtures for Phase-2

Sl. no	Food waste (kg)	Co-digester		Biogas Obtained (Kg)
		Mixture	Quantity (kg)	
1	5	Water hyacinth+ cow dung	5+5	5.24
2	5	Water hyacinth+ cow dung	8+2	6.69
3	5	Water hyacinth+ cow dung	2+8	5.12

4	5	Water hyacinth+ cow dung	10+0	6.12
5	5	Water hyacinth+ cow dung	0+10	5.89

The efficiency of biogas is much increased combination of food waste with co-digesters of water hyacinth and cowdung in the quantity proportion of 8 Kg and 2 Kg respectively.

2.4 Measurement of Biogas through Water displacement method

Water displacement method is used for measuring the volume of biogas produced after 28 days. The setup of volume displacement method is 20L capacity bottle with half filled water and closing the mouth of bottle by using a lid. The arrangement is placed upright in to a basin containing water. Biogas collected in the tire tube is transferred to the mouth of bottle by removing the lid. Flow can be controlled by opening and closing the valve when water reaches to the bottle, water level in the bottle get raised and it can measure by the initial and final level of water in the bottles respectively.

2.5 Cost Benefit Analysis

The primary data were used to calculate total requirement LPG of UKF canteen for Cooking. The comparative study was contacted between amount of biogas production and requirement of LPG. It was found the overall cost benefit is Rupees 4, 26,315/ year

The yearly total requirement of LPG for UKF canteen for cooking purpose is 5700 kg and cost the required for LPG is Rupees 360000 (Three lakh sixty thousand). Our designed biogas plant can produce yearly up to 15000m^3 of biogas that equal to 6750kg of LPG. So that can meet annual requirement of UKF canteen and also it can satisfy excess need of 1050kg LPG that worth Rupees 66315.

Table.5 Cost benefit Analysis

Biogas production per day	Required LPG for canteen per day
Generation of biogas per day = 50m^3 (50 m^3 biogas = 22.5 kg of LPG)	Required LPG for canteen/day = 19 kg
Cost of 22.5 kg LPG = 1421.05 Rupees / day = 1421.05*30*10 = 4,26,315Rupees / year	Cost of 19kg LPG needed for canteen=1200 Rs/day =1200*30*10 =3,60,000 Rs/year
The amount of biogas produced = 22.5*30*10 = 6750 Kg/year	The requirement of LPG =19*30*10 =5700 Kg / year
Cost of biogas = Rupees 4,26,315/ year Excess cost Benefit of Biogas = 4,26,315-3,60,000 = 66,315 Rupees/ year	Gas benefit = 6750-5700 =1050 Kg / year

3. Result and Conclusion

The development of our civilization results in an ever increasing demand for energy. In the last years, the reserves of traditional fossil fuels such as oil, coal and natural gas have been determined. One of the most commonly debated issues is their negative impact on the environment. One of the possibilities for increasing the share of renewable energy could be the agricultural biogas. Biogas is most frequently used in co-generation when creating heat and electric energy. It's becoming more and more popular source of bio methane. The experimental and field results from this study from the operation of biogas production system lead to the following conclusions;

1. The use of water hyacinth with cowdung and food waste can improve the rate of biogas production.

2. A fixed dome biogas plant was designed according to the obtaining survey results that can produce the 50 m^3 of biogas per day.

3. Biogas having higher cost benefit than LPG that can save Rupees 4, 26,315/ year.

Since food waste is easily biodegradable and is having high volatile solids, it can be potentially used as a feed stock for biogas production. Use of co-digester mixtures along with food waste can improve the biogas production and also produce the energy which can be used for the domestic purpose like cooking, lighting etc.

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