International Journal of Engineering, Science and Mathematics
Vol.13 Issue 5, May 2024,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

DESIGN AND PRODUCTION OF BIOGAS FROM KITCHEN WASTES IN ETHIOPIA

BIRUKMATHEWOS*
MULUGETA TADESSE **
DAVID SANTOSH CHRISTOPHER***

Keywords:

Kitchen wastes;
Urea;
Biogas;
Slurry;

Abstract

Due to its high organic content, kitchen wastes make excellent raw material for anaerobic digestion.Anaerobic digestion of these wastes is once again challenged by issues including low biogas/methane output and process instability, which pose a threat to its dependability and effectiveness This study assessed the impact of urea addition and temperature variation on the biogas (methane) potential and retention period of particular kitchen wastes after characterization.Laboratory experiment was conducted in WolaitaSodoUniversity,Ethiopia on both urea and changing temperature level digestion . Statistical software, basic tools, and analytical equipment were employed for data analysis. Utilizing vegetable and food scrap wastes as substrates. The final biogas yield was 1.34 L/g VS with adding urea and 1.2 L/g VS without adding urea. The biogas yield from co-digesting of vegetable and food scrap wastes as substrates is 1.2L/g, 2.0L/g, and 3 L/g VS, at ambient temperature, mesophilic temperature, and thermophilic temperature levels respectively. As a result, adding urea and variation of temperature dramatically increased biogas yield.

Author correspondence:

Dr.David Santosh Christopher
Associate Professor
Department of Mechanical Engineering
WolaitaSodo University, Ethiopia

1.Introduction

Due to rising global population, burgeoning economies and rising energy consumption,

*M.Sc Student, Department of Mechanical Engineering. WolaitaSodo University, Ethiopia
**Head, Department of Mechanical Engineering, WolaitaSodo University, Ethiopia
***Associate Professor, Department of Mechanical Engineering. WolaitaSodo University, Ethiopia

there is a constant rise in global energy demand.The majority of the world's energy needs are currently met by fossil fuels, but if demand for these fuels continues to grow at the current rate, it won't be enough for generations to come [1].The primary source of electricity's reliance on fossil fuels has resulted in global climate trade, environmental degradation, and health problems for people. Fossil fuel combustion still accounts for over 80% of global energy consumption [2]The reserves do not, however, keep up with the rapid population expansion, and burning them significantly raises the concentration of greenhouse gases (GHGs), which causes climate change and contributes to global warming [3]. Consequently, one of the most important choices is the creation of energy from biomass, often known as bio-energy. The processes involving microorganisms, among the numerous bio-energy-related ones currently under development, are particularly promising since they have the ability to provide renewable energy on a large scale without significantly harming the environment or human activities [4]. Biogas is a renewable and environmentally benign source of energy made from biodegradable elements such as feces, sewage, food wastes, plant materials, abattoir wastes, crop leftovers, etc. Depending on the substrate, it primarily contains 55–65% methane, 35–45% carbon dioxide, and traces of hydrogen sulfide, nitrogen, and hydrogen[5]. Additionally, it is thought that biogas generation will lead to greater job opportunities, which will lower poverty [6]. In addition to these benefits, it enhances agriculture by supplying biofertilizer with macro- and micronutrients [7]. In biogas facilities or anaerobic digesters of two sorts, batch and continuous reactors, biogas is created using the multiphase processes of mesophilic and thermophilic digestion, which include phases of hydrolysis, acetogenesis, acidogenesis, and methane formation.Pretreatment of biodegradable waste, mixing of various waste kinds, and chemical additives are a few methods for enhancing anaerobic digestion processes [8]. By calculating the amount of total and unstable solids destroyed and by keeping an eye on the daily production of fuel, the reactors' overall performance is assessed. Anaerobic digestion is compatible with the mixture of vegetable wastes chosen for the study, according to the performance evaluation of specific gas generation based on the number of total solids added and volatile solids added [9].

Ethiopia creates a lot of solid trash as well as a lot of food and vegetable waste. To reduce environmental pollution, it is therefore vital to create the proper waste treatment technology for vegetable wastes.

Figure 1 (a) Food waste (b) Vegetable waste

2.1 Materials

The plastic biogas digester is made from a variety of materials. These consist of Geomembrane made of high-density polyethylene (HDPE): Due to its durability and resistance to corrosion, HDPE is used to build biodigesters. Other materials include plastic sheeting, which can be used to connect the digester's different parts (such as the feed pipe, gas outlet, drain, and overflow provision), used car or bicycle tire inner tubes, which are used to seal the gap between the digester and the gas collector, valves that control the gas flow from the gas collector, and super glue. Each and every component needed to build a bio-digester may be easily obtained from the market.

2.2 Design of biogas digester

The design of a plastic biogas digester is intended to supply biogas from wastes from exclusive university cafeterias. Biogas digester dimensions and materials of manufacture are vital elements of attention at some point in the design segment. The materials utilized, the size, and the system's overall functionality must all be carefully taken into account while designing and making a 20-liter plastic biogas digester. Selecting high-quality plastic that is resilient and resistant to environmental conditions like temperature changes and sunlight exposure is crucial. The digester's size also needs to be appropriate for the intended usage because it will determine how much organic waste can be treated at once. Elements like an outlet for releasing biogas and an inlet for feeding in organic waste is fitted. The final step in the fabrication process is putting the various components into a working system that can efficiently produce biogas from organic waste, which may then be used for energy production or other advantageous uses. Overall, careful preparation and attention to detail are needed to design and construct a 20-liter plastic biogas digester in order to assure optimal performance and lifetime.

3 Determination of Properties

3.1 Total solids (TS)

The term "total solids" refers to both the sum of the dissolved particles and the sum of the suspended solids. The total solids of food and vegetable wastes were determined using GP - 65B which is a recommended methodology for the analysis of water and wastewater [10]. A weighted, dry, clean crucible was used to place the sample in the oven at 105 ^{o}C. The sample was allowed to dry at this temperature for 24 hours in order to get constant mass over-drying. In order to stop moisture from absorbing, the dried sample was refrigerated in the desiccator before being measured.

The crucible spent the full night in the oven before being taken out, desiccated to cool, and weighed. It is quickly weighted to stop moisture absorption because of the way the dry pattern is made.

Then the proportion of the TS became calculated as:

$$\%TS = \frac{MD}{MW} * 100\% \qquad \text{………… 3.1}$$

Where:

%TS = percent of total solids

M_W = Mass of wet (fresh) sample in gram

M_D = Mass of dry sample in gram

3.2 Volatile solids (VS)

Total volatile solids are substances that entirely evaporate from water at higher temperatures (550 ^{o}C). The organic component of the water is another name for these substances. At higher temperatures (550 ^{o}C), materials that do not volatilize from water are referred to as total fixed solids. These particles are frequently referred to as the water's inorganic component. In a weighted dish on a steam bath, the sample is evaporated, and it is then dried to a constant mass in an oven heated to 103 to 105 °C. The acquired residue is burned at 550 ^{o}C to a consistent weight. Total fixed solids are represented by the solids that are still present, while total volatile solids are represented by the weight that was lost during ignition. The sample was dried using the GP - 65B [10] method to a consistent weight before being burnt in a muffle furnace at 550 0C to determine the volatile solids. Before inserting the sample, the muffle furnace was warmed to this temperature. The sample was heated for approximately 15 minutes before cooling in the desiccator for measurement. The percent volatile solid was determined according to the equation:

$$\%VS = \frac{MV}{MD} * 100 \qquad \text{……….. 3.2}$$

Where:

%VS = percent of volatile solids

M_V = Mass of volatile solids

M_D = Mass of dry sample in gram

M_{ash} = Mass of ash remained in the crucible after burnt in the muffle furnace

$$M_V = M_D - M_{ash} \quad \text{..........3.3}$$

3.3 Organic loading rate (OLR)

An indicator of how much organic material can be processed in a biogas factory is the organic loading rate. This is the rate at which substrates or feedstock are introduced into a digester. It is expressed as kilograms of volatile solids (VS) added per day per cubic meter of reactor volume. Operators can calculate the organic loading rate to ascertain how much substrate to add to the reactor without going over its capacity. In order to ensure that anaerobic digestion takes place successfully and efficiently, it is crucial to maintain an adequate organic loading rate. The inadequate breakdown of the substrate, the buildup of volatile fatty acids (VFA), and the reduced generation of methane can all be effects of a high organic loading rate. However, using a low organic loading rate during digestion lowers the stability and productivity of the process.

3.4 Hydraulic retention time (HRT)

During the wastewater treatment process, a gallon of wastewater will typically stay in a specific basin for a certain amount of time, known as the hydraulic retention time (HRT). The average time a soluble chemical spends in a built-in biogas reactor or aeration tank might be thought of as the definition of HRT in a more technical sense. The length of time organic material stays in a biogas reactor or bioreactor is known as the biogas time. The anaerobic digestion process, in which microbes break down organic materials and produce methane gas, depends on this to work. The HRT decreases the likelihood that any organic waste will be left in the effluent at the end of the operation while giving these microorganisms ample time to function properly.

4. Chemical analysis

4.1 Chemical analysis of kitchen solid wastes

Diverse types of kitchen trash had diverse chemical compositions. According to Table 4.1, which details their chemical composition, less than 52% of carbon may be found in the peels of avocados, garlic cloves, cabbage leaves, and carrots. Bread had a maximum carbon content of 54.7%. More than 52% of carbon was found in onion peel, tomato peel, pepper, cooked rice, egg shell, and ginger peel.

In 15 samples, the amounts of N were less than 5%, while in tea waste, they were 5.5%. Ammonia production will be minimal if these wastes are handled by anaerobic digestion. Because of this, these wastes will benefit from biochemical treatment.Tomato peel and ginger peel both contained 5.1% and 5.35 percent of H, respectively. In the remaining samples, the percentage of H ranged from 0.86% to 4.94%. Egg shells had a minimum hydrogen content of 0.86%.Spaghettis and onion peels both had 60.2 and 60.93% percent oxygen, respectively. Less than 55% of the remaining samples were covered, as shown in Table 4.1.

Table 4.1: Analysis of Kitchen Solid Wastes

No	Name of sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Oxygen (%)
1	Onion peel	51.0	4.7	1.92	42.3
2	Potato peel	53.0	4.3	2.64	34.8
3	Garlic peel	50.2	2.9	3.2	34.1
4	Tomato peel	53.8	5.3	1.76	42.8
5	Cabbage peel	50.4	4.8	3.89	38.8
6	Carrot peel	50.4	4.9	1.57	39.5
7	Avocado peel	49.1	2.6	1.58	42.2
8	Pepper	51.1	4.8	0.22	38.8
9	Injera	52.4	3.9	2.83	31.9
10	Cooked rice	52.5	3.8	0.22	40.8
11	Bread	54.7	1.6	1.88	26.5
12	Spaghettis	55.0	3.7	0.26	60.2
13	Tea waste	52.5	4.4	5.50	35.2
14	Egg shell	5.7	0.8	1.32	13.8
15	Ginger peel	52.2	5.1	0.10	40.8

The proportion of carbon in potato peel and cabbage peel, respectively, was 39.86% and 40.18%, according to a study by [11]. Carbon content in potato and cabbage peels was 30.6% and 45.1%, respectively, in the current study. These sample values were comparable between the two investigations.

5.06%, 5.86%, 6.02%, 4.85%, and 5.68%, respectively, of H were found in the study by Mane et al. (2015) in the peels of cabbage, potatoes, tomatoes, onions, and carrots. When compared to the results of the aforementioned samples in the current investigation, which were 4.85%, 4.36%, 4.91%, 5.35%, 4.36%, 4.79%, and 4.94%, respectively.In a 2015 study by Mane et al., the oxygen content of tomato peel and carrot peel was 45.65% and 45.10%, respectively. In the current investigation, 42.8% and 39.55% were attained for the samples mentioned above, respectively.

4.2 Waste Sample Characterization

The concentrations of total solids (TS) and volatile solids (VS) are two of the most significant waste properties that affect the production of biogas through anaerobic digestion. Following adjustment with a 1:1 substrate to water ratio, samples B1, B2, and B3 have TS values of 8.65%, 19.59%, and 23.2%, respectively, as shown in table 4.2. Due to the significant water content in vegetable wastes, the TS value of waste sample B1 is the lowest when compared to the other waste samples.

Table 4.2Waste sample characterizations

Sample	**Characterization parameter**			
	TS (%)	VS (%)	C: N	PH
B1	8.65	82.52	19.2	6.2
B2	19.59	75.21	24.6	5.7
B3	23.2	91.3	22.8	5.2

The VS values of the substrates for B1, B2, and B3 are 82.52%, 75.21%, and 91.3%, respectively. As we can see from the table 4.2, the value of a volatile solid varies depending on how much organic material is present. For example, B1 has a higher volatile solid value than B2 because organic material from vegetables is more abundant than organic material from food waste.

The reason why B1's carbon to nitrogen ratio (C: N) is lower than that of the other samples is because vegetables naturally contain a lot of nitrogen, which lowers B1's C: N. One of the elements with the greatest distribution, nitrogen makes up 80% of the atmosphere in soil. It is a crucial component of plant tissues that makes up proteins, nucleoproteins, hemoglobin, nucleic acids, chlorophyll, and other compounds. It is estimated that it makes up 3% of a person's body weight and 4% of a plant's dry matter, which explains why vegetables contain a lot of nitrogen.

5. Biogas production from anaerobic digesters

5.1 Effects of temperature and retention time on biogas production

A reduced overall biogas output was seen at room temperature, according to the experimental findings. After 20 days of retention time from VW, FW, and CO-, respectively, 1.05, 0.99, and 1.2 liters of the maximum biogas production were collected at room temperature, as shown infigure 5.1. However, as we know, room temperature varies depending on the weather, and when the temperature is low,it takes longer for microorganisms to form. It is possible to see that the biogas lines are growing in this area, which indicates that the substrates are beginning to be eaten and will take longer to use up all of their available capacity.

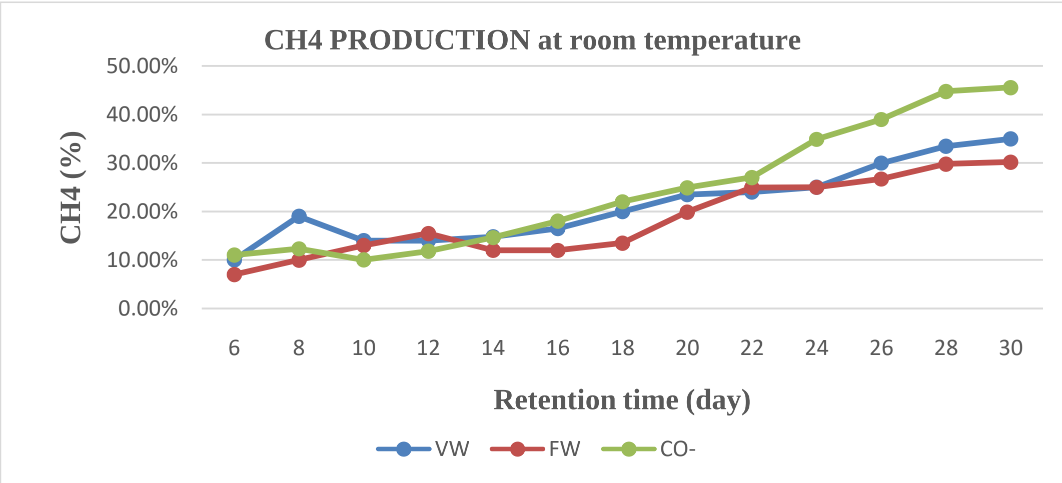

Figure 5.1: Methane composition of biogas at room temperature

At 37°C, a higher biogas generation rate was seen in the mesophilic temperature range. The largest biogas generation was generated at the days of 10, 12, and 16 as seen on the graph, and this was due to by raising the temperature beyond which biogas production declines due to the bacterial enzymes being destroyed by elevated temperatures, biogas output can be greatly enhanced as shown in figure 5.2.

Maximum biogas generation from FW, VW, and CO- respectively between 6 and 14 days of retention time was 1.8, 2.3, and 3 liters at temperature 50°C, as shown on the (figure 5.3). Comparatively, the temperature level of 50° C investigated exhibited a higher rate of biogas production than both the room temperature range and the mesophilic temperature range.

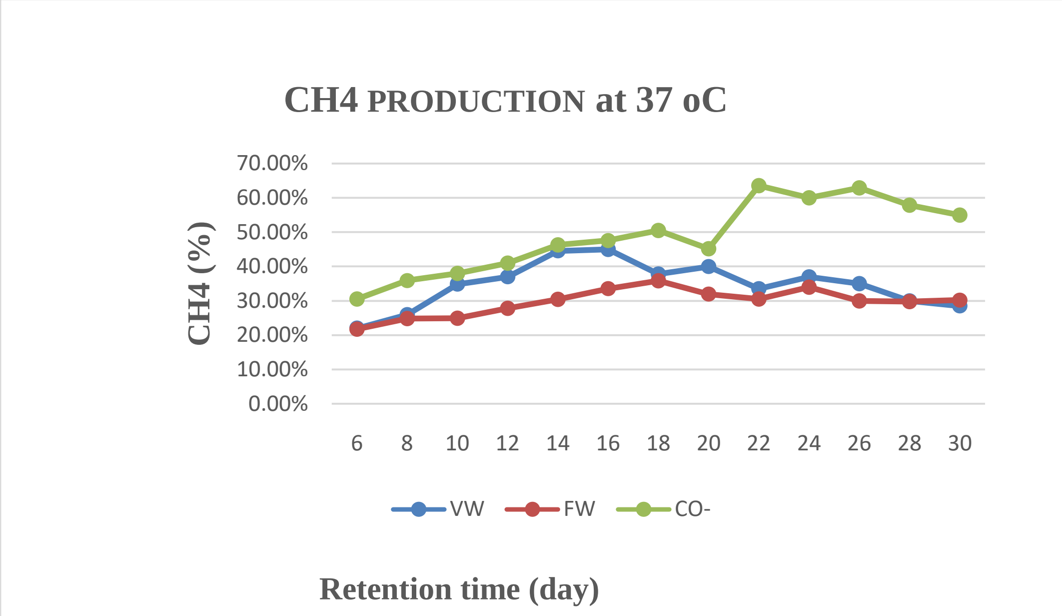

Figure 5.2: Methane composition of biogas at37°C temperature

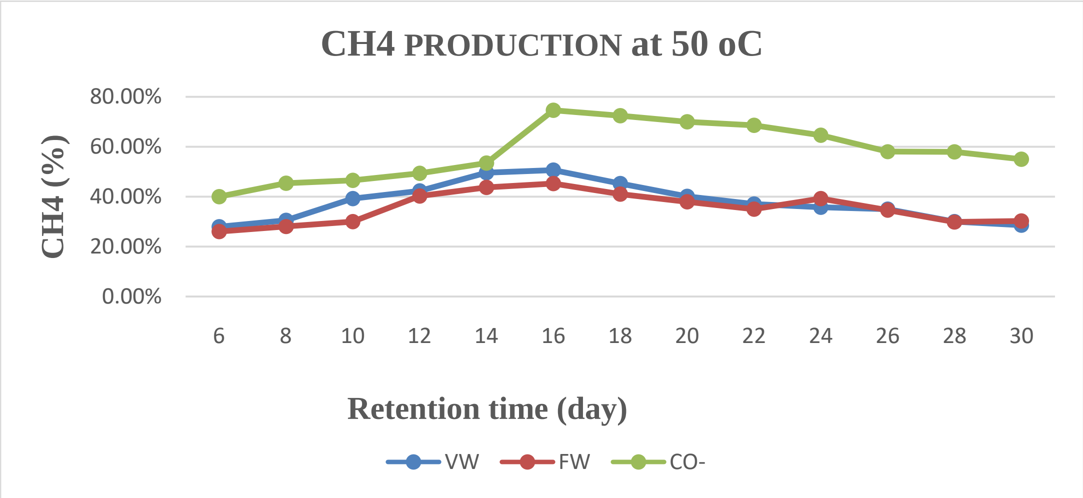

Figure 5.3: Methane composition of biogas at 50°C temperature

5.2 Biogas yield with and without urea

Biogas production with urea, also known as urea supplementation, is a technique used to enhance the biogas production process in anaerobic digesters. Urea is a compound containing nitrogen that serves as a source of additional nutrients for the microbial community responsible for biogas generation. When added to the digester, urea acts as a nitrogen supplement, stimulating the growth and activity of methanogenic bacteria as shown in figure 5.4. These bacteria play a crucial role in the breakdown of organic matter and the production of methane gas, by providing an extra source of nitrogen, urea supplementation helps optimize the microbial metabolism, leading to increase biogas production and improve process efficiency. This approach is particularly beneficial when the feedstock lacks sufficient nitrogen content, as it ensures the availability of nutrients necessary for optimal biogas generation.

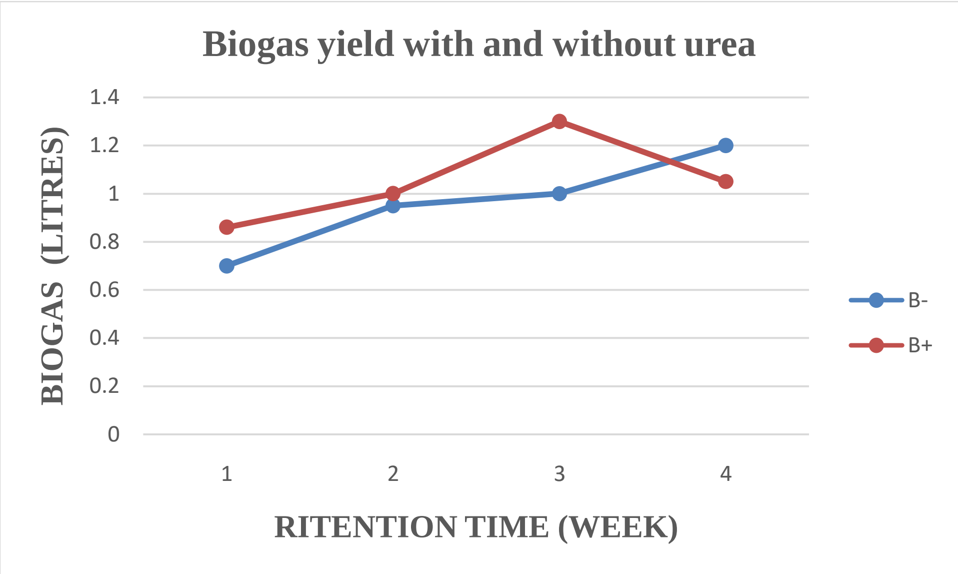

Figure 5.4 Biogas Production with and without urea

6. Conclusion

Problems existed with segregation, collection, reuse, storage, composting, and disposal. The goal of this study was to create an effective biogas production using food scraps and vegetable wastes from the campus cafeteria.. The work is innovative since it increases biogas yield in several ways, such as by utilizing urea as a catalyst and by growing microorganisms at various temperatures. Major findings include:

- Case studywas conducted in WolaitaSodo University, Ethiopia The university has a lot of cafeterias, and the waste that accumulates from them is often large. This waste is then stored somewhere, where it spoils and contributes to environmental damage.
- Designing a biogas digester, in this study a plastic digester with dimensions of 25 cm in diameter and 45 cm in length was used. Additionally, a 1.27cm diameter inlet and outlet pipe were used to add substrate to the digester and transport the gas to the collector.
- The egg shell's inorganic composition deviated significantly more from the standard. Because of its high inorganic content, egg shells were not used for anaerobic digestion.
- Chemical characteristics of wastes including onion peels, potato peels, tomato peels, cabbage peels, and carrot peels are selected
- The characteristics of kitchen wastes are investigated in the laboratory by estimating the total solid and volatile solid content. This is important for the production of biogas because it provides important data for determining the suitability of feedstock, enhancing process conditions, forecasting biogas yields, and assessing the overall effectiveness of the anaerobic digestion system. The TS values for B1 and B2 are 8.65 and 19.59%, respectively, and these values are suitable for the production of biogas.
- In this research, laboratory testes are conducted in three different temperatures at room, mesophilic and thermophilic levels that mean 28^{o} C, 37 ^{o} C and 50 ^{o} C at each temperature level the biogas yield varies at room (28^{o} C) temperature the maximum biogas yield is 1.2 liter, mesophilic at 37 ^{o} C 2 liter at thermophilic (50 ^{o} C) 3 liter that when I change it to 79.54% methane gas produced at thermophilic temperature rang.
- By using urea as a catalyst to minimize biogas production time by increasing micro bacteria's production.

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