

Biogas Production from Improvised Anaerobic Digester Using
Vegetable Waste and Horse Dung

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Biogas Generation from Vegetable Waste and Horse Dung through Improvised Anaerobic Digester

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ABSTRACT

Biogas significantly reduces the environment's vast supply of animal manure and food waste, which causes nitrogen and water pollution. Biogas is a sustainable fuel created when microorganisms decompose organic matter, such as food or animal waste, without oxygen, which is known as anaerobic digestion. This study considered vegetable waste (VW) and horse dung as substrates in producing biogas. The study aims to generate biogas in 34 kg of mixed vegetable waste and horse dung into two designs of experiments with different proportions and study how these proportions affect the amount of biogas produced within the period of 10 and 13 days. This study employed an experimental research design wherein data were collected through surveys, timely observations, and primarily through experiments. After ten days, the first experiment produced yellow with a little blue, while the second experiment produced blue with a little yellow. Likewise, after 13 days, the mixed waste consisting of 30% each of VW and Horse manure was fed into the digester (experiment 1) and lasted 3.22 minutes. In contrast, the mixed waste, consisting of 20% VW and 40% Horse dung, was fed into the digester (experiment 2) for 7.22 minutes. Furthermore, both experiments produced blue with a little bit of yellow. On water temperature, experiments 1 and 2 were able to boil 200 ml of water from 3°C to 5.20°C and 6.10°C, respectively. These results signify the effectiveness and efficiency of the chosen substrate in producing biogas. It is recommended that future research in the same field shall consider economy and comparison between different substrates. Also, to measure biogas's heat capacity and design a digester with catalyst and substrate mixer.

Keywords: *Substrate, sustainable fuel, methanogenic bacteria, biogasification*

INTRODUCTION

In the rapidly growing population of today, energy consumption is increasing at unforeseen rates. Although using renewable energy sources including hydropower, geothermal, solar, wind, and biomass, the Philippines still faces an oncoming energy crisis since the Malampaya natural gas fields, which presently provide 30% of Luzon's energy needs, are predicted to run out by 2024. The generation of renewable and sustainable energy sources is the best response to the nation's energy needs. It would be ideal if newly created renewable energy had no adverse environmental effects.

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There is no denying the benefits of producing renewable energy from locally and easily accessible materials, which also lowers the cost of doing so.

It is very interesting to know that despite its small size, Santa Catalina, located at the west of the Heritage City of Vigan, has managed to evolve as an important part of the province's economy. The small town of 9.68 sq. km. has been dubbed the "vegetable bowl of the north." The town is utilized for crop production, in addition to rice and corn, farmers plant vegetables such as onions, cabbage, cauliflower, sweet pepper, eggplant, beans, tomato, sweet potato, yam beans, mongo and peanuts in the town. Unfortunately, after the harvest, most vegetables produced end up as waste, causing environmental problems due to microbial degradation. Some produce is rejected at the farm gate by supermarkets due to stringent quality standards governing crop weight, size, shape, and appearance. As a result, large portions of crops are never harvested. Despite the fact that some rejected crops are used as animal feed, quality standards may divert food intended for human consumption to other uses. Some vegetable harvests are wasted due to spoilage posing a challenge to the country's food security and solid waste management. Vegetable waste is commonly disposed of in municipal landfills or dumping sites, resulting in environmental problems. They deteriorate quickly and emit a foul odor due to their nature and composition. Sta. Catalina being the Vegetable Bowl of the North, ordered the adaptation of the Solid Waste Management Act of 2000. This is to safeguard and maintain the local production of products and public health as well (Batara, 2019).

On the other hand, Vigan City is renowned for its amazing ambiance despite solid waste having grown to be a significant problem in many areas. It gained attention by becoming one of the Seven Wonder Cities of the World. Vigan offers a variety of endearing scenes that are worthy of being documented. It is not just the landscape which made it to the 7 Wonder Cities of the World but also because of the backbone of it, history (Zenrooms, 2022). It made a very big impact on the Biguenos and is still used as part of their daily life, one example is the Vigan Calesa. These Vigan Calesa are being rented by the tourists as well as the localites who want to enjoy a chilling ride from a horse. Little did they know that the smell of horse dung can cause a disease. It is a must that it is a safe place to visit not only for the tourist but also its localities thus the horse dung should be collected and disposed properly or it can be a source of renewable energy.

A waste management system can be used to solve waste and energy problems by converting waste into biogas. Biogas is a type of renewable energy as well as a clean source of energy that is produced by the decomposition of animal and plant wastes. It is made up of methane, carbon dioxide, and trace impurities such as hydrogen, hydrogen sulfide, and some nitrogen (Tanigawa, S. 2017). It is a technology that has been recognized as a suitable technology for improving energy access, waste management, and sanitation. The byproduct of the biogas generation process is

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enriched organic digestate, which is an excellent supplement to or replacement for chemical fertilizers. The fertilizer discharge from the digester can accelerate plant growth and disease resistance, whereas commercial fertilizers contain chemicals that are toxic and can cause food poisoning, among other things. The amount and type of material added to the system determines the amount and type of methane produced during anaerobic digestion of biologically degradable organic matter. Given the high moisture and organic content of vegetable wastes, biological treatments such as anaerobic digestion can treat them more effectively than other techniques such as incineration and composting.

Horse dung produced biogas yield with an average methane yield of 51% without co-digesting it with other wastes. Therefore, horse dung is a good substrate for biogas generation, and its use in biogas digesters can reduce greenhouse gas emissions into the atmosphere leading to climate change, (Mukumba et al., 2017). Truly the potential of a horse dung for biogas is very high considering its composition. As a result, VW and HD can be subjected to anaerobic digestion in a variety of ways for energy generation. It is also a simple and low-cost technology that promotes a circular economy.

Objectives of the Study

This study aimed to generate biogas from vegetable waste and horse dung through an Improvised Anaerobic Digester. It specifically determined how the proportions of 30% Horse Dung (HD), 30% Vegetable Waste (VW), and 15% Water (W), and the 40% HD, 20% VW, and 15% W affect the generation of biogas after 10 and 13 days, color and duration of flame, and ability to raise the temperature of 200 ml of water at 3 degree Celsius.

METHODOLOGY

Research Design

The experimental research design was used in the study. It was conducted at Nagbattedan, Sto. Domingo, Ilocos Sur. It utilized a 45-kg improvised Anaerobic Plastic digester with a height of 21.5 inches. Its container's lid was impaled with a 1/4-inch diameter for the outlet of biogas and the container's lid as the inlet for slurry. The impaled hole of the drum was sealed with silicone sealant to prevent biogas leakage into the ambient air. Figure 1 shows the plastic digester diagram based on the study of Bernard et al. (2020) which required the assembling of the containers' lid and hose connected to the storage. To assure that the digester is leak-free, the connections, hoses, and fittings were properly sealed considering durability, air tightness, availability of local materials and easy operation during the design process.

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There were two proportions of mixed substrate used in this study: the first proportion or experiment 1 contained 30% of HD and 30% VW, and the second proportion or experiment 2 had 40% HD and 20% VW. Tables 1 and 2 show the two proportions of the experiment.

Table 1 shows that a total of 75% by weight of wet mixed waste for Experiment 1 consists of 30% each of VW and HD and 15% water was fed into the digester. The remaining 25% weight served as spaced for the biogas generated.

Table 1

Composite of biomass used for the experiment 1 for the generation of biogas

Name of waste	Weight in percent
Horse dung	30
Vegetable Waste	30
Water	15
TOTAL	75

Table 2 shows the Experiment 2 mixed waste, consisting 20% of VW and 40% HD, was fed into the digester. The VW and HD portions of the mixed waste fed into the digester consisted of wet weight of waste, as indicated in Table 2. The remaining 25% weight will serve as spaced for the biogas generated.

Table 2

Composite of biomass used for the experiment 2 for production of biogas

Name of waste	Weight in percent
Horse dung	40
Vegetable Waste	20
Water	15
TOTAL	75

Data Gathering Procedure

The general flow of the experiment is from the construction of the digester, the selection of the location of the collection of the HD and VW, chopping and weighing of VW and HD based on the two experimental proportions, and settling of HD within 20 days. After which, the slurry was hand-mixed and placed in the digester. After 10 days,

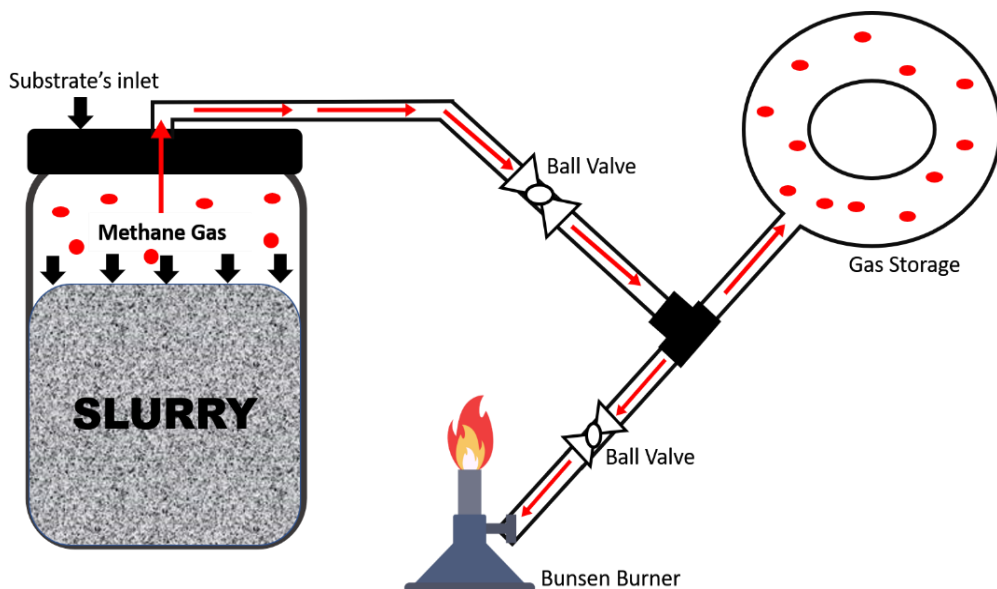
the amount of biogas produced was measured and extended again for another three days for the measurement of biogas produced. The following procedures were then specified:

1. Construction of Improvised Anaerobic Digester

Figure 1 shows the plastic digester diagram. The diagram's construction was adopted from Bernard et al. (2020). The diagram was made with minimal change in sizes, materials, number of plastic drums, and substrate used.

Figure 1

Diagram of anaerobic digester



2. Collection of substrates

Figure 2 shows the construction of an improvised anaerobic digester. A 45-kg anaerobic plastic digester has a height of 21.5 inches. The lid was impaled with a 1/4-inch diameter for the outlet of biogas, and the lid was as an inlet for slurry. The impaled hole of the drum was sealed with silicone sealant to prevent biogas leakage into the ambient air.

Figure 2

Construction of improvised anaerobic digester



Figure 3 shows the collection of VW at Sta. Catalina Ilocos Sur which may be of help to significantly reduce the waste produced which can cause numerous waste and pollution problems. The VW can be lessened through converting these waste into renewable biogas.

Figure 3

Collection of vegetable waste (VW) at Sta. Catalina, Ilocos Sur



3. Preparation of mixed waste

Figure 4 and 5 show the collection of substrates. VW for the present study were collected from farms and public market of Sta. Catalina, Ilocos Sur. The wastes were hand-picked, and with utmost care was taken to include several varieties of vegetable waste such as onion, cabbage, cauliflower, sweet pepper, eggplant, tomatoes, sweet potatoes, and beans.

Figures 5, 6, and 7 show the preparation of substrate. Slurry was obtained by mixing not more than one-day old horse dung and tap water to start the digestion for 20 days. Vegetable wastes were chopped into small pieces. Before feeding into the improvised anaerobic digester, the slurry was mixed by hand in a separate container for a few minutes. With this drum size, the slurry filled 75% of the digester's volume and allowed at least 11 inches of height for air circulation.

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Figure 4
Collection of horse dung (HD) in Vigan City



Figure 5
Preparation of slurry from Horse Dung. (a) Weighing horse dung (b) Adding water (c) Digestion of slurry



Figure 6
Chopping vegetable wastes



Figure 7

Mixing of substrates



Figure 7 shows how the substrate is mixed and fed into the digesters. In experiment 1, a slurry of 34 kg of mixed waste (consisting of 30% VW and 30% horse dung) is fed into the digester. In contrast, experiment 2 uses 40% VW and 20% HD. The mouth of each digester is then closed after feeding the mixed wastes. The researchers ensure that the gas storage or reservoir is not placed higher than the digester and leave it where it can receive sunlight. High temperatures can help the digester produce more biogas.

4. Measuring biogas produced

After ten days, the biogas flame color produced by each digester was measured. Moreover, after three days it was intended to observe whether or not the digesters were still generating biogas. An alcohol-based thermometer was used to measure the change in water temperatures when heating 200 ml of water at 3 degrees Celsius using a Bunsen burner to burn the biogas produced. Timers have also been used to measure the flame's duration.

RESULTS AND DISCUSSIONS

Generated Biogas

The biogas generated was tested after 10 and 13 days of anaerobic digestion of substrate using flame color test, duration of the flame, and its ability to increase the temperature of 200 mL water. number of days,

Figure 8

Result after ten days. (a) Experiment 1: and 30% VW and 30% HD (b) Experiment 2: 20% VW and 40% HD

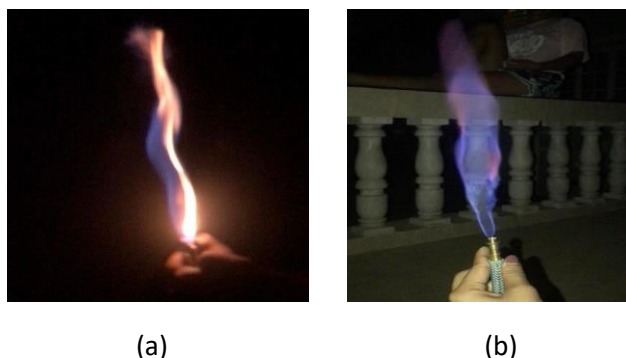


Table 3

Result of 10 days of anaerobic digestion of substrate

Experiment	Flame's Color
1	Yellow with a little bit of blue
2	Blue with a little bit of yellow

Table 3 shows the result after ten days of generating biogas. Only the flame color was observed and interpreted to test each experiment. The flame from burning biogas with the same proportion of horse dung and vegetable waste is more a yellowish color than blue compared to biogas from experiment 2, which has a higher proportion of horse dung than vegetable waste and produces a blue flame with a little bit of yellow. The result implies that the blue flame of the biogas generated from the 40% HD and 20% VW is hotter than the orange flame generated in the 30% of HD and 30% VW substrates.

Figure 8

Result after 13 days



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Table 4 shows the observation results after 13 days of biogas generation of each experiment along the duration and color of the flame produced, ability to raise the temperature of 200 ml of water using an alcohol-based thermometer. Experiment 1 produced a blue flame with a little bit of orange that lasted for 3.22 minutes, and the water temperature was 5.2 degree Celsius. Experiment 2 also produced blue with a little bit of orange flame but lasted for 7.22 minutes and the water temperature is 6.1-degree Celsius.

The result implied that the 40% HD and 20% VW substrate generated a longer and hotter flame, and higher temperature biogas than the 30% of HD and 30% VW substrate.

Table 4

Result of 13 days' anaerobic digestion of substrate

Experiment	Duration (mins.)	Water Temperature (°C)	Flame's Color
1	3.22	5.20	Blue with a little bit of yellow
2	7.22	6.10	Blue with a little bit of yellow

CONCLUSIONS

These solid wastes, such as horse dung, vegetables, and other organic wastes, are proven good biogas producers. Biogas is very common and helpful to most people, especially those in rural and agricultural communities. However, despite its importance, only some people are still interested in planning to use biogas. Here, procedures and things to consider in planning a biogas digester were employed. Characteristics of the substrates, such as vegetable waste, horse manure, cow dung, and food waste, in biogas production should be considered. Adding a catalyst, the limestone powder, to the substrate will make the decomposition of organic waste faster, resulting in biogas generation in a short period. Once the digester has been set up, biogas production will start immediately, so unnecessary movements toward the digester are not recommended. In designing an improvised digester, a hand pump for storage is recommended to avoid the inconsistency of its pressure and to avoid manually squeezing the storage/interior. The mixer inside the digester will make the substrate decompose evenly for a higher chance of generating more biogas. Please avoid burning the biogas at a place where it is adequately ventilated. The use of the digester is recommended in a closed area but not shut to enable it to remain running continuously, as strong winds can stop its flame quickly.

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RECOMMENDATIONS

Based on the findings and conclusions, measuring the energy released depending on the different proportions of substrates is recommended using the formula $Q = mc\Delta T$. To conduct further research on the comparison of different substrates and proportions, such as horse dung and cow dung, in which of the following can produce more biogas, which proportion can produce biogas longer, and which will last longer. Future research must also consider the cost-effectiveness of mixed vegetable waste and horse dung compared to other substrates. Vegetable waste and horse dung have an unpleasant odor that might be inhaled and contain bacteria; thus, using PPEs is recommended for health and safety. Using gas meters shall be considered for future researchers conducting the same study. The gas meters will give more accurate results regarding the gas the digester produces.

ETHICAL STATEMENT

The content presented in this study is the writers' unique report based on existing studies. No other publications are considering publishing the paper, and have never been submitted to any reputed journal or publisher. The study accurately and thoroughly covers the writers' investigation and analysis. The significant contributions of co-authors and co-researchers are duly acknowledged in the work. The findings are suitably positioned within the framework of earlier and ongoing studies. Every source is appropriately cited and disclosed. Text that is copied verbatim needs to be marked as such with quote marks and the appropriate citation. Each author shall accept public accountability for the paper's content, having directly and actively contributed to a significant portion of its creation.

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