International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 20-24

Design and Implementation of Biogas System from Dining Hall Waste of Students Cafeteria at Jimma Institute of Technology, Ethiopia

Fikiru Tafase Mosisa[1], Dr. Getachew Shunki Tibba[2]
[1]Lecturer, [2]Assistant professor,
Department of Mechanical Engineering,
Mettu University, 318, Ethiopia

Dr. Nasim Hasan[3]
[3]Assistant professor,
Department of Mechanical Engineering
Jagdishprasad Jhabarmal Tibrewala University, Jhujhunu 333001, Rajasthan-India

Abstract
Biogas is a clean-burning, "green" fuel used for heating and cooking, transport and power generation. Biogas usually contains about 55-65% methane, 30-35% carbon dioxide, and traces of hydrogen, nitrogen and other impurities. From food and kitchen wastes of Kito Furdisa Campus of Jimma Institute Technology about 33,902 kg of wastes is assessed within a month and biogas plant of 322 m^3 volumes is designed and also total biogas produced is calculated 113 m^3 / day. This gas produced using energy conversion gives us 722 kwh of power per day. Based on biogas produced it diverted to combined heat and power (CHP) system to generate electricity and heat that recovered to produce hot water using stove for cafeteria of Kito Furdisa and its kitchen itself. Energy consumption of this anaerobic digestion of system in dining hall & kitchen wastes give us 41.03 kwhr and the net energy used is 681 kWh which used for CHP [15]. This means the production of electricity will be 75.42 MW h/y and the production of heat will be 138.27 MW h/y. We have done an experiments using small scale up digester in the laboratory. The Experiment contains fresh cow dung, bread and enjera and its digester is covered with 'combust' insulator for conserving temperature.

Keywords: Biogas, Food waste, Temperature

Introduction

Anaerobic digestion is a complicated biochemical process. Based on temperature and input substrate, different strains of bacteria digest complex chains of carbohydrates, fats, and proteins into their component parts, then again into intermediate, simpler molecules, and eventually into a biogas which is rich in methane and can be burned as fuel in the place of natural gas [1-5]. Anaerobic digestion of organic waste provides many benefits [6-10]. This includes the generation of renewable energy, a reduction of greenhouse gases, a reduced dependency on fossil fuels, job creation and closing of the nutrient cycle. It transforms organic waste material into valuable resources while at the same time reducing solid waste volumes and consequently waste disposal costs. Biogas as a renewable energy source not only improves the energy balance of a country but also contributes to the preservation of the natural resources by reducing deforestation and to environmental protection by reducing pollution from waste and use of fossil fuels [11-16].

Jimma University, Jimma Institute Technology (JiT), Kito Furdisa Campus currently generates approximately 33,902 Kg/month of food waste and kitchen waste by the on-campus dining halls. Production of dining hall and kitchen wastes are seasonal, as food preparation needs decrease significantly in mid of July and August. This waste provides a significant potential source for feedstock energy and in anaerobic digestion processes. These wastes also should be an acceptable feedstock for the anaerobic digestion process [9].

Methods

In this Experiment we have used the following materials: From dining hall**,** Enjera with 'atar kik', Very small amount of bread, and Cow dung. In addition, we have used insulating digester using combust to conserve inside and outside temperature.

This Experiment is done at Jimma University Institute of Technology, School of Mechanical Engineering; on date of January 29, 2016 to May 11, 2016 for 103 days. It is combination of 15 Kg of Fresh cow dung, 10 Kg of bread and 10Kg of enjera and 35 L of water

Figure 1: Experimental set-up

In Jimma Institute of Technology (JiT), Kito Furdisa campus student's cafeteria and kitchen wastes, potential have been assessed for one month (from April 27, 2015 to May 26, 2015).

According to data collected for 30 days; 28,574 kg of dining hall wastes (food wastes) measured. 5,328 kg of kitchen wastes measured. Totally 33,902 kg of wastes from both dining hall &kitchen wastes measured. From experiment we have done above moisture content of food waste and kitchen is 46.5%. This means amount of dryness is 53.5%. The

density food and kitchen wastes are taken from graphical representation figure below and it is 515 kg/m^3.
Average mass food waste= 28,574 kg /30 days=952kg/day Average mass of kitchen waste =5328 kg/30 days =178 kg/day. Volume of food and kitchen wastes per day = (952kg/day+178kg/day)/515kg/m^3 =2.19 m^3 / day. Total volume of both wastes (food and kitchen) =2.19 m^3per day. Since the waste is wet, applying one to one ratio of water added to waters, volume of daily charge will be (2.19 *2) (m^3 /day). Which implies that 4.38 m^3 /day.
The volume of digester is defined as, the product of volume of daily charge (Q) and hydraulic retention time (HRT). But HRT, by referring different literatures, taken as 60 days [Experiment-Three]. Therefore, volume digester (V_D) = Q*HRT = 4.38 m^3 per day*60 days V_D = 263 m^3 ~ (6.4m X 6.4m X 6.4m) let us fix size of digester (i.e. LXWXH). Consequently, we have to take volume digester 263m^3.
Organic loading rate is determined as a counter check for the digester volume. By referring different literatures assume that, -Ratio of volatile solid to total solid is 90%. Therefore, from the above graph, density of our wastes gives us 515kg/m^3.
Organic Loading Rate (OLR) = $\frac{Q*S}{V}$ [17].
Where: Q: Flow rate of input [m^3/day]
S: Concentration of VS in the input [kg/m^3]
V: Reactor Volume [m^3]
Hence S= 515 kg/ m^3 * 0.9 = 463.5 kg/ m^3

Consequently, OLR = $\frac{Q*S}{V}$ = $\frac{4.38*463.5}{263}$ = 7.72 kg substrate / m^3 / day. Therefore, organic loading rate is 7.72 kg substrate / m^3 / day. Therefore, 7.72 kg substrate / m^3 / day are found to be acceptable and the calculated digester size then valid. Other studies have shown that the OLR for food waste can go as high as 10 kgVS/m^3 [18]. We have used; hydraulic retention (HRT) of this design is taken as 60 days.

Design of hydraulic tank

Hydraulic tank is designed which contain 3 days of food waste for bacteria to do or work place and also, the feed flow rate of 4.38 m^3 per day. Hence, size of hydraulic tank = $(HRT)_{ht}$ *Q [17].
V_{ht} =3days *4.38 m^3 V_{ht}=13.14m^3

In terms of diameter, (hydraulic tank is cylindrical and its diameter is equal to its height $Vht = \pi r^2 h$
$V_{ht} = \frac{\pi d2\ (d)}{4} = \frac{\pi d3}{4} = 13.14$
d^3 = 16.73 d = 2.55m

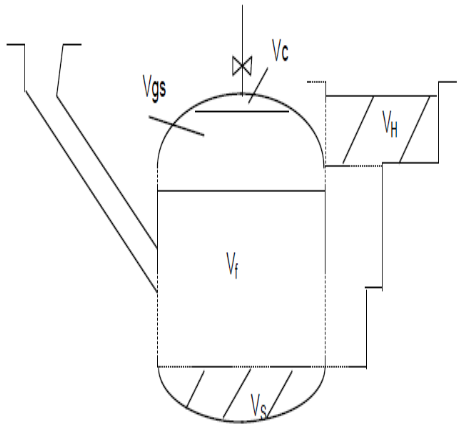

Figure 2: Cross section of digester

i) Volume of gas collecting chamber=V_c

(ii) Volume of gas storage chamber=V_{gs}
(iii) Volume of fermentation chamber=V_f
(iv) Volume of hydraulic chamber =V_H
(v) Volume of sludge layer=V_s
(V i) Let R_1&R_2 is the crown radius of upper and bottom spherical layer of digester respectively.
(vii) $S_{1\ \text{and}}$ S_2 are the surface area of upper and lower dome respectively.
(viii) F_1&F_2 are max. Distance of upper and lower dome.
For structure stability and efficient performance, fixed dome digester is expressed by the following correlation.

Table 1: Correlation for fixed dome digester

For volume	**For geometrical dimensions**
$V_c \leq 5\%$ V	D=1.3078 X $V^{1/3}$
$V_s \leq 15\%$ V	V_1=0.0827 D^3
V_{gs} + V_f = 80% V	V_2 = 0.05011 D^3
V_{gs} = V_H	V_3 = 0.3142 D^3
V_{gs} = 0.5 (Vgs + Vf + Vs) K	R_1= 0.725 D
Where K = Gas production rate per m^3 digester volume per day.	R_2= 1.0625 D
	$f_1 = \frac{D}{5}$
	$f_2 = \frac{D}{8}$
	S_1 = 0.911 D^2
	S_2 = 0.8345 D^2

Volume of digester (v_D) = V_3+ V_2

263 = (0.05011+0.3142) D

721.91 = D^3 D = 8.97 m

*R_1 = 0.725D = 0.725(8.97)m, R_1= 6.5 m

*V_3 = 0.3142D^3 = 0.3142$(8.97)^3$, V_3 = 226.76 m^3

* V_2=0.05011D^3 = 0.05011$(8.97)^3$ = 36.166 m^3

*V_c = 0.05V=0.05(263) m^3 = 13.15 m^3

*f_1 = D/5= 8.97 /5= 1.79 m

* f_2 = D/8=8.97 /8= 1.12m

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 20-24
© Research India Publications. http://www.ripublication.com

* $S_1 = 0.911D^2 = 0.911(8.97)^{2} = 73.3\ m^2$

$V_1 = 0.08227(D^3) = 0.08227(8.97)^3 = 59.37\ m^3$

$R_2 = 1.065(D) = 1.065(8.97)\ m = 9.55\ m$

$S_2 = 0.8345(8.97)\ m^2 = 67.14\ m^2$

Total Volume (V_{tot}) = $V_1+V_2+V_3$

= $(59.37 + 36.166 + 226.76)\ m^3$

= $322\ m^3$

$$V_{gs} = \frac{k(V2+V3)}{1-0.5(k1-0.5(0.4))}$$

$$V_{gs} = \frac{0.4(36.166 + 226.76)}{0.8}\ m^3 = 74 m^3$$

From $V_1 = (V_c + V_{gs}) - \left(\frac{\pi D2H1}{4}\right)$

$59.37 = (13.15 + 74) - \left(\frac{\pi(8.97)2H1}{4}\right)$

$111.12 = \pi(8.97)2H1$

$H_1 = 1.87\ m = 187cm$

The value of the height of the above dome up to the end, have fixed h = 8m (water volume, 1mm = 10 N/ m^2)

$h = h_3 + f_1 + H_1$

$h_3 = h - (f_1 + H_1)$

$= 8 - (1.79 + 1.87)$

$= 4.34m$

Again we know that

$Vgs = V_H$

$74 = \frac{\pi(DH)2h3}{4}$

$(D_H)^2 = \frac{74}{3.14}$

$D_H = 4.85m$, diameter of hydraulic chamber

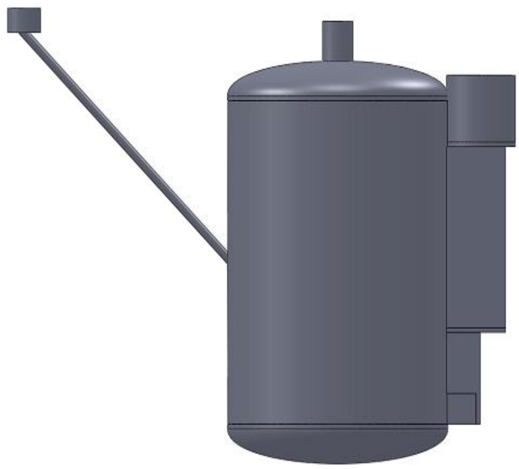

Figure 3: Designed digester

Total Gas produced

Total gas produced from food waste is calculated as, amount of food waste per day time its gas production rate.

- $952*0.1m^3 = 95.2m^3$/day (for food waste).
- $178*0.1m^3 = 17.8m^3$/day (for kitchen waste)

Total gas production = $(95.2+17.8)\ m^3$/day = $113m^3$ / day.

From energy conversion [4].

$1m^3$ of bio gas =6.39kwh

$113m^3$ =x

X=722kwh, therefore from our wastes we can get, 722kwh of power is received per day.

Below diagram is systematic diagram of proposed food & kitchen waste to energy system.

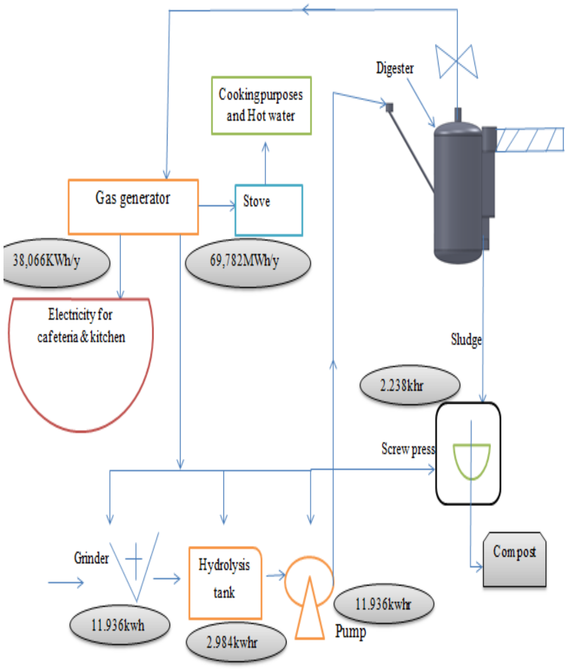

Figure 4: Proposed food & kitchen wastes to energy system

Results and discussion

From Experiment, Inside digester temperature and ambient temperature are directly proportional; as ambient temperature increases inside digester temperature is also increases.

From Experiment also we have done measurements of inside digester temperature at different days; at the beginning the temperature values some extent high, but when time goes longer it become less and lastly it goes to rise. It depends on ambient temperature. Graph 5. below describes the relationship between inside digester temperature values and Days.

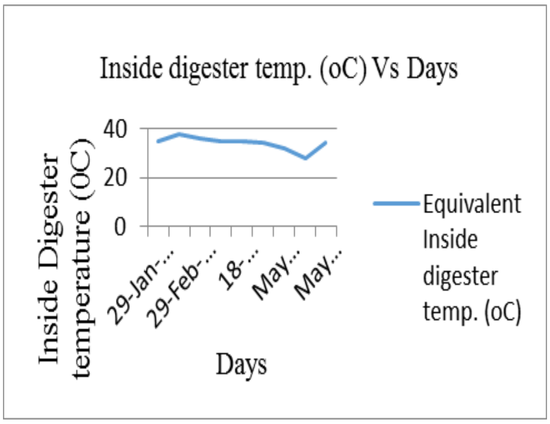

Figure 5: Graph of measurements of pH values against duration of time

Graph 6. Below describes the relationship between inside digester temperature values and Days.

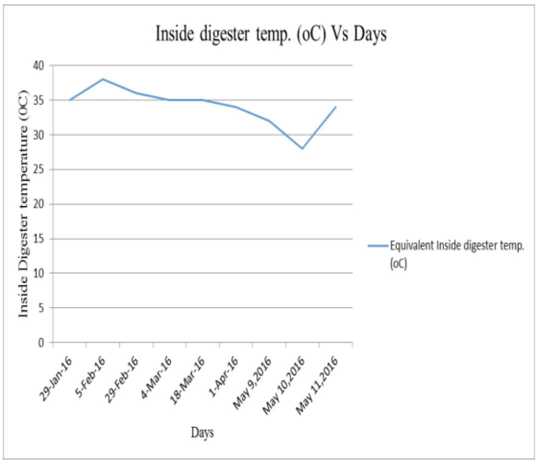

Fig. 6 Graph of measurements of pH values against duration of time

Conclusion

Total gas produced from food and kitchen wastes calculated, from amount of food and kitchen wastes per day. Total gas produced is 113m^3 / day. This gas produced using energy conversion gives us 722kwh of power per day. Based on biogas produced it diverted to combined heat and power (CHP) system to generate electricity and heat that recovered to produce hot water using stove for cafeteria of Kito Furdisa and its kitchen itself. Energy consumption of this anaerobic digestion of system in dining hall & kitchen wastes give us 41.03 kwhr and the net energy used is 681 kWh which used for CHP. This means the production of electricity will be 75.42MWh/y and the production of heat will be 138.27MWh/y.

When we generate the biogas from food and kitchen wastes, we have to use like fresh cow dung, addition of a bacteria from other generating biogas which can quickly give up bacteria that start up the process of generating biogas and using insulators for conserving temperatures of digester is also very crucial. Cleaning unusable and dirty oil is speeding up our work progress easily. From our experiment we have done, what we analyze is that increasing inside temperature of the digester, addition of bacteria from other generating biogas and controlling the pH values are very important for overall progress.

References

[1] Ruihong Z., Hamed M., El-M., Karl H., 2007. Characterization of food waste as feedstock for anaerobic digestion. Bioresource Technology;1:(929-936).

[2] Gijzen H. J., 2002. Anaerobic Digestion for sustainable development: a natural approach.Water research and technology. 45(10): 321-328.

[3] Charles W., Walker L., Ruwisch Cord R., 2009. Effect of pre-aeration and inoculum on the startup of batch thermophillic anaerobic digestion of municipal solid waste. Bioresource technology. 100: 2329-2335.

[4] EPA, 2009. United States Environmental Protection Agency. Municipal solid waste generation, recycling and disposal in the United States.

[5] Troschinetz A. M., and Mihelcic J. R., 2009. Sustainable recycling of municipal solid waste in developing countries. Waste management. 29:915-923.

[6] Chandrappa R., and Das D. B., 2012. Solid waste management. Environmental science and Engineering. Springer Verlag Berlin Heidelberg.

[7] Khalid A., Arshad M., Anjum M., Mahmood T., Dawson L., 2011.The anaerobic digestion of Solid organic waste. Waste management. 31:1737-1744.

[8] Curry N., Pillay P., 2012. Biogas prediction and design of a food waste to energy system for the urban environment. Renewable energy 41:200-209.

[9] Zupancic G. D., and Jemea A., 2010. Anaerobic digestion of tannery waste: semi continuous and anaerobic sequencing batch reactor process. Bioresource technology. 101: 26-33.

[10] Schober G., Schäfer J., Schmid Staiger U., and Trösch W., 1999. One and two stage digestion of solid organic waste. Water research. 33(3):854-860.

[11] Cho J. K., Park S. C., Chang H. N., 1995 Biochemical methane potential and solid state anaerobic digestion of Korean food wastes. Bioresource Technology 52:245-253.

[12] Zhang R., El-Mashad H. M., Hartman K., Wang F., Liu G., Choate C., Gamble P., 2007. Characterization of food waste as feedstock for anaerobic digestion. Bioresource technol. 98:929–935.

[13] Neves L., Gonçalo E., Oliveira R., and Alves M. M., 2008. Influence of composition on the biomethanation potential of restaurant waste at mesophilic temperatures. Waste management 28: 965-972.

[14] Kumar S., 2010. Effective municipal solid waste management in India (In waste management). 232.

[15] Khoiyangbam R.S., Kumar S., Jain M.C., Gupta N., Kumar A., Kumar V., 2004. Methane emission from fixed dome biogas plants in hilly and plain regions of northern India. Bioresource Technology. 95:35–39.

[16] Kumar S., Gaikwad S. A., Shekdar A.V., Kshirsagar P. S., Singh R. N., 2004. Estimation method for national methane emission from solid waste landfills. *Atmospheric* Environment 38: 3481–3487.

[17] Kashyap D. R., Dadhich K.S., and Sharma S. K., 2003. Biomethanation under psychrophilic conditions: a review. Bioresource Technol 87:147-153.

[18] Alemayehu G., Abile T., 2014. Co-Digestion of Ethiopian Food Waste with Cow Dung for Biogas Production: International Journal of Research (IJR), 1:7475-500.

[19] Molla A., 2014. Design of cylindrical fixed dome bio digester in the condominium houses for cooking purpose at Dibiza Site,East Gojjam, Ethiopia: American Journal of Energy Engineering 2(1): 16-22

[20] Yang S. J., Hamilton S. D. B., Engle N. L., Tschaplinski T. J., Doeppke C., Davis M., Westpheling J., and Adams M. W. W., 2009. Efficient Degradation of Lignocellulosic Plant Biomass, without Pretreatment, by the Thermophilic Anaerobe “Anaerocellum thermophilum” DSM 6725. Applied And Environmental microbiolog,75(14):4762-4769.