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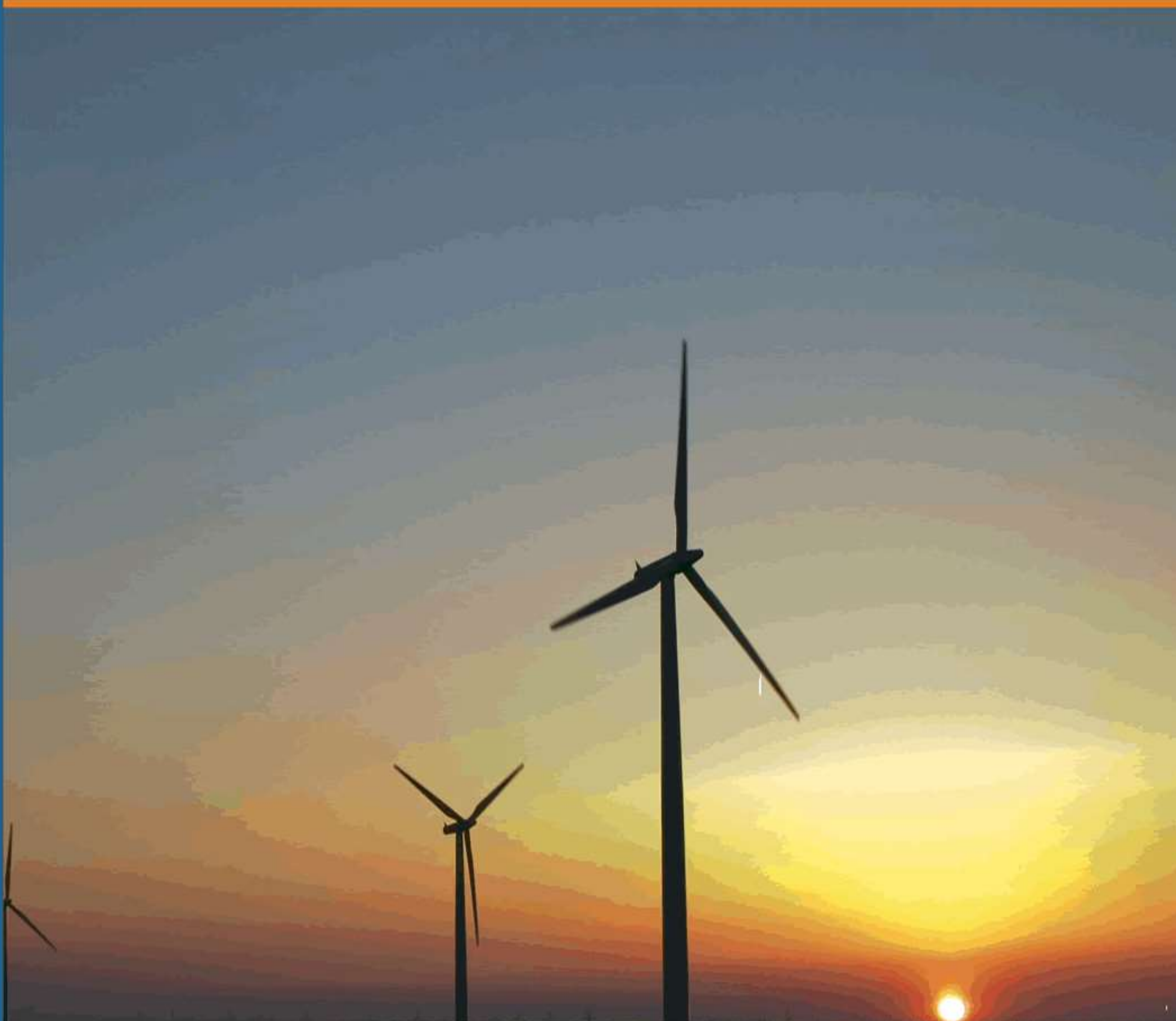

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Performance of Interspersed Loading of Animal Waste of Cattle Dung and Vegetable Waste of *Brassica oleracea* in Continuous Anaerobic Digester

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ABSTRACT

Purpose: The purpose of this work is to explore the addition of vegetable waste of *Brassica oleracea* interspersed with cattle dung into a continuous anaerobic digester that normally uses cattle dung as a substrate.

Methodology: In this work, a 200-liter continuous anaerobic digester was operated to conduct the research. The digester was filled fully with cattle dung and water (50%:50%). The digester then was operated by continuously adding every day with a 5-liter mixture of waste *Brassica oleracea* and water (50%:50%) for odd days and a mixture of cattle dung and water (50%:50%) for even days interspersed.

Findings: The CH4 content is in the range of 22-60 % with average value 36.8%. The CO2 content in the range 33-68% with average 44.3%. The pH of slurry inside an anaerobic digester is found in the range 6.6-7.6 with average value. 7.0. The addition of *Brassica oleracea* puts the pH in the range of about neutral for all 30 days. The temperature inside a continuous anaerobic digesterisin the range 30^{o}C- 37^{o}C and average 33.6^{o}C which is still in the range of mesophilic condition. For the note, the ambient temperature outside the digester, lowest30^{o}C, highest 35^{o}C and average 32.2^{o}C .

Unique contribution to theory, practice and policy: Cattle waste and Brassica oleracea vegetable waste can be processed in a continuous anaerobic digester by feeding it interspersed. In this way, pretreatment and acclimatization are not needed

Keywords: *Cattle, Dung, Vegetable waste, Brassica oleracea , Continuous, Digester*

INTRODUCTION

The biogas plant was considered an optimal tool for the prevention of water pollution and odor annoyance by an uncontrolled discharge of livestock wastewater to open water sources and integrated rural clean water supply and environmental sanitation (Nguyen, 2011). The effluent from the digester can be used as a fertilizer because rich in nitrogen, potassium, and phosphorus. The leftover digestate can be directly used as a fertilizer in farming (Rajendran et al. 2012; Abubakar, 2022). Therefore, the development of technologies and biogas production for biomethane generation has been encouraged by many countries as an alternative for the cogeneration of internal engines or electricity generation (Guimaraes & Maia, 2023). Household digesters could reduce the pressure on the environment by loss of cultivable land, soil erosion, greenhouse gas emissions, and reducing deforestation. (Rajendran et al. 2012; Jegede et al. 2019; Banarje et al 2022).

Large capacity biogas plants (natural rubber tube, floating-drum, and fixed-dome) were not attracted due to high investment costs, problematic access to spare parts as well as maintenance and difficulties in installing. The disadvantages of this model are its high cost, difficulty in transport, and lack of ability of technicians and skilled laborers in biogas construction, operation, and maintenance works (Nguyen, 2011).

Millions of simple biogas digesters have been constructed to produce biogas, mainly for cooking and lighting in India, China, Bangladesh, Vietnam, Pakistan, and Tibet. Most biogas digesters in these countries are made out of concrete or plastic composite, bricks, and are unstirred and unheated. Approximately 40% of CH_4 losses from small-scale digesters by emission from outlet and inlet, leaking from non-airtight gas valves, and intentional releases or broken/ cracked caps of digester (Pham et al. 2014).

In fixed-dome bio-digester, the design lacks agitation action that causes a slower anaerobic digestion reaction, which effects on volume of biogas produced. The gas pressure will fluctuate substantially depending on the volume of biogas stored which is invisible. Water particles get separated after some time and create two unusual layers (Zaki et.al, 2021). Because it is underground, if such a leak, occurs in the digester construction it would be difficult to repair. The leak certainly will cause the formation of the biogas process cannot take place as it should (Randjawali & Waris, 2016; Budiman, 2020; Abubakar, 2022).

An improvement design from the fixed-dome bio-digester is a floating drum digester. A gasholder provides more space to store biogas with constant pressure. For this design, mild steel is commonly used to create the gas holder, making it less costly. The volume of stored biogas is visible directly as the drum rises when biogas is produced and moves down when it is consumed. The fixed dome type could last longer than the floating drum because the floating drum is not prone to corrosion (Zaki, et al., 2021; Budiman, 2020; Abubakar, 2022).

Plug flow bio-digesters were introduced to separate two processes therefore two-phase systems were produced, which are acidogenesis and methanogenesis longitudinally. Plug flow bio-digesters have a constant working volume (Zaki, et al., 2021).

A balloon bio-digester consists of a heat-sealed rubber bag or plastic, combining biogas storage and digestion parts. If the gas pressure exceeds the limit of the balloon's designed pressure, the balloon explodes. One limitation of this design is its shorter lifespan, which does not exceed 2–5 years (Zaki, et al., 2021; Abubakar, 2022).

For optimum performance, anaerobic digestion depends on several different parameters, these parameters are: hydraulic retention time (HRT), Temperature, pH, mixing, C/N ratio, substrate, and temperature (Rajendran et al., 2012; Banerjee, et al., 2022).

The household digesters often stop use by people in the long run due to gas leakage, lack of knowledge, inadequate supply of substrate, low gas production, and slow recovery. A solution for these is needed. But it demands more research and development. For instance, straw is a potential substrate for household biogas digesters, (Rajendran et al. 2012).

Hydrolysis, acidogenesis, acetogenesis, and methanogens are the four-step processes that typically occur in anaerobic processes (Postawa and Kułażyński, 2021; Banerjee et al. 2022). Nitrate and sulfate reduction are other processes that also occur, with side products are gases of hydrogen sulfide, nitrogen, and ammonia. The breakdown of protein, lipids, and carbohydrates (i.e. complex polymeric organic substrates) into fatty acids, sugar, and amino acids (i.e. smaller monomeric compounds) occurs during the hydrolysis reaction. The enzymes that are produced by a variety of consortium hydrolytic bacteria facilitate this reaction. During hydrolysis, the monomer is released and converted by fermentative bacteria (also known as acid-forming bacteria) into alcohols, lactic acid, fatty acids, ammonia, pyruvate, carbon dioxide, and formate or hydrogen. The byproduct gaseous are mainly carbon dioxide (CO_2), and methane (CH_4). The trace gases are hydrogen (H_2) and hydrogen sulfide (H_2S), (Deublein & Steinhauser, 2011; Akunna, 2019; Abubakar, 2022). The biogas also is detected contain with water, siloxanes, nitrogen, ammonia, and ammonia, (Abubakar, 2022).

The disadvantages of batch systems are, that the quality of biogas is different every day, and even at the beginning of the process the biogas cannot be used as a fuel because of minimum or low methane content. Another disadvantage is that, by the batch system, the waste cannot be processed daily. It developed then the continuous system of anaerobic digester that makes it possible to process organic waste daily with produce about high methane content of biogas so that can be used as a fuel daily and also can process animal waste (cattle dung) daily. In this continuous system, the feeding volume and retention time should be carefully studied for optimum results because all four processes (hydrolysis, acidogenesis, acetogenesis, and methanogenesis) in an anaerobic digester will be run at the same time. A more complex situation will be faced if continuous anaerobic digestion is used also for processing vegetable waste. The volume of vegetable waste and retention time in the anaerobic digester should be well studied.

The organic or lignocellulosic waste is collected from markets, municipal, agriculture, and other activities in large quantities. The slurry of animal manure, municipal solid waste, food waste, and sewage sludge are the most typical forms used in the anaerobic digester of the energy industry. That is typical of waste that can be used in anaerobic digester for biogas production in a wide range (Achinas et al. 2017).

To void failure and increase efficiency during the process of that wide range of lignocellulosic waste, the pretreatment application method is necessary to enhance the degradation process of the substrate. The decomposition process can be sped up by applying enzymatic mechanical, thermal, and chemical although the result does not necessarily in higher biogas production yield (Achinas, et al., 2017).

Since animal manure contains methanogenic bacteria, it is not difficult to proceed with the use of animal dung in the anaerobic digester. Many projects were successful in processing animal waste in anaerobic digesters such as poultry (Marchioro, et al., 2018), goat (Hanafiah, 2017), elephant (Rangseesuriyachai, et al., 2023), and pig (Gaworski, et al. 2017). But not like animal waste, processing vegetable waste is more complex since should be accelerated with methanogenic bacteria that are present in an established aerobic digester.

Vegetable waste is an example of biomass residue that can be used to produce bioenergy, for example, biohydrogen, biogas, biodiesel, and bioethanol, rather than being disposed of and causing environmental pollution and contamination. It can be said that this is a solution to solve various problems such as waste management, energy shortages, incineration and greenhouse gas emissions in landfills, the emergence of unpleasant odors, protecting natural landscapes, and thousands of other environmental problems. However, despite the many benefits and potential obtained from converting fruit and vegetable waste into bioenergy, technological developments for utilizing vegetable and fruit waste into bioenergy are not yet widely available. This means that stakeholders and active activists from the global energy industry do not have sufficient information to make this happen (Adamu et al. 2023).

Furthermore, pre-treatment has both advantages and disadvantages, especially if it is too excessive it can cause a decrease in the CH_4 content in the biogas. Besides that, various operational variations in parameters such as pH, temperature, carbon/nitrogen ratio, correct types of microbes (inoculum), and grain size of the feedstock are challenges for the anaerobic digestion process (Adamu et al. 2023).

The addition of vegetable waste into the batch type of anaerobic digester was a common method that was practiced to process organic waste and at the same time provide a beneficial product of energy and fertilizer (Lahbad et al. 2021). The addition of vegetable waste into the feeding system of continuous anaerobic digestion is not well practiced at the moment since the route to optimum results is not well understood.

This work specifically gives attention to the processing waste of cabbage (Brassica oleracea) in a continuous anaerobic digester. The established anaerobic digester was fed with cattle dung. The way of feeding is interspersed with cattle dung to ensure the availability of methanogenic bacteria inside the anaerobic digester.

MATERIAL AND METHOD

The source of cattle dung was from the species of Bali cattle (Bos javanicus). Bali cattle are an important livestock species for Malaysia and Indonesia because this livestock species reproduces easily, is very efficient even when fed with low-quality feed, and can adapt well to tropical areas (Nindhia et al. 2021). The waste of vegetables that was used in this research was from the types of Brassica oleracea.

In this work, a 200-liter continuous anaerobic digester was operated to research as presented in Fig. 1, for ease of transportation of the digester to the site (Taghinazhad et al. 2017). The digester was completed with a stirrer for mixing the substrate. Mixing in a biogas digester needs to be done so that reduce precipitation, no scum is formed, can facilitate the release of gas produced by bacteria to the biogas reservoir and mixing methanogenic bacteria with substrates, (Fahriansyah et al. 2019). Stirring increases both the biogas production and the degradation of organic compounds because it improves the hydrodynamics inside the reactor and the hydrodynamic has a great influence on mass transfer phenomena (Elsawy et al. 2021). The advantages of making this mini-sized biogas digester are that it allows users to make repairs if something goes wrong at the time of manufacture and relatively low manufacturing cost. Mini-sized biogas digester can be a solution to energy shortages (Randjawali and Waris, 2016).

The anaerobic digester tank in this research was using steel. The steel is easily corroded by hydrogen sulfide (H_2S) that is found in the biogas (Abubakar, 2022; Zaki et al. 2021; Banarje et al. 2022; Nindhia et al. 2013). To overcome this problem, a small cut of magnesium metals was affixed outside the steel tank as a sacrificial anode to provide cathodic protection (Pathak et al. 2012; Nindhia et al. 2016). The most electrochemically active metal is Magnesium (Mg). This metal has very important uses in the field of engineering. Magnesium will immediately experience corrosion in certain environments. Magnesium metal and magnesium alloys are used to prevent corrosion through a sacrificial anode mechanism for structures made of steel such as pipelines and ship hulls. (Pathak et al. 2012).

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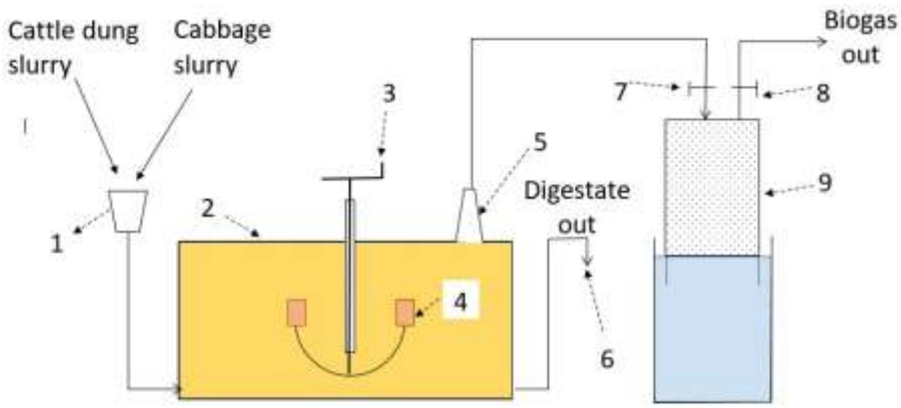

Figure. 1. Schematic of continuous anaerobic digester with capacity 200 liter, 1. Inlet slurry, 2. Steel digester tank, 3. Handle for stirrer, 4. Manual agitator, 5. Outlet for biogas 6. Digestate out, 7. Inlet valve of biogas, 8. Outlet valve of biogas, 9. Biogas storage in floating drum

The anaerobic digester was filled with slurry in the inlet slurry of the system (1). The digester tank (2) is filled with slurry. The stirrer (3) was provided to rotate the agitator to make the slurry well mixed and flow from the inlet (1) to the outlet (6) while feeding the digester.

Various researchers have observed the effect of stirring on anaerobic digesters on a laboratory scale and also on a pilot scale. It was found that the anaerobic digester required an efficient and adequate (Bridgeman, 2012; Conklin et al. 2008; Halalsheh et al. 2011). The system in this research is equipped with a stirrer. However, the stirring process is only carried out during feeding. This was done based on information from previous research which explained that minimal and intermittent stirring produced more biogas than if it was stirred continuously. This also means that performance will be better if stirred slowly compared to vigorously (Karapaju and Rintala, 2008).

The biogas was produced and collected in the floating drum (9) by opening the inlet valve (7) and closing the biogas outlet valve (8). If the biogas inside the floating drum will be used as fuel, the inlet valve (7) should be closed and the outlet valve (8) should be closed.

The digester was operated in a batch system for about 1 month at the beginning. The digester then was operated by continuously adding every day with a 5-liter mixture of cattle dung and water (50%:50%) for 1 month. Subsequently, the digester was operated for 1 month with an additional 5-liter slurry of Brassica oleracea waste and water (50%:50%) for odd days and the mixture of cattle dung and water (50%:50%) for even days, interspersed. The purpose of feeding interspersed was to keep supplying methanogenic bacteria into the digester as an inoculum (Maamri and Amrani, 2014; Bella and Rao, 2022). The slurry of Brassica oleracea was prepared by putting waste Brassica oleracea and water in the blender.

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For all processes, the digester was stirred only during feeding time for easy flow of the substrate inside the anaerobic digester. Also, too much mixing stresses the microorganisms. Without mixing, foaming and the formation of scum occur (Rajendran et al. 2012; Deublein and Steinhauser, 2011). Rapid mixing inhibits flock structure thereby disrupting the relationships between the nutrients of the organism (dystrophic). Meanwhile, stirring at medium speed was found to be optimal for substrate conversion (Abdel-Hadi and El-Azeem, 2008).

The biogas digester that was developed in this work, according to feed types was a continuous type. According to scale was a type of small-scale household (Rianawati et al. 2018), and it was from a dry digester (Elsawy et al. 2021)

The biogas production was measured and methane as well as carbon dioxide composition was detected. The data on pH and temperature inside and outside the digester were provided to understand the process that may occur inside the digester.

RESULT AND DISCUSSION

The biogas production with only cattle dung as a substrate is found almost linearity increase. The additional waste of *Brassica oleracea* made the production of biogas higher until the day of the 17th, the biogas production then was found the same until reach day of the 22nd, and after the day of 22nd, the production of biogas was found to flatten with addition waste of *Brassica oleracea (Fig. 2).*

This is due to the main composition of *Brassica oleracea* is 89% water, 7% carbohydrates, mainly fiber and sugar, 3% protein, and 0.4% lipids (Streitwieser, 2017). The more detailed result is informed that, if the *Brassica oleracea* was processed in the form of flour, then the composition is found: moisture (10.35%), ash (18.05%), protein (12.28%), lipid (0.80 %), and total carbohydrate (59.59 %). In this report, the moisture and ash contents of the flours were determined gravimetrically, (Brito et al. 2020). Both reports (Streitwieser, 2017; Brito et al. 2020) informed that the main composition of *Brassica oleracea* are carbohydrates, protein, and lipids that make the process of hydrolysis become longer and produce less CH_4 and increase the production of CO_2 gas (Fig. 3 and Fig.4) as explained in detail by (Deublein and Steinhauser, 2011; Akunna, 2019). Keep feeding the system with the waste of *Brassica oleracea* until the day of the 22nd the process of hydrolysis is washed out (Deublein and Steinhauser, 2011) and limited biogas is produced and flattened the biogas production (Fig. 2).

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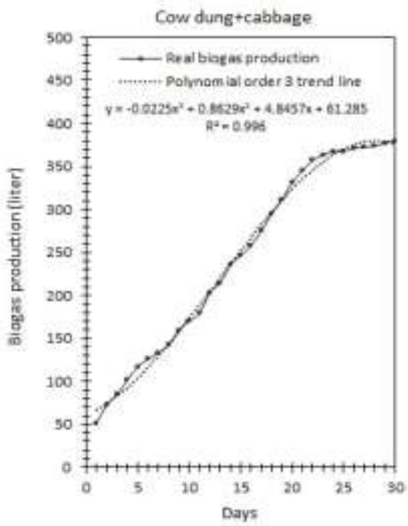

Figure 2. Biogas production in continuous anaerobic digestion feeding with cattle dung and waste of *Brassica oleracea* interspered. It was follow the order 3 of polynomial trend line

It was observed in this work that the system is fed with mixed cattle dung and *Brassica oleracea* the CH_4 content is in the range of 22-60 % and the average is 36.8%. This condition convinced that by addition of *Brassica oleracea* into the system made the process late to reach the next 3 stage processes (namely: acidogenesis, acetogenesis, and methanogenesis) which can be proven by low CH4 composition if added with *Brassica oleracea* . This condition can be overcome by a reduction of the organic waste load (increase in the residence time) (Deublein and Steinhauser, 2011), meaning that the addition of *Brassica oleracea* should take longer than every 2 days.

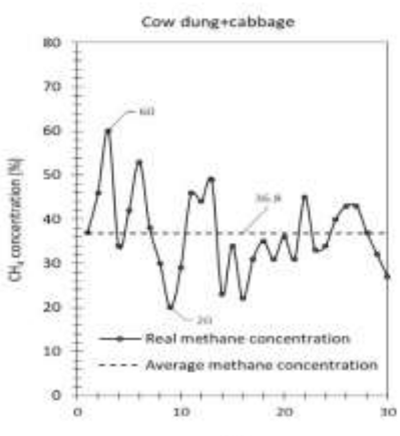

Figure 3. Methane composition in biogas that was produced in continuous anaerobic fed with cattle dunk and waste of *Brassica oleracea* interspersed. Lowest 20%, highest 60%, average 36.8%

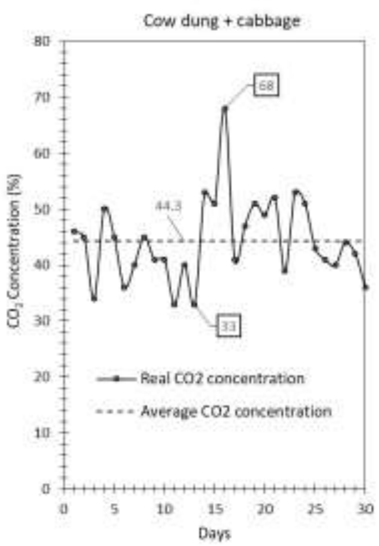

Figure 4. Carbon dioxide composition in biogas that was produced in continuous aerobic digester feed with that is fed with mixed cattle dung and waste of *Brassica oleracea* interspersed. Lowest 33%, highest 68% and average 44.3%

The temperature inside the digester for 30 days is presented in Fig. 5. The lowest was found at 30^{o}C and the highest was 37^{o}C. In this work, the temperature inside the digester never reached 38^{o}C which is a condition that reportedly destroys 99.9% of pathogens (Abdel-Hadi and El-Azeem, 2008). Meanwhile, during operation with cattle dung and waste of *Brassica oleracea* interspersed, the lowest ambient temperature was 30^{o}C and the highest was 35^{o}C. temperatures inside the digester are found around the range of mesophilic process (Deublein and Steinhauser, 2011). To increase the temperature, the concept of a greenhouse coupled with a digester should be introduced for future work. The one-year study revealed almost a 100% increase in biogas yield when applying a digester inside a greenhouse (Sodha et al. 1987).

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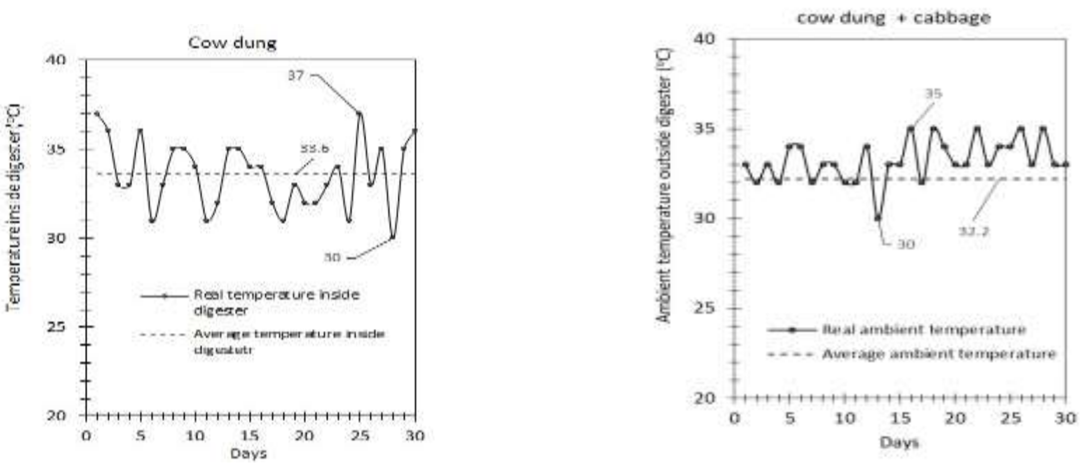

(a) (b)

Figure 5. (a) The temperature inside a continuous anaerobic digester lowest 30ºC, highest 37ºC and average 336ºC. (b)Ambient temperature outside the digester, lowest30oC, highest 35ºC and average 322ºC. The substrate is cattle dung and waste of *Brassica oleracea* interspersed

Anaerobic digestion is influenced by the concentration of hydrogen ions (pH) present in the digesting material. Because excess acidity prevents digestion, the hydrogen-ion concentration of the culture medium immediately influences microbial growth (Banerjee et al. 2022).

Methanogens thrive in neutral to slightly alkaline conditions and die in acidic environments. The optimum pH of the system is in the range of 7-8.5 (Banerjee et al. 2022), the nitrogen will be released and accumulate into ammonia which can raise the pH of the substrate (Randjawali and Waris, 2016). The swing in pH is an indication that all processes of anaerobic digestion (hydrolysis, acidogenesis, acetogenesis, and methanogenesis) occur. Meanwhile by addition of Brassica oleracea makes the pH in the range of about neutral for all 30 days that indication acidogenesis process does not occur and process hydrolysis is washed out (Deublein and Steinhauser, 2011).

Methanogens thrive in neutral to slightly alkaline conditions and die in acidic environments. The optimum pH of the system is in the range of 7-8.5, with values approaching 7 for optimal activity when the aerobic digestion process is stable. To overcome this situation the appropriate pretreatment of *Brassica oleracea* waste should be discovered for suitable pH condition is achieved. The pretreatment could be thermal, chemical, or biological (Achinas et al. 2017; Mozhiarasi, 2022) which can be explored as future work of this research.

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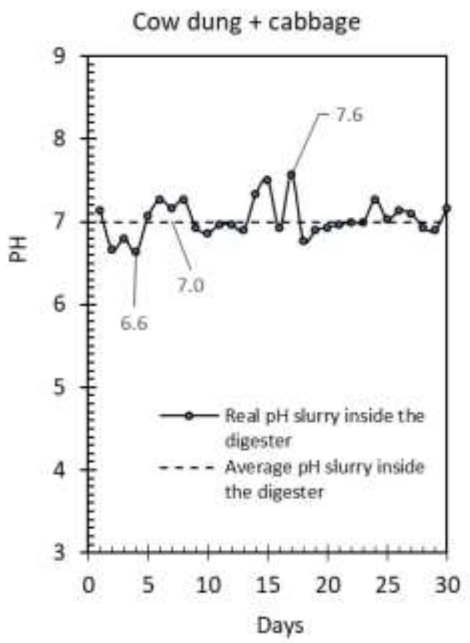

Figure 6. The pH of slurry inside an anaerobic digester.Lowest 6,6, highest 7.6, average 7.0

The required pH for anaerobic digestion (AD) should be in the range of 6.5–8 (Abubakar, 2022). The rate of methane production declines at pH values below 6.3 or exceeding 7.8. Most methanogenic bacteria function optimally at pH 7 to 7.2, (Abdel-Hadi and El-Azeem, 2008).

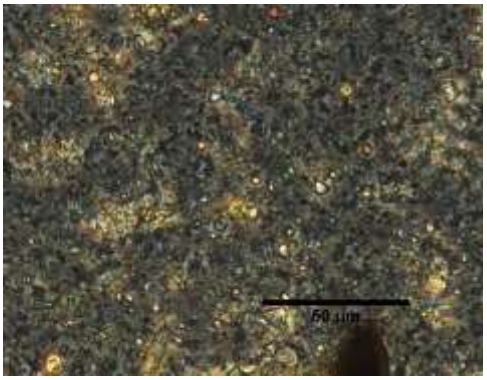

Figure 7. Observation of the digestate under phase contrast inverted microscope after 30 days. System feed with cattle dung and waste of Brassica oleracea interspersed

The concentration of the microorganisms plays a vital role in anaerobic digestion. Methanogenic microorganisms have a long regeneration time in general. To avoid washing out from the reactor, hydraulic residence times must be at least 10 – 15 days with reactor systems that do not have any facilities for retaining and returning biomass (Deublein and Steinhauser, 2011). In this regard observation under an inverted phase contrast optical microscope revealed that the concentration of microorganisms is found in the system (Fig. 7) therefore for the more optimum result if Brassica oleracea waste is introduced into the system, the retention time should longer (Rajendran et al. 2012).

The microbial diversity of anaerobic digesters depends on various factors such as pre-treatment type, granulation, seed inoculum, feedstock type, temperature, mixing speed, aeration, digester design, organic loading rate (OLR), hydraulic retention time (HRT) and solids retention time (SRT). The microbial granule resembles a filamentous consortium through which fluids and gases can flow slowly (Harirchi. et al. 2022).

Biogas production may benefit from the use of specialized microbial consortia (inocula) to increase biogas yields in anaerobic digesters. Inoculum can be provided from raw pig slurry by applying an innovative procedure (Marchetti, 2022). A unique and effective inoculum can be developed from wastewater treatment, thin stillage, and agricultural waste with different retention times (Liu et al. 2017). Other sources of inoculum can be sewage sludge (Bella and Rao, 2022). The ratio of inoculum and substrate should also be a consideration (Omawah et al. 2021). In this work the ratio of inoculum (cow dung) and substrate (waste Brassica oleracea) is 1:1. Other ratios should be introduced for future work. As another consideration, the inoculum can also be prepared from solid-state anaerobic digestion for the substrate from empty fruit bunches, using recycling solid-anaerobic digested sludge and liquid-anaerobic digested sludge (Suksong et al. 2019). The more complex method of preparing inoculum is by using rumen fluid. A flexible oral stomach tube with a metal strainer was inserted into the rumen, and the content was collected by suction (Sohail et al. 2022). Malaysia and Indonesia have been countries that provided various palm oil products for more than the last decade with production approaching 85% of the world's palm oil (Papilo et al. 2022; Mahlia et al. 2001; Jayed et al. 2011). Anaerobic digestion for palm oil mill effluent (POME) is widely known for its potential in biogas production and can be used as inoculum with cattle manure (Saidu et al. 2013). In this work, the waste of Brassica oleracea just adds to the existing cattle dung systems without any concern for the affectivity of additional inoculum from the previous research. Therefore future work is addressed for finding suitable inoculum to enhance the performance of processing waste of Brassica oleracea into cattle dung in continuous anaerobic digestion.

Besides the addition of inoculum, another important process i.e. acclimatization is not yet applied in this work due to the limitation of time and experience in this field. An example of acclimatization over a long period is the acclimatization of anaerobic sludge which is carried out using a mesophilic process that is stirred continuously by feeding food waste and cow manure. It was found that there was a continuous increase in enzymes during the acclimatization process over a long period, which caused the microbes to become stable and produce 13 times more methane compared to the initial conditions without acclimatization (Bella and Rao, 2022; Xinga et al., 2020). The acclimatization even can introduce other types of microorganisms that are not related to established methanogenic bacteria in the system (Wang et al. 2021). It is suggested acclimatization of the methanogenic bacteria in this work should experience acclimatization with the addition of waste *Brassica oleracea* to enhance the performance of the aerobic digester in producing higher CH_4 content in the biogas.

The government provides funding for those interested in voluntarily using biogas. This biogas program targets households, small community groups such as farmer groups, and communities around forests. Funding is also supported by foreign development aid and from non-governmental bodies (Budiman, 2021).

From this viewpoint, the result of this research can be used as a consideration during the implementation of government programs.

CONCLUSION

It can be concluded that for continuous anaerobic digester system with capacity 200 liter, that is fed with a slurry of water and cattle dung (50%:50%) and slurry of water and Brassica oleracea (50%:50%) interspersed, the CH4 content is in the range of 22-60 % with average value 36.8, The Carbon dioxide content in the biogas having lowest value at 33%, highest at 68% and average 44.3%. The pH of slurry inside an anaerobic digester is found in the range 6.6-7.6 with average value. 7.0. The addition of *Brassica oleracea* puts the pH in the range of about neutral for all 30 days which indicates the acidogenesis process did not occur and process hydrolysis is washed out. The temperature inside a continuous anaerobic digester is in the range 30^{o}C- 37^{o}C and average 33.6^{o}C which is still in the range of mesophilic condition. For the note, the ambient temperature outside the digester, lowest30^{o}C, Highest 35oC and average 32.2^{o} C . It is suggested that the retention time should be longer and pretreatment of the waste of *Brassica oleracea* should be suggested. Another concern for future work is the acclimatization of methanogenic bacteria due to the addition of *Brassica oleracea* waste should be conducted for better results.

RECOMMENDATION

In this work, the waste of *Brassica oleracea* just adds to the existing cattle dung systems without any concern for the affectivity of additional inoculum from the previous research. Therefore recommendation for future work is addressed for finding suitable inoculum to enhance the performance of processing waste of *Brassica oleracea* into cattle dung in continuous anaerobic digestion. Acclimatization is not yet applied in this work due to the limitation of time and experience in this field. It is suggested acclimatization of the methanogenic bacteria in this work should experience acclimatization with the addition of waste *Brassica oleracea* to enhance the performance of the aerobic digester in producing higher CH4 content in the biogas. The government provides funding for those interested in voluntarily using biogas. This biogas program targets households, small community groups such as farmer groups, and communities around forests. Funding is also supported by foreign development aid and from non-governmental bodies.

From this viewpoint, the result of this research can be used as recommendations during the implementation of government programs.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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