Journal of Scientific and Innovative Research 2016; 5(5): 197-200
Available online at: www.jsirjournal.com

Mini Review

ISSN 2320-4818
JSIR 2016; 5(5): 197-200

Received: 07-10-2016
Accepted: 27-10-2016

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Pretreatment technique on digester for algae Biogas production during winter

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Abstract

Aim- Biogas is the one of essential renewable energy source for modern applications which can be replaced to the fossil fuels. An alga is a new renewable feedstock introduced for replacing the cow dung based bio gas system, which takes the less time digestion of slurry. But in spite of it during winters the digestion process takes long time, low slurry temperature of the digestion result in comparatively low efficiency or even a interruption in the fermentation. Proper temperature keep maintains for the biogas production in winter is the major problem. This paper purposes efficient fermentation for obtaining the digester is then designed, optimizing these performance parameters, for biogas production. Low carbon: nitrogen can be increased by mixing of high rich carbon content material in a proper ratio by using coil fitted in the digester for productive biogas in winters.

Keywords: Biogas, Temperature, Agitators.

INTRODUCTION

Biogas starts to produce during the nineteen century by the manure and kitchen waste like feedstock in Asian countries. It contains of mixes of gases the Biogas is a renewable fuel which is produced by anaerobic digestion of organic feedstock. Biogas is a mixture of gases (mainly CH_4 + CO_2) with four main stages is normally involved in the anaerobic digester (AD) process including hydrolysis, fermentation, anaerobic oxidation& methanogenesis. Raw biogas mainly consists of methane, carbon dioxide, moisture, and minor components such as H_2S, H_2, NH_3, O_2, N_2 [1]. Temperature is considered to be the main factor which affects the biogas production. The digesters efficiency may deteriorate to control temperature and removal of dissolved oxygen hence it affects on overall efficiency of production of biogas specifically in winter season [2]. Waste, residues and energy crops are main feed stocks to produce biogas through anaerobic digestion process. Waste from animals, human, sewage, food industries and residue from agriculture and industries have great potential to produce biogas. Biogas is produced on small scale for domestic use as well as on large scale for transportation and industrial use. In houses biogas is used for cooking and lighting. In transport sector biogas is used as a fuel due to its high calorific value (20MJ/Nm^3). For automobile, enriched biogas is required. Enriched biogas means at least 90% methane content. For transport sector upgraded biogas is used. Upgrading and biogas enrichment is done by various methods. Water scrubbing is one of them. In this method, water is used as a scrubber, which absorbs carbon dioxide and increases the methane yield in biogas. Water scrubbing is more efficient, less energy intensive and safe as compared to other methods [3]. Carbon dioxide and hydrogen sulphide in biogas cause many types of problems. For making a biogas, a suitable bio-fuel, up gradation is necessary. Enrichment of biogas added the cost of biogas production. Enrichment of biogas is possible in commercial plants. Because for scrubbing, more amount of biogas is required. Composition of raw biogas is shown in Table 1.

These are variables for different feed stocks, type of digestion system, temperature and retention time. Biogas with methane 50 % has heating value of 20MJ/Nm^3,density1.22Kg/ $Nm^3$and mass is similar to air (1.29Kg/Nm^3).

History of pretreatment

Over the last few years, the research and technology is tremendously increasing in all over the world. (NRREP) Substrate is preheated before enter in digester For preheating the slurry, the water used for cooling the generator will be used incorporating Waste Heat Recovery as shown in the figure. The heat exchanger used in the process is a cross flow type named as Shell and Tube Heat Exchanger.

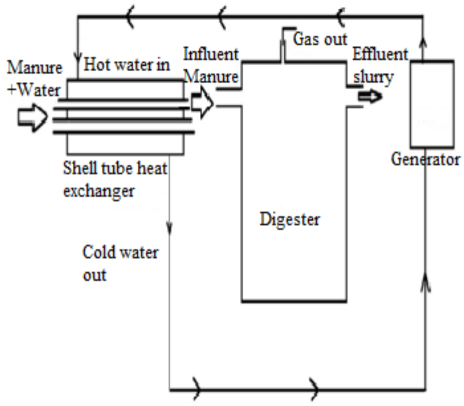

Figure 1: Preheating of substrate

Table 1: Composition of Biogas

Composition of biogas	Content (volume %)
Methane	50 -75
Carbon dioxide	20-45
Water vapor	2-8
Oxygen	Less than 2%
Nitrogen	Less than 2%
Ammonia	Less than 1%
Hydrogen	Less than 1%
Hydrogen Sulphide	Less than 1%

From the outside, the heat exchanger just looks like a large cylinder, while inside the water is circulated across a series of manure pipes. The water is heated by circulating it across several heat sources. The primary heat source for this water loop comes from the waste heat off the engine-generator that burns the biogas. Heat is added to the water from the engine-generator in two ways. First, the water is run through a separate heat exchanger to collect heat from the exhaust of the internal combustion engine. Next, the water is circulated through the coolant system of the engine block. If the engine is not able to provide enough heat, there are additional boilers that can provide the needed heat [4]. Stainless steels improve the reliability and efficiency of biogas plants, Sometimes substances in the inlet and/or outlet areas must be heat treated so that germs and bacteria are rendered harmless and do not spread. Two different methods of heat treatment are used:

• Hygienisation: the material is heated to 70°C (158°F) and held at that temperature for 60 minutes.

• Pasteurisation: the material is heated to 133°C (271.4°F) and held at that temperature for 20 minutes [5]. A small amount of charcoal (250 g) was mixed with about 15 liters of digested slurry a bucket. The mixture was pasted on the ground in a 1-m-wide strip around three out of the six biogas plants. The other three plants were kept as controls. This method increased the temperature by 3 °C and gas production by 7%–15%, but the digester had to be coated every one and a half months. This method is however economical as farmers can prepare charcoal by burning wood pieces. To maintain the temperature in the reactor, it is not enough to only blacken or glaze (coating).

Table 2: Annual variation in gas production from six biogas plants as affected by temperature during 1990

Months	Gas production (per day)	Ambient temp. (°C) Maximum	Minimum
Jan.	556+- 29	22.2	3.1
Feb.	692 +-68	21.8	9.1
Mar.	697+- 60	26.7	11.3
Apr.	1065 +-43	35.6	18.4
May	1396+- 33	40.2	24.9
Jun.	1581+- 44	40.8	26.3
Jul.	1506+-57	35.2	26.5
Aug.	1487+-56	35.1	24.4
Sept.	1282+-67	33.9	23.7
Oct.	1278+-59	32.0	15.6
Nov.	1063+-70	27.7	9.9
Dec.	682+-64	22.8	6.0

Aluminum metal is more efficient to increase the sufficient temperature inside the digester which increases the production rate of biogas [5]. Hybrid heating system for household biogas digesters in cold regions, where in the winter and fell below 10°C in the coldest days. Correspondingly, the biogas production rate was less than 0.114 $m^3/(m^{-3}d)$. Employing the proposed hybrid heating system, the slurry temperature and the biogas production rate could be increased to 19.82 °C and 23.50 °C, and the average production rate be increased to 0.389 $m^3/(m^3\ d)$ and 0.472 $m^3/(m^3\ d)$ respectively. Moreover, using GRP insulation materials in digester structure helps to increase the slurry temperature and to promote the biogas production rate [6].

Temperature

Temperature plays important role in anaerobic digestion process is possible between 5°C-70°C. There are mainly three temperature ranges for AD process.

- Psychrophilic temperature <20° C,
- Mesophilic temperature between 20°C to 40°C,
- Thermophilic temperature between 40°C to 60°C

Stability of temperature in digester is main factor for AD. Operating temperature of digester is decided according to the feedstock. Required temperature for slurry is provided by heating systems, inside the digester or from a heat source. Temperature and hydraulic retention time affect biogas production rate. Operational temperature for digesters is mesophilic which destroys the pathogens and inhibitors in AD process. Anaerobic digester also can operate at thermophilic temperature, which has many advantages as faster AD process, low HRT, more decomposition of substrate. With this it has some negative points also, as more energy and more temperature balancing are required.

Agitator technique for mixing

Density of algae is 800 kg per cubic meter. So a proper mixing of algae biomass with slurry in the digester is necessary. For this agitator is used. This can be manually, mechanically or electrically. In this digester, radial type agitator which is operated manually is used. Radial type agitator is used for proper mixing. Material of the strips is also important so mild steel is used and its does not get rust. By proper mixing microorganism in the digester have more area for digestion and it is designed even which can not disturb other parts so digestion rate of feedstock is increased. Agitator has four blades at an angle of 45°. At this position blade of agitator applied maximum force to the slurry. This agitator is fixed in the floating drum. By rotating the floating drum mix the fresh feed stock is mixed with slurry. The cell of algae is complex, so breaking of these cells in the digestion process is very difficult. For cell destruction of algae in digester, it needs pretreatment, so that algae can be used as a good feedstock. Cell destruction of algae before feeding increases the rate of digestion process and thus yield of methane.

Figure 2: Agitator fitted in tank

Pretreatment of algae is done by mechanical pressing or thermal destruction. Problem of low carbon nitrogen ratio can be controlled by adding carbon rich content as straw, garden waste or waste paper. For low density of algae stirring operation is requires, it may be manually, pneumatic, or mechanical. Normally seven to eight rpm is required for mixing the fresh feedstock with the mixer in the digester. By stirring, fresh feedstock is well mixed with existing slurry and enzymes can act on more surface area. Thus biogas production is increased by stirring process.

Thermal pretreatment of digester

For efficient production of biogas, favorable conditions should be maintained in the digester because anaerobic digestion is a complex process. Performance parameters like solid loading rate, stirring, pH are independent of environment. But temperature of digester is affected by ambient temperature. So it is most affected parameter in the digestion process. For a mesophilic digester temperature should be maintained at 35-40 degree C. Then two conditions should be fulfilled in the digester:-

- Raising the digester temperature up to mesophilic temperature through a heat source;
- Maintaining the temperature in digester by perfect insulation of digester.

Two types of losses from the digester,

- Heat lost from the body of digester due to ambient conditions,
- Adding the feedstock in the digester.

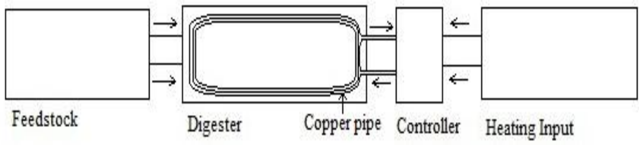

Figure 3: Schematic diagram of Heat treatment Digester

As it shown in the diagram cupper tube is fitted inside the digester for maintain the slurry temperature and controller is placed for controlling the variation of temp due to presence of calibrated thermocouple in the digester. Heat can be give either by immersion rod or the engine exhaust gases.

Heat lost from the digester can be reduced by providing the insulation. To raise the temperature in digester a coil type of heat exchanger is used. The working fluid in heat exchanger is water; engine exhaust can be used for heating the water to circulating in the pipes and temperature which is to be monitored by the display meter.

Heat required raising the temperature = (mass of slurry x specific heat of slurry x Temperature difference)

$Q_{slurry} = (M_{slurry})$ X (C_{slurry}) X ($T_{slurry} - T_{feedstock}$) --(1)

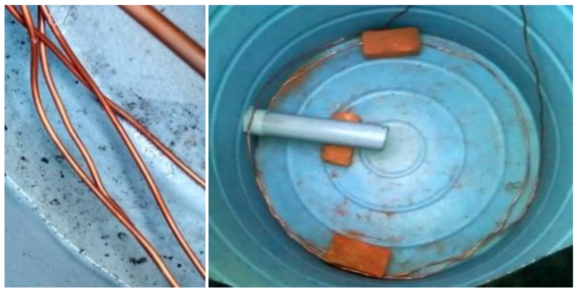

Figure 4: Copper tube fitted in tank

Assuming steady state in heat exchanger,

Uniform distribution of temperature and neglecting radiation losses

Heat transferred from heat exchanger:-

$Q_{H.E}$ = (Mass flow rate of water)X (Specific heat of water) X(Temperature difference of water in and water out)

$Q_{H.E} = mCp\ (T_{water} - T_{slurry})$ ———————— (2)

$Q_{H.E}$=(Convective heat transfer) X (Area of pipe)

X ($T_{in} - T_{out}$)

Calculate convective heat transfer (h) using convection formulation.

$T_{mean}=(T_{in}+T_{slurry})/2$ ——————————— (3)

At T_{mean} , determining the properties of water and calculate Nusselt Number

Nusselt Number = (convective heat transfer) x (Diameter of pipe)/Thermal conductivity

Calculate 'h'.

$Q_{H.E.} = Q_c = h_c A$

Determine the length

A= (3.14) X (diameter of pipe) X (length of coil)

Find the number of coil.

Assumptions

Temperature of fresh feedstock= 15°CAmbient temp. = 5°C

Temperature of slurry in digester=35°C

Using above formulas, mean temperature=70°C

At 70° C, properties of water,

Viscosity = 0.4127mm2 /second

Thermal conductivity, K = 668 and

Prandantl number Pr. =2.45 W/mk

If dia. of tube = 6.25mm is assumed, then

Gr.Pr.= {g*(1/mean temperature)*(temperature difference)*cube of tube dia.}/ Kinematic viscosity

Putting values in formula, Nusselt number = 20.42

Nusselt number= hd/ k ; h= 2.18W/mk

Heat transferred from tube to slurry for unit mass=4200*(100-40)

4200*60=2.18*3.14*6.25*Length of tube

Length of tube= 5.89 meter~ 6 meter

The heating system is required during winter season only. In summer duration temperature is favorable for digestion process.

CONCLUSION

Energy from the biomass is conceptual which has been investigated, through the analytical method and further in literature. The optimistic results concluded that the by giving some external treatments the rate of fermentation is to be increased.

Acknowledgement

Author specially thanks for my IIT Delhi friends and PI who motivated and helped me.

No conflict of interest: Nill

Financial assistance: No

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