An Enhanced Biogas Production from Organic Waste and Biotech Culture

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Abstract

This project aimed to produce bio-fertiliser and recycle organic waste into Biogas (bio-methane) as an alternative to traditional renewable energy production methods that use inorganic fertiliser. Anaerobic bacteria, specifically methanogenic bacteria, were used to break down solid waste in an air-tight environment or closed system called a biodigester or bioreactor. This process resulted in the production of Biogas, or biomethane, which contains methane (CH_4), carbon dioxide (CO_2), and hydrogen sulphide (H_2S) as its primary elements. All gases, including methane, hydrogen, and carbon monoxide (CO_2), can burn or be oxidised by oxygen, allowing Biogas to be used as a fuel source. To create the Biogas, three biodigesters were constructed. The first biodigester was filled with water and cow dung (1 dm^3 + 1 dm^3), the second with solid waste and water (1.5 dm^3 + 0.5 dm^3), and the third with biotech culture and cow dung (2 dm^3) and was designated as Control-K. After a homogenisation and stabilisation period of 4-12 days, each biodigester produced Biogas, and the slurry, or liquid component, was collected and used as a liquid fertiliser (biofertiliser).

Keywords: *Biomass; Biodigester; biomethane; energy; organic waste.*

Introduction:

Sustainability is a critical topic that many nations are considering, with a need to decrease fossil fuel consumption to achieve it. A more sustainable future may be realised by developing renewable energy sources such as biomass, solar, tidal wave, wind, and other fantastic techniques. The rising cost of gasoline and taxes partly drives the need for more affordable and ecologically friendly energy sources for homes and the entire country (Rajendran et al., 2012). Anaerobic digestion of organic waste (food waste and animal manure) for biogas production is an alternative way to reduce food waste and generate electricity. The primary by-product of this process, Biogas, which is a mixture of CH_4 and CO_2, can be used to create energy, fuel, and cooking gas. This technique can also decrease the emission of greenhouse gases such as methane. Furthermore, the anaerobic digestion process reduces the smell of the waste by removing pathogens. Additionally, it provides a better feedstock for the composting process, creating fertilisers with high nutrient levels that can aid crop growth (Sárvári Horváth et al., 2016).

Food waste is one of the growing concerns in many societies today. The European Commission defines three types of food waste: Food losses, which are items lost during the production phase, unavoidable food waste, which describes items lost during the consuming phase (such as fruit peels and cores); and avoidable food waste, which are items that might have been consumed but were lost. In Malaysia, this garbage is classified as municipal solid waste and has the most significant percentage (49.3%) when compared to other debris such as paper (17.1%), plastic (9.7%), glass (3.7%), ferrous metal (Fe^{2+}) (1.6%), and aluminium (Al) (0.4%) (Moh & Abd Manaf, 2014).

Malaysia produces 15,000 tonnes of food daily, which can be used as feedstock to create fertiliser and Biogas (Islam, 2016). According to Yasar et al. (Yasar et al., 2017), 0.62 litres of kerosene or 0.43 kg of L.P.G. has comparable energy content to 1 m3 of Biogas. Therefore, installing a domestic biogas plant at the household level could result in annual savings of up to US$837.67 for M.S.

Floating drums, US$829.03 for F.R.P. floating drums, and US$845.25 for fixed dome-type domestic biogas plants, respectively. Biogas production from food waste is still being developed in Malaysia. However, Malaysia's climate is ideal for the growth of biogas generation due to high and consistent temperatures all year round (20-35°C), which is suitable for the mesophilic bacteria involved in the anaerobic respiration process of food waste. The anaerobic digestion process involves several steps, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis, with a particular type of microbe predominating in each technique depending on the kind of component present in the suspension and other conditions. Various variables can affect biogas production efficiencies, such as pH, temperature, mixing, substrate, C/N ratio, and hydraulic retention time (H.R.T.). Pre-treatment and applying additives can also improve process efficiency by increasing the substrate's surface area and speeding up the reaction.

Because producing biogas benefits many industries, creating a high-efficiency reactor with a minimal environmental impact is crucial, especially for commercialising the process. CH_4 (up to 60%), CO_2 (up to 40%), and small amounts of H_2S are the primary components of Biogas, the end product of anaerobic digestion (A.D.) (McKendry, 2002, Hiremath et al., 2009). CH_4 is the most sought-after by-product of A.D. The blue-burning gas CH_4 produces can be used for lighting, heating, and cooking (Itodo et al., 2007). In addition, Biogas is a clean, efficient, and renewable energy source that can replace conventional fuels in rural areas to save energy (Yu et al., 2008). During A.D., microbes use organic matter to break down into methane without oxygen, hydrogen sulphide, and some carbon dioxide. Because the digested substrate contains a lot of ammonium and other nutrients, it can be used as fertiliser (Almomani, 2020, Ram Bux Singh, 1973, R B Singh, 1974, Sathianathan, 1975, Meynell, 1976, Santerre & Smith, 1982) . Bacteria interact syntrophically with one another to make methane when A.D. Exoenzymes produce methane, and bacterial cellulosomes hydrolyse complex carbohydrates, proteins, and lipids into their corresponding monomers during the hydrolysis process. Through the acidogenesis process, these monomers are further broken down into acids, alcohols (CH_3COOH), hydrogen (H), and CO_2. During acetogenesis, acids are then broken down into acetate (CH_3COO), H, and CO_2. The methanogenesis process subsequently transforms these intermediates into CH_4 and CO_2, with CH_4 created when carbon dioxide is reduced by about one-third (Deublein & Steinhauser, 2011).

The ideal conditions for microorganisms can be achieved by adjusting variables such as pH, temperature, substrates, H.R.T., and C/N ratio to maximise methane yield. When there is a change in substrate or temperature, the bacteria require a minimum of three weeks to adapt (Deublein & Steinhauser, 2011). Therefore, a symbiotic interaction between the H-producing acetogenic microbe and the H-consuming methanogens is essential. Since most methanogens thrive at pH values between 6.7 and 7.5, a neutral pH is required to maximise CH_4 generation. Temperature regulation is crucial because mesophilic conditions are advantageous for acid-forming microorganisms, while high temperatures are necessary for methanogens (Deublein & Steinhauser, 2011). Mixing is also significant but should be done carefully to avoid foaming or stressing the microbe.

H.R.T. requires at least 10-15 days unless the bacteria are kept due to the slow growth of the CH_4-forming microbe, which quadruples after 5-16 days. The substrate should be slowly digested to prevent a quick acid rise in the digester. Moreover, the carbon (C)-to-nitrogen (N) ratio needs to be between 16:1 and 25:1, as significant deviations from this ratio may impact gas production. In other words, the solid content should be between 7% and 9%, and particle size may play a role in the creation of petrol.

Temperature is the most crucial digester parameter, as methanogens can still exist at low temperatures (10–15°C), but ten times more Biogas can be produced by raising the temperature from 10 to 25°C. Low temperatures with high H.R.T. and high temperatures with low H.R.T. both create comparable amounts of biogas (I Ferrer et al., 2009). The reactor can be altered to maintain the temperature by installing solar panels, heating equipment, burying the digester, or covering the charcoal (Stevens & Schulte, 1979, L. Singh et al., 1993, L. Singh et al., 1995).

On average, 5% to 10% of solids comprise a residential digester (Xavier & Nand, 1990, Nazir, 1991, Shyam & Sharma, 1994, Bouallagui et al., 2003, Bond & Templeton, 2011). Reducing biogas output may increase the substantial percentage to 19% (Shyam & Sharma, 1994). A digester's O.L.R. in mesophilic conditions is roughly 2-3 kgVS/m^3 daily, and a high O.L.R. is possible if the sludge content is over 10% (Subramanian, 1977). In a residential biogas digester, daily biogas production ranges from 0.26 to 0.55 m3/kgVS. H.R.T. for mesophilic household digesters ranges from 20 to 100 days (I Ferrer et al., 2009, Xavier & Nand, 1990, (Bond & Templeton, 2011 and Garfí et al., 2011). Digestion performance can be improved by raising the O.L.R., reducing the H.R.T. from 90 to 60 days, and diluting the substrates from 1:4 to 1:2 (Schnurer & Jarvis, 2010, Ivet Ferrer et al., 2011).

The primary goal of this study is to assess conventional reactor designs and carry out a multistage procedure to increase efficiency while reducing the footprint. Chicken food waste will be co-fed with cow dung to produce Biogas by anaerobic digestion under ambient temperature conditions (30°C). Every day, the Biogas will be collected.

Materials and Methods

2.1 Bioreactor/Biodigester Design and Construction

A circle was drawn on the side of the water tank around an extra piece of P.V.C. pipe cut to the same size as the water tank cap, marking the tank's top. A hole was formed at the centre of the circle using a soldering iron. Another spot was constructed on the side of the tank for the output pipe by soldering. Next, the intake and outlet pipes were inserted into the tank, and an elbow was attached to the outlet pipe by drilling a hole in the water tank's cover. The iron nipple was attached to it using superglue and sand, ensuring a secure connection between the pipe and the tank. Finally, the biogas plant system was inducted (Kleerebezem & van Loosdrecht, 2007, Schnurer & Jarvis, 2010, Colombo et al., 2017).

2.2 Preparation of Samples

To prepare a suspension of cow dung that was seven days old, 6.0 kg of water and 3.0 kg of cow manure were mixed in a 1:2 ratio. A solid waste suspension was also created by combining 1.5 kg of food waste (fermented by microorganisms, also known as biotech culture) and 3.0 kg of water in a 2:1 ratio and its compere's a suggested revision:

Experiment to Produce Biogas (Bio-methane)

The fermentation of organic waste, such as cow dung and biotech culture, can be used to generate bio-methane. Recycling organic waste is an efficient environmental investment and a crucial step towards promoting ecological thinking. In addition to cow dung and biotech culture, residues from distillation and thin manure can also be utilised to produce bio-methane (Colombo et al., 2017, Jinjiri et al., 2022).

To investigate the potential of bio-methane production, an experiment was conducted for 30 days. The experimental bio-digesters had a load of approximately 40 dm^3 of cow dung (slurry) and biotech culture, and a functional capacity of around 50 dm^3. After the homogeneity and stabilisation process period, the following treatment combinations were applied in each bio-digester:

- Bio-digester 1: contained 50 V/V% cow dung (20 dm^3 cow dung and 20 dm^3 water) in the reactor.
- Bio-digester 2: was modified to have biotech culture makeup 25 V/V% of the reactor's content (30 dm^3 of food waste and 10 dm^3 of fruit water).
- Bio-digester 3: contained fresh cow dung and biotech culture at 5 V/V% of the reactor's content.

During the comparative studies, which ran from day 13 to day 40 of the trials, the continuous biogas-producing technology in the reactor was changed to 5 V/V% (2 dm^3) biodegraded biomass of the digester content to fresh biomass. The modification, which maintained the rates in effect on the 12th day, took place as follows:

- Bio-digester 1: 1 dm^3 cow dung + 1 dm^3 water
- Bio-digester 2: 1.5 food waste + 0.5 dm^3 water
- Bio-digester 3: 2 dm^3 cow dung/biotech mixture

The bio-digesters were loaded with dry content (dry solid) of 3-5%, and the reactor content temperature was maintained at 36.2-37.9°C in an anaerobic environment. During homogeneity, the pH readings indicated an essential medium. In addition, the amount and content of the Biogas produced during the experiment were recorded.

To study the intensification impact of various treatment combinations, regularly managed technology is required in these conditions for anaerobic fermentation, and the input and output material properties were tested, position examined.

Result and Discussion

Each biogas production digester was monitored during the experiment's homogeneity phase (1-3 days) and stabilisation phase (4-6 days). During the comparison phase (13-30 days), the methane content of the Biogas was analysed along with the impact of various recipes on biogas and methane production. Table 1 shows the effects of treatments on biogas and methane production and the test results of the trials.

Table 1. Biogas generation of various treatment combinations

Days	Bio-digester 150:50		Bio-digester 275:25		Bio-digester 5 K	
	Biogas production [dm^3]	CH_4 content [%]	Biogas production [dm^3]	CH_4 content [%]	Biogas production [dm^3]	CH_4 content [%]
1	0	0	0	0	0	0
2	0	0	8	0	9.0	0
3	12	0	26.0	0	9.0	0
4	18	0	32.0	0	23.0	0
5	24.3	0	39.7	0	42.0	0
6	24.3	0	39.7	0	36.0	0
7	24.3	0	50.0	0	31.0	0
8	36.0	0	51.0	0	27.0	0
9	36.0	0	36.0	0	25.0	0
10	36.0	0	43.0	0	25.0	0
11	25.0	0	41.0	0	24.0	0
12	27.0	0	43.0	0	25.0	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 fermenter contains only cow dung mixture), 50:50_this Bio-digester contains 50 % cow dung, 50% water, 75:25_ this Biodigester contains 75% Food waste, 25% water.

The data in Table 1 demonstrates that the capacity of each biodigester to produce Biogas significantly differed from that of the control digester, which used a mixture of cow dung and biotech at varying rates and conditions to have Biogas (bio-methane). During the comparative period, biodigesters treated with waste alcohol produced 2.3-2.5 times as much Biogas as the control digester, while biodigester 5 had the least Biogas. Although the methane content of the Biogas made from biodigester 2, which contained 25% alcohol waste (water), differed significantly from that of the control digester, the methane content of the generated Biogas varied only slightly compared to the control. Biodigester 4, which contained 50% food waste alcohol, was found to be the most productive. However, when looking at the methane content of the Biogas produced, biodigester two achieved values that were 5% higher. During the comparison period, the methane content of Biogas made in each biodigester was 10-20% higher than that of the control digester, even though the methane content of the produced Biogas was compensated in both digesters. The pH of the biodigester content was measured and found to be acidic, which suggests that the digester cannot run steadily if it contains more than a certain percentage of alcohol waste. Since methane bacteria prefer basic environments, it is essential to maintain the pH of the content in the appropriate range.

Figure 1 shows the biogas production (dm^3) and CH_4 content percentage (%) distributions of Biogas generation of various treatment combinations per days.

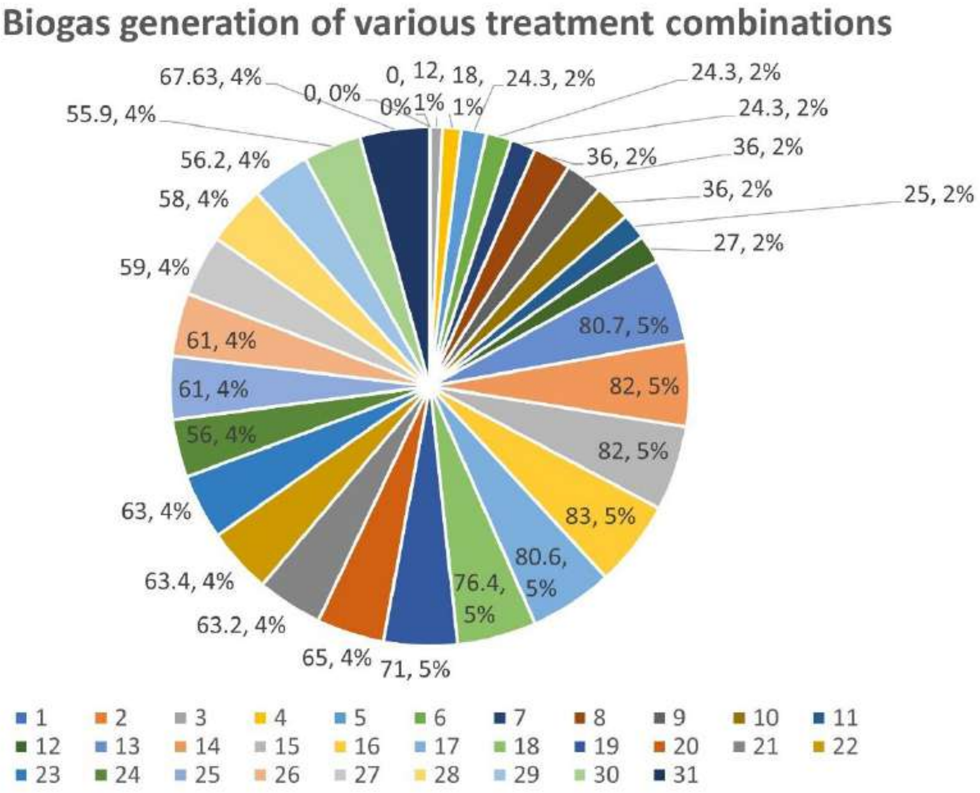

Figure 1. Biogas production (dm^3) and CH_4 content percentage (%) distributions of Biogas generation of various treatment combinations per days.

The table 2 below summarises the volume of slurry (liquid fertiliser) collected after the production of Biogas.

Table 2. Production of liquid fertiliser using a variety of treatment methods

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

Compared to the other digesters, Biodigester 1 produced more liquid fertiliser with 50% methane. As a result, the level of bio methanation is higher in the first digester and lower in the third digester, even though Biodigester 3 (k) control produced less liquid fertiliser than the other digesters.

Conclusion

Energy policy considerations, environmental protection, competitiveness, and rural development drive renewable energy production and use. Utilising biomass from agriculture for energy production can provide a valuable opportunity for Nigerian agriculture and the region as a whole to catch up. However, there are questions about biomass energy production's current and future state, and global market developments can significantly impact the national economy. Therefore, it is essential to determine the profitability of producing Biogas and using it. Regardless of the situation, we must consider the energy requirements of the facilities, as well as the availability of material throughout the year, which should consist of appropriate quantity and quality byproducts. The process must also be designed with better technology, which adapts to the properties of the available material. The primary product has always been crucial in determining production and value in agriculture and business. However, the use of waste and byproducts has recently gained significant interest. The income from the sale of bio-fertiliser and the benefits of environmental protection must be considered when calculating the investment expenses for biogas production and the expected return period.

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Competing Interests

The authors have affirmed that there are no conflicting interests.

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