Studies On The Production Of Biogas From Organic Waste And Biotech Culture

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Abstract: Biogas (biomethane) production is achieved through digestion of solid waste by anaerobic bacteria (methanogenic bacteria) in an air tied environment or closed system called biodigester or bioreactor. Biogas primarily is methane (CH_4), carbon dioxide (CO_2) and hydrogen sulphide (H_2S). The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel. Three biodigesters were designed, first is loaded with caw done and water ($1dm^3$ + 1dm3), second is loaded with solid waste and water (1,5dm3 + $0,5dm^3$) and the third is loaded with cow dung and biotech culture ($2dm^3$) labelled as Control-K. After homogeneity and stabilization period (4-12 days) biogas production was registered from each biodigester, the slurry (liquid content) were collected and used as liquid fertilizer. In a nutshell, organic waste was recycled into biogas (biomethane) and liquid fertilizer.

Index Term: Biodigester, Biomethane, biomass, Energy, Organic waste.

I. Introduction

Sustainability is one of the main issues in that was discussed by many countries. To achieve sustainability, reduction in fossil fuel consumption is necessary. The development of renewable energy using biomass feedstock, solar, wind, tidal wave and many others are few excellent practices that can lead to more sustainable future. The increasing price of fuels and taxes is also one of the driving force to find more economical and clean energy source for household and even nation [1]. Anaerobic digestion of organic waste (food waste and animal manure) to produce biogas is an alternative process to reduce food waste and generate energy. Biogas (mixed of methane and CO2), the main product of this process can be cooking gas, electricity production and fuel. By using this method, the release of greenhouse gas such as methane can be reduced. In addition, anaerobic digestion process also helps to reduce the odor (remove pathogens) of the waste and can provide a better feedstock for composting process to produce fertilizer containing high nutrient that can help the growth of crops [2].

Food waste is one of the growing problem in many society nowadays. According to the European Commission (2014), food waste can be classified into three categories: (i) food losses: food products lost during the production phase; (ii) unavoidable food waste: referring to food products lost during the consumption phase (fruit peels and cores, etc.) and (iii) avoidable food waste: products that could have been eaten but were lost during the consumption phase. In Malaysia, this waste was put under municipal solid waste and it has the highest percentage (49.3%) compared to the other wastes which are paper (17.1%), plastic (9.7%), glass (3.7%), ferrous metal (1.6%) and aluminum (0.4%) [3]. According to [4], Malaysia produced 15,000 tons of food daily which has potential to be used as a feedstock to produce biogas and fertilizer. Yasar et al. found that 1 m3 biogas has energy content similar to 0.62 liter of kerosene oil or 0.43 kg of LPG [5]. The household scale biogas installation could save up-to US$ 837.67$ for MS floating drum, US$ 829.03 for FRP floating drum and 845.25$ for fixed dome type domestic biogas plants respectively annually. In Malaysia, biogas production from food waste is still under development. Malaysia can be a suitable place for the development of biogas production as the atmospheric condition is almost suitable for the process. The country has high and constant temperature (20-35°C) throughout the years. This temperature range is suitable range for anaerobic respiration process (mesophilic bacteria) of the food waste. Anaerobic digestion process consists of several stages. The stages include hydrolysis, acidogenesis, acetogenesis and methanogenesis. In each process, certain type of microorganism will dominate due to the type of component available in the suspension and several other factors that will affect the efficiency of biogas production. Some of the factors are pH, temperature, mixing, substrate, C/N ratio and hydraulic retention time (HRT) [1]. Other than that, pretreatment and uses of additives may also increases the efficiency of the process. Pretreatment involves mechanical, physicochemical and biological, can increase the surface area of the substrate, hence increases the rate of reaction.

As biogas is a beneficial practice for many sectors, developing a high efficiency reactor (smaller footprint) is very essential especially for the commercialization of the process. Biogas, products of anaerobic digestion (AD) process mainly contain methane (up to 60%), carbon dioxide (up to 40%) and low quantity of other chemicals such as nitrogen and hydrogen sulfide [6, 7]. The colorless gas which is the most desired product of AD was called methane. Methane produces blue burning gas that can be used for cooking, heating and lighting [8]. As a clean, efficient and renewable energy source, biogas can be used to substitute other fuels for energy saving in rural area [9]. During AD in the absence of oxygen, the organic matter was decomposed by bacteria into methane, carbon dioxide and some hydrogen sulfide. Another product from the aerobic digester which is the digested substrate can be used as fertilizer since it is rich in ammonium and other nutrients [10-15]. In production of methane through AD, bacteria interact in syntrophic manner with each other in order to produce methane. Hydrolysis process is where complex carbohydrates, proteins and fats are hydrolyzed by exoenzymes and bacterial cellulosome into their respective monomers. These monomers are further degraded into acids, alcohols, hydrogen and carbon dioxide through acidogenesis process. In acetogenesis, acids are further digested into acetate, hydrogen and carbon dioxide. These intermediaries are then converted into methane and carbon dioxide through methanogenesis. Approximately carbon dioxide is reduced by one-third to form methane [16]. In order to increase the methane yield, parameter such as pH, temperature, substrates, hydraulic retention time(HRT), C/N ratio can be manipulated to ensure the optimum condition for microorganism. To adapt to a new condition, the bacteria requires minimum of three weeks when there is a change in substrate or temperature [16]. It is necessary for the hydrogen-producing acetogenic microorganism to have symbiotic relationship with the hydrogen-consuming methanogens. Neutral pH is needed since most methanogens grow around pH of 6.7-7.5 to increase the production of methane. Besides control of temperature, it is also important as mesophilic condition is favorable for acid forming microorganism while high temperature is required for methanogens [16]. Mixing can also play an important role as without mixing, foaming will occur while too much mixing can stress out the microorganism. Due to the slow growth of methane-forming microorganism which doubled after 5-16 days, HRT needs not less than 10-15 days, unless the bacteria are retained. The substrate should be digested slowly to avoid sudden increase of acid in the digester. The carbon and nitrogen ratio also need to be around 16:1-25:1 as too much increases or decrease of this ratio may affect the gas production. The solid content in another way should be around 7- 9%. Particle size can be a factor for the gas production process. The most important parameter of the digester is the temperature. Even though in low temperature (10-15°C), methanogen is active [17-20]. By increasing the temperature from 10 to 25°C, the production of biogas can be increase by tenfold. Biogas produced by high temperature with low HRT is comparable with low temperature with high HRT [17]. To maintain the temperature, modification could be made to the reactor. Installation of solar panel, heating devices, building the digester underground and charcoal coating are some way to maintain the temperature. Average solid content in household digester is around 5 to 10% [21-25]. Increase of the solid content to 19% can cause drop in the biogas production [24]. Under mesophilic condition, OLR of a digester is around 2-3 kgVS/m3 /day. It is possible for high OLR if the concentration of the sludge is over 10% [26]. The average biogas production in the domestic biogas digester in between 0.26 to 0.55 m3 /kgVS/day. According to literature, for mesophilic household digester, HRT vary from 20 to 100 days [17, 23, 25, 27]. By increasing the OLR and decreasing the HRT from 90 to 60 days and diluting the substrates from 1:4 to 1:2 can increase the performance of the digestion [28]. The main objective of this study is to evaluate conventional reactor design and perform a multistage process to achieve higher efficiency with smaller footprint. Chicken food waste will be co-feed with cow manure to produce biogas via anaerobic digestion process in ambient temperature condition (30°C). The gas will be collected every day and analyzed for their composition.

II. Material and Method

Design and construction of Bioreactor/Digester

An extra length of the pvc pipe was cut (it should be equal to the tank cap); a circle was drawn around the pvc on one side of the water tank. Then circle showing one top side of the tank, and make a hole with the help of soldering iron. Fit the pipe inside the hole and inlet the pvc fitted up to the bottom, also make a hole with the help of soldering iron in the side of the tank for outlet pipe. Inlet pipe and outlet pipe fill in the tank and pix the elbow with outlet pipe by making hole on the cap of water tank, fix the iron nipple on it and then sealed the joint of the pipe with the tank by superglue and sand, finally inlet the system of biogas plant. [29].

Sample preparation

1. A Cow dung (7 days old) suspension was prepared by taking 3000g of cow manure and 6000g of water (ration 1:2 of cow dung and water).

2. Solid waste suspension was prepared by taking 1500g of food waste (biotech culture. I.e. fermentation of food waste by microorganism) and 3000g of water (ration 2:1 of food waste and water).

Biogas (Bio-methane) Production Experiment

Used wastes during the biogas (bio-methane) production are: cow dung and biotech culture (fermentation of organic waste). The reason for the choice is that the first step of prevailing of ecological thinking is predomination of the principles of sustainability, indeed the most effective environmental investment is recycling of organic wastes. Besides the biologically active thin manure in high concentration and quantity, which is a source of potential environment pollutant in animal breeding, the residues of distillation can also serve as the basic material of biogas production, which takes form on the course of the production of alcohol, and in distillery. The period of the experiments is 30 days (30, December 2020 – 29, January 2021). We loaded the experimental bio-digesters with ~40 dm3 cow dung (slurry) and biotech culture, the bio-digesters have ~50 dm3 useful capacity and then on the 12th day (after homogeneity and stabilization process period) we applied different treatment combinations in each bio-digester:

1. Bio-digester 1: we changed 50 V/V% of the reactor content to cow dung (20 dm3 cow dung + 20 dm3 water).

2. Bio-digester 2: we changed 25 V/V% of the reactor content to biotech culture (30 dm3 food waste + 10 dm3 fruit water).

3. Bio-digester 3: we changed 5 V/V% of the reactor content to fresh cow dung/biotech culture.

During the comparative experiments (started from the 13th day to 40th day of the experiments) we continued the treatments modelled the continuous biogas producing technology in the reactor in such a way that we changed 5 V/V% (2 dm3) biodegraded biomass of the digester content to fresh biomass. The change – kept the rates which are applied on 12th day – happened follows:

• Bio-digester 1: 1 dm3 caw dung + 1 dm3 water

• Bio-digester 2: 1,5 food waste + 0,5 dm3 water

• Bio-digester 3: 2 dm3 cow dung/biotech mixture

In the bio-digesters during the comparative experiments we modelled continuous loading biogas producing technology under circumstances outlined below. - temperature of the reactor content 36.2 – 37.9 °C - anaerobe environment - during homogeneity the pH values sign basic medium - dry content (dry solid) 3-5 % During our experiment we controlled regularly technological circumstances they are necessary for anaerobe fermentation, we registered the quantity and the composition of generated biogas, we tested the characteristics of the input and output material for analyzing intensification effect of different treatment combinations.

III. Result and discussion

In the homogeneity (1-3 days) and the stabilization period (4-12 days) we registered the biogas production in each bio-digester, and then in the comparison period (13-30 days) of the experiments besides the quantity of biogas we registered also the methane content of biogas and we analyzed the effect of different recipes on the biogas and methane production. In the table 1 below it can follow the test results of the experiments, the effect of treatments on biogas production and on methane content of biogas.

Table 1 Biogas production of different kind of treatment combination

Days	**Bio-digester 1** **50:50**		**Bio-digester 2** **75:25**		**Bio-digester 5** **K**	
	Biogas production [dm^3]	Methane content [%]	Biogas production [dm^3]	Methane content [%]	Biogas production [dm^3]	Methane content [%]
1	0		0		0	
2	0		8		9.0	
3	12		26.0		9.0	
4	18		32.0		23.0	
5	24.3		39.7		42.0	
6	24.3		39.7		36.0	
7	24.3		50.0		31.0	
8	36.0		51.0		27.0	
9	36.0		36.0		25.0	
10	36.0		43.0		25.0	
11	25.0		41.0		24.0	

12	27.0		43.0		25.0	
13	80.7	73.1	71.0	76.4	23.0	54.6
14	82.0	73.6	69.7	75.3	27.0	54.4
15	82.0	73.5	69.0	76.1	24.0	54.7
16	83.0	74.2	69.0	76.5	25.0	54.8
17	80.6	74.9	43.0	74.3	23.0	55.7
18	76.4	74.1	54.0	71.2	27.0	57.9
19	71.0	68.2	66.0	69.7	21.0	56.3
20	65.0	67.8	67.0	72.2	21.0	52.2
21	63.2	68.3	42.7	74.2	21.7	54.8
22	63.4	68.9	53.0	76.4	18.0	57.4
23	63.0	72.6	63.0	77.1	16.0	59.3
24	56.0	64.3	61.0	66.8	22.0	56.3
25	61.0	66.9	67.0	71.6	24.0	56.1
26	61.0	66.7	62.0	69.6	22.7	56.3
27	59.0	68.1	53.0	74.1	22.6	57.1
28	58.0	67.6	63.0	70.2	22.8	54.1
29	56.2	68.4	61.1	70.1	21.0	54.2
30	55.9	67.2	59.0	70.1	24.0	54.0
Average (12^{th} – 30^{th} days)	**67.63**	**69.91**	**60.71**	**72.94**	**26.10**	**55.57**

KEY:

K_kontroll (this fermentor contains only cow dung nixture)

50:50_this Bio-digester contains 50 % cow dung, 50 % water

75:25_ this Biodigester contains 75 % Food waste, 25 % water

Data of table 1 it can be determined that because of mixed in different rates – created different conditions for formation of biogas (bio-methane) – organic wastes which were involved in the test the biogas production capacity of each biodigester changed greatly compared to production of the control digester which contains cow dung/biotech mixture. According to the data of comparison period the biogas production of control digester (biodigester 5) is behind the treated digesters. The biogas production of treated digesters is 2.3-2.5-fold of control digester. The digester (biodigester 2) which contains 25 percent waste of alcohol (water) considering the produced biogas though shows significant differences compared to the production of control digester, but the methane content of generated biogas also varies compared to the methane content of biogas in the control digester. From the digester which contain 50 percent waste of alcohol (food waste), the digester proved to be more productive, however, considering the methane content of produced biogas the digester with 25 percent waste of alcohol (biodigester 2) able to produce ~5 percent higher methane content values. Noted that methane content of produced biogases can consider harmonized (compensated) in both the digesters, the methane contents which was measured in comparison period was 10-20 percent higher in every case like the methane content of produced biogas in control digester. It can be also observed that the digester which contains more percent waste of alcohol cannot operate stable, indeed the system has become acidic, it was indicated by the pH of the digester content which was measured in comparison period. In every case it is necessary to keep the pH of the content in basic range, being that the methane bacteria like basic environment.

Production of liquid fertilizer from the Biodigesters

The table below summarize the volume of slurry (liquid fertilizer) collected after the production of biogas.

Table 2 production of liquid fertilizer from different kind of treatment combination

S/N	Biodigester	Volume of Liquid fertilizer
1	Digester 1	13.5 dm^2
2	Digester 2	8.7dm^2
3	Digester 3	9.8dm^2

Therefore, Biodigester 1 with 50 percent methane produced more liquid fertilizer compared to the rest of the digesters. While, the biodigester 3 (k) control produced less liquid fertilizer compared to the rest of the digesters, for this reason biomethanation is higher in the first digester and lower in the third digester.

IV. Conclusion

Producing and utilization of renewable energy sources is motivated by not only energy policy, environment protection, competitiveness but rural development aspects. Energy utilization of biomass originated from agriculture can create odds, opportunity for catch up for Nigerian region, Nigerian agriculture. But present situation and future situation of biomass production for energy is contested, the economy is influenced strongly by trends of global market. Nevertheless, economic assessment of the biogas producing, and the utilization is still not clear. In every case we have to take into consideration the energy demands of facilities and it must be added available material during the year which consist of by-products in suitable quantity and quality. Adapted to the characteristics of available material must take into consideration the process with improved technology. Until today in the agriculture and in the industry the main product had always a decisive role for formation of the production value. Only in the recent years the utilization of by-products and waste received good attention. During the rate of investment costs of biogas production and rate of return period have to take into considering both the income of sold biofertilizer and the advantages of environment protection, too.

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