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Evaluating the Efficacy of Using Cow Manure as an Inoculant on Biogas Production from Vegetable and Fruit Market Waste

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Abstract: Greenhouse gas emissions is a progressive issue in today's world, with factors such as scattered wastes that emits methane as one of the leading causes. Cow manure and scattered market wastes such as fruits and vegetables were used as substrates and inoculum in this study to mitigate the impact of methane secretion in the environment. Cow manure has shown exquisite signs of bacterial growth which aids in microbial activity, this study aims on evaluating its effects of adding it in the anaerobic process of mixed fruits and vegetables. A mixed method is applied in this study using mixed fruits and vegetables (MFV) as substrates and cow manure as the inoculum. Four ratios were created with varying proportions of cow manure and water to test the efficacy of adding it in the biogas production of mixed fruits and vegetables. The cow manure to MFV to water ratios were; 0:2:2, 1:2:1, 2:2:2, 4:2:4. The ratio that yielded the highest methane content was the 2:2:2 ratio, with 100% LEL (Lower explosive limit) and 2.5% methane, the lowest yield of methane came from the 0:2:2 ratio with 0% LEL and 0% methane, showing the effects of adding cow manure to the anaerobic process.

Keywords: *Anaerobic Process, Methane, Mixed Fruits and Vegetables, Cow Manure, Substrates, Inoculum, LEL%(Lower Explosive Limit), Greenhouse Gas Emissions, Microbial Activity.*

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I. INTRODUCTION

Approximately 30% of all vegetables produced in the Philippines are lost or wasted because of ineffective logistics (Tiu-Laurel, 2024). As food scarcity becomes increasingly severe, the paradox is that market food waste, including vegetables and fruits, has also surged, often left to decompose unattended. Fruit and vegetable waste in landfills quickly break down due to microorganisms, leading to the creation of toxic liquids and harmful greenhouse gases (GHG) (Zafar et al., 2023). Vegetable and fruit waste (VFW) are not just an economic or a social issue, for these wastes often contribute to one of the most rampant environmental issues, the greenhouse gas emissions, which is the leading cause of global warming. Rotten wastes such as fruits and vegetables can produce and excrete methane in our environment, methane being a compound that is more potent than carbon dioxide (CO2), causes bigger and harmful effects.

Scattered agricultural waste including livestock manure, commonly cow manure is one of the leading contributors of methane secretion in the environment, due to it being left out everywhere. It can also be a breeding ground for bacteria if not handled properly, bacteria and pathogens that can potentially harm those in contact. Studies have recorded several negative consequences from improperly disposing of agricultural waste including foul and noxious smell, the spread of diseases and illnesses carried by microorganisms, and pollution of land and water resources (Sihlangu et al., 2024). A circular approach is implemented when handling the disposal of such wastes, this approach is an alternative to the linear method that promotes immediate disposal of wastes and is considered ineffective, the circular approach proposed

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a step-in replacement for the last stage, namely reuse (Ankathi et al., 2024). Utilizing efficient and sustainable solutions to such dilemmas and applying a circular flow of agricultural disposal will lessen its implications and negative impacts not only on our environment but also on the population's health. Production expenses and overall process is reduced since biogas production will come from substances that are already present in the surroundings (Tasnim et al.,2024).

The MVMFCM treatment consisting of mixed fruit and vegetables as substrates and cow manure as an inoculant, presents promising results for biogas production, this is done in an oxygen free environment. Anaerobic digestion breaks down organic material from the loaded wastes inside the digester through microbial decomposition, it is done with the help of symbiotic microorganisms converting complex organic matter into a renewable energy source, the biogas (Garkoti, 2024). This process operates effectively at a controlled temperature range of 30-40°C (86-104°F) and involves both a substrate and an inoculant. In this context, cow manure is used, as it produces high levels of biogas yield. The use of cow manure not only boosts the efficiency of the digestion process but also provides a sustainable method for managing animal waste. In a study of Sihlangu et al., investigating gas composition in various organic waste, conducted in 2024, cow manure exhibited a Ph level of 8.8%, as for volatile solids, cow manure is recorded to have 84.77% of total volatile solids, these are the basis of organic matter present in feedstock, it also assesses overall biogas yield. In addition to that, cow manure also contained 25.06% carbon, 0.5% sulfur, 6.5% nitrogen, 30.6% carbohydrate, 10.25% protein, and 1.23% fat. These compounds are essential for the occurrence of methanogenic activities, microbial activities, and overall biogas production.

As for mixed fruit and vegetables, percentages of nitrogen, carbon, and sulfur are significantly lower as these substrates take time to rot, as opposed to cow manure. It is also because of the water content present in these crops that such elements are likely to be diluted. However, we're fighting for sustainability by addressing common issues in our community and environment, the ongoing surge of vegetable and fruit wastage in our local markets, which in turn causes great harm to our environment, a low percentage does not imply zero effects. Mixed fruits and vegetables alone cannot produce high amounts of biogas because of their dependency on factors that will speed up their rotting process, that is why an MVMFCM treatment is applied, using cow manure as an inoculate to speed up rotting on vegetable and fruit scraps and overall digestion period.

This study aims on assessing the effectiveness of the MVMFCM treatment in biogas production, however, feeding the anaerobic digesters, although an essential part of keeping the digestion process continuous, is not included in the study as the researcher's objectives is to only produce and test the efficacy of biogas production from the MVMFCM treatment, measure the methane content of three different ratios on a standardized period, and to assess biogas production on three ratios daily. The conversion of biowastes into usable products can provide numerous benefits to both the community and the environment. It offers a sustainable solution to waste management challenges, reduces landfill use, creates opportunities for local energy production, and lessens the dependence on fossil fuels. By examining these factors, the study seeks to contribute to more effective alternatives of providing solutions for managing wastes as well as practices that promotes sustainability.

II. LITERATURE REVIEW

The literature review highlights the effectiveness of a co digesting process, using cow manure as an inoculant and vegetable and fruit wastes as substrates though a batch system of anaerobic digestion in mesophilic conditions.

AD is composed of four stages: Hydrolysis, Acidogenesis, Acetogenesis, and methanogenesis, which can be done though mono or co digestion (Kunatsa & Xia, 2022). AD operates effectively in mesophilic temperatures as it prevents the loss of the microbial community inside the digester, and promotes stability of microbial processes to ensure an effective break down of organic matter, enabling more biogas yield. Aside from temperature, other factors such as pH levels and contents of lignocellulosic substances such as CM and VFW are also considered as biogas production highly depends on it (Pradeshwaran et al., 2024).

Cow manure is known as one of the most scattered organic waste in our environment, it is also rich in bacteria essential for AD processes, making it both an effective inoculum and substrate (Muhammad et al., 2021; Alkhrissat, 2024). Livestock manure normally produces 55-65% methane, which is useful in producing biogas, with it generating a biogas yield of 934.54 mL/gVS (Hamzah et al., 2023). In co digestion studies such as one by Oladejo et al. (2020), it was proven that mixing manure with other organic wastes increases biogas yield. Previous research done by Awosusi et al. (2021) found that a 3:1 ratio of kitchen waste to cow manure is the optimum, establishing basis for this study.

Vegetable and fruit waste (VFW) are produced in large quantities worldwide, impacting both the economy and the environment. Neto et al. (2021) reported that various parts of fruits and vegetable contains the following: Total Solids (TS) 7.4-17.9%, Volatile Solids/Total Solids (VS/TS) 83.4-95.3%, Carbon to Nitrogen Ratio (C: N) 15.2:18.9, pH 3.7-4.2, Methane Yield 0.16-0.35 m3/t, indicating a strong potential for anaerobic digestion. Patil et al. (2023) found that the overall VS/TS ratio is 93% supporting the suitability of the VFW as a substrate. However, VFW can lead to acidification and accumulation of volatile fatty acids (VFA) which may inhibit microbial activity (Azevedo et al., 2023).

The co digestion of CM and VFW addresses the low carbon ratio typically present in livestock manure, enhancing organic loading rates and balancing carbon levels to reduce ammonia toxicity inside the digester. Although reducing particle size of VFW can improve digestion rates, it can also lead to faster accumulation of VFA potentially affecting

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methanogenic growth. In a study conducted by Vian et al. (2024), a model was formulated to identify optimal particle size for enhanced methane yield. Simple carbohydrates present in VFW may also negatively affect digestion process, necessitating careful management (Chatterjee & Mazumder, 2020). Overall, applying a co digestion process using CM and VFW than stabilize methanogenic activity and boost methane production.

A. Research Objectives

➢ *General Objectives*

- To produce biogas and test the efficacy of produced biogas from cow manure and mixed fruit and vegetable wastes.

➢ *Specific Objectives*

- To Measure and compare the methane content of biogas produced every five days in a standardized digestion period of 20 days from four different ratios of the MVMFCM treatment:

✓ 1) 0:2:2 ratio: 0 kg cow manure, 2 kg MFV, 2L water
✓ 2) 1:2:1 ratio: 1 kg cow manure, 2 kg MFV, 1L water
✓ 3) 2:2:2 ratio: 2 kg cow manure, 2 kg MFV, 2L water
✓ 4) 4:2:4 ratio: 4 kg cow manure, 2 kg MFV, 4L water

- To Investigate how four different inoculum-to-substrate ratios influence the amount of Lower Explosive Limit (LEL) percentage that is present in the digester, determining the gas's flammability.

B. Hypothesis

➢ *H_o:*
Different substrate-to-inoculate ratios does not influence the amount of methane and LEL (Lower Explosive Limit) percentage, not affecting biogas production.

➢ *H_a:*
Different substrate-to-inoculate ratios influences the amount of methane and LEL (Lower Explosive Limit) percentage, affecting biogas production.

III. METHODOLOGY

This study utilizes a True-Experimental research design. In this design, independent variables are manipulated by the researchers, these variables are known as treatments, and the results of the treatments are what we call the dependent variables, these variables are observed in a randomized manner (DeCarlo et al. 2021). Fruit and vegetable wastes are not categorized based on properties and composition but are randomly picked from the local market. As for cow manure, the study does not consider the gender, health and the food intake of the cattle, but will only look if whether the manure is a byproduct from recent defecating of the animal, therefore true experimental design is an appropriate approach.

This study was conducted to identify the efficacy of using cow manure as an inoculant on biogas production from vegetable and fruit market waste, cow manure being the independent variable, and biogas from vegetable and fruit market wastes being the dependent variable, therefore an experimental approach would be the most appropriate method to use since it incorporates scientific methods, data collection from experimental processes, and as well as scientific analysis of collected data, making an experimental design the most suitable approach in increasing the study's success and fulfilling the study's objectives. Methods that were used in this study came from existing literatures as well as proportions and ratios, to further increase the success rate of biogas production. It involves making and designing an anaerobic digester, selecting and gathering cow manure base on the recency of the cow's defecating as well as collecting scattered and discarded vegetables from the local market bagsakan. A gas test was then conducted, performing a gas test is essential to distinguish and identify differences in methane concentration among different ratios to conclude an optimal ratio for biogas production as well as methane accumulation. This involved collaborating with San Carlos City Bioenergy Inc. and use the company's gas detector device to measure gas content particularly the presence of methane.

This experimental research, evaluating the efficacy of using cow manure as an inoculant for biogas production in mixed fruit and vegetable waste, took place in Brgy. 1 Gemilina Extension, San Carlos City, Negros Occidental in one of the researchers' resident house. The gas test was conducted at San Carlos City Bioenergy Inc. The research had been done since January 1, 2025 until data were fully collected on January 21, 2025.

This study utilizes various materials, including hose clippers, Teflon tape, cutter, valve, screw driver, lighter, tire, 8m pressurized hose, ball valve, container, t valve, air pump, scissor, containers cup, gloves, funnel, scoop, knife, bucket, sack and chopping board.

➢ *Preparation of Samples*
The gathered samples were grouped into four groups, labeled as Ratio A, B, C, and D. Each ratio had different proportions of Cow Manure and Water. With ratio D having the highest amount of cow manure, Ratio C having an equal amount, Ratio B having a lesser amount, and Ratio A having none. The different proportions of cow manure help in understanding if whether cow manure is an excellent inoculate for biogas production in mixed fruits and vegetables.

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Table 1 Preparation of Samples

Ratio label	Ratios	Amount of Cow Manure	Amount of MVF	Amount of Water
A	0:2:2	0	2kg	2L
B	1:2:1	1kg	2kg	1L
C	2:2:2	2kg	2kg	2L
D	4:2:4	4kg	2kg	4L

- *Standard Operating Procedures*

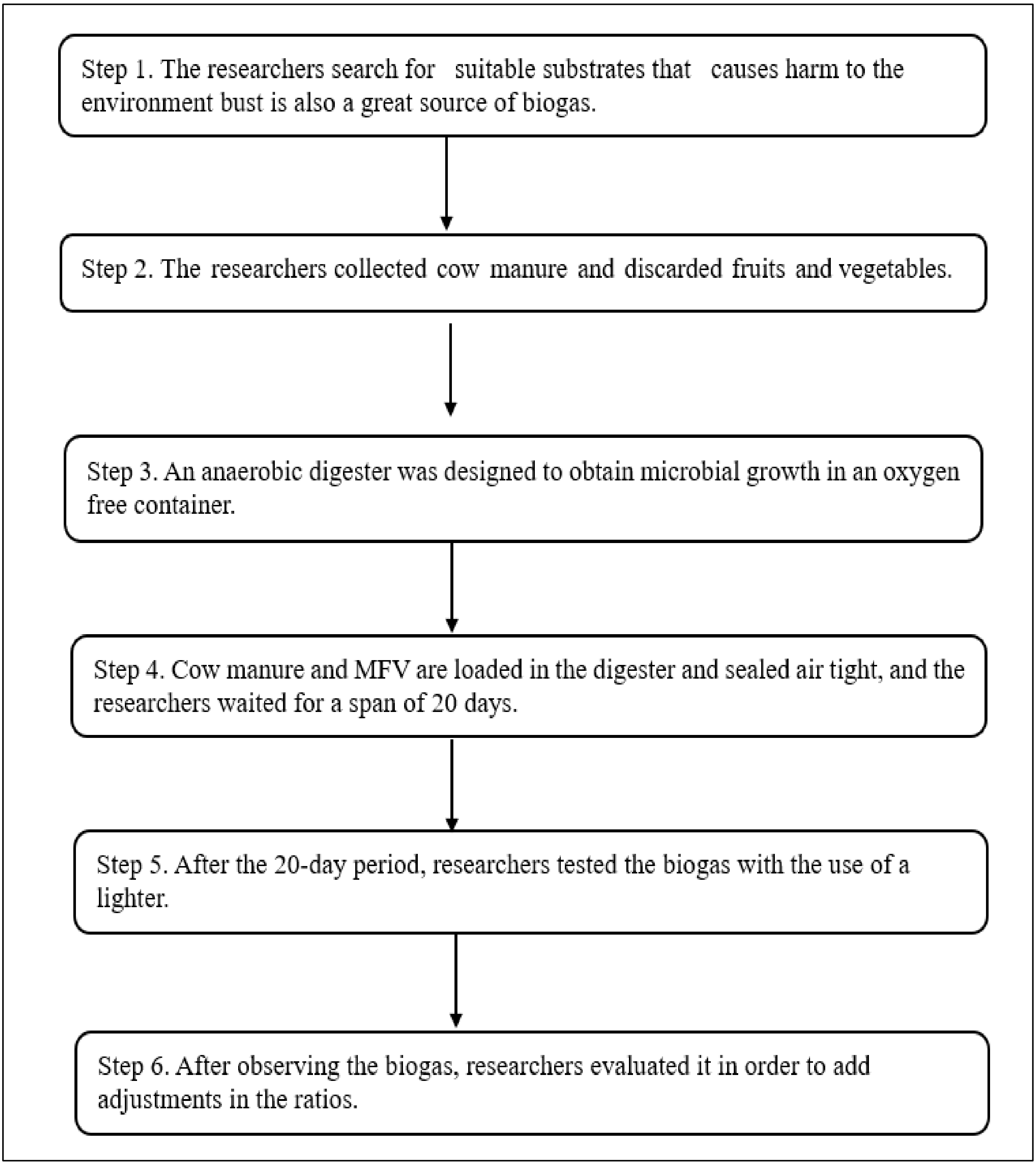

Fig 1 Standard Operating Procedures

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IV. RESULTS AND DISCUSSIONS

The findings of the study were relative to the objectives of the study, particularly in the general and specific goals wherein:

➢ *We Successfully Produced Biogas from four Different ratios of Cow Manure, Water, and Vegetable and Fruit Market Wastes.*

- We were able to measure and compare the four ratio's methane content every 5 days for a period of 20 days. This was done through a gas analyzer device wherein Lower Explosive Limit (LEL) identifies the methane content. 100% of LEL is equivalent to 5% of methane, the researchers converted the LEL% into methane% by multiplying it to 5%.

✓ For ratio 0:2:2, all throughout the four-gas test it didn't produce any measurable methane having only 0% of LEL.

✓ For ratio 1:2:2, it contained 3% of LEL and 0.15% of methane on the first 5 days, on the 10 day mark it contained 7% LEL and 0.35% Methane, on the 15th day 10% LEL and 0.5% methane was already present inside the digester and on the 20th day it produced and overall 18% LEL and 0.9 % methane.

✓ For ratio 2:2:2, it contained 16% of LEL and 0.8% of methane on the first 5 days, on the 10 day mark it contained 38% LEL and 1.9% Methane, on the 15th day 46% LEL and 2.3% methane was already present inside the digester and on the 20th day it produced an overall 50% LEL and 2.5 % methane.

✓ For ratio 4:2:4, it contained 10% of LEL and 0.5% of methane on the first 5 days, on the 10 day mark it contained 20% LEL and 1% Methane, on the 15th day 33% LEL and 1.65% methane was already present inside the digester and on the 20th day it produced an overall 34% LEL and 1.7 % methane.

- The four inoculum-to-substrate ratios influenced the amount of LEL% inside the digester, 2:2:2 having the highest flammability and ratio 0:2:2 having the lowest LEL%.

According to the data gathered which is shown in Table 1, it indicates that the ratio with equal portion of cow manure, mixed vegetables and fruits, and water had the highest percentage of Lower explosive limit and methane.

Table 2 Raw Data of LEL% and Methane%

Ratio	**5 Days**		**10 Days**		**15 Days**		**20 Days**	
A	0% LEL	0% METHANE	0% LEL	0% METHANE	0% LEL	0% METHANE	0% LEL	0% METHANE
B	3% LEL	0.15% METHANE	7% LEL	0.35% METHANE	10% LEL	0.5% METHANE	18% LEL	0.9% METHANE
C	16% LEL	0.8% METHANE	38% LEL	1.9% METHANE	46% LEL	2.3% METHANE	50% LEL	2.5% METHANE
D	10% LEL	0.5% METHANE	20% LEL	1% METHANE	33% LEL	1.65% METHANE	34% LEL	1.7% METHANE

One-way analysis of variance (ANOVA) was performed to determine the hypothesis of the study. The results showed that the P value of the given data is <.001, which implies that if the p-value goes lower than the alpha or significance level of (0.05) the null hypothesis can be rejected.

Therefore, in the results shown in figure 1, it indicates that there is a strong evidence of significant difference of methane content among the four ratios, containing statistical significance. To identify biogas production rate, a graph is shown in figure 2 and 3, wherein the ratio with equal portion had the highest rate of biogas production.

Table 3 Differences in Methane content among 4 ratios.

ANOVA - METHANE%

Cases	Sum of Squares	df	Mean Square	F	p
RATIO	8.154×10^{-4}	3	2.718×10^{-4}	10.829	< .001
Residuals	3.012×10^{-4}	12	2.510×10^{-5}		

Note. Type III Sum of Squares

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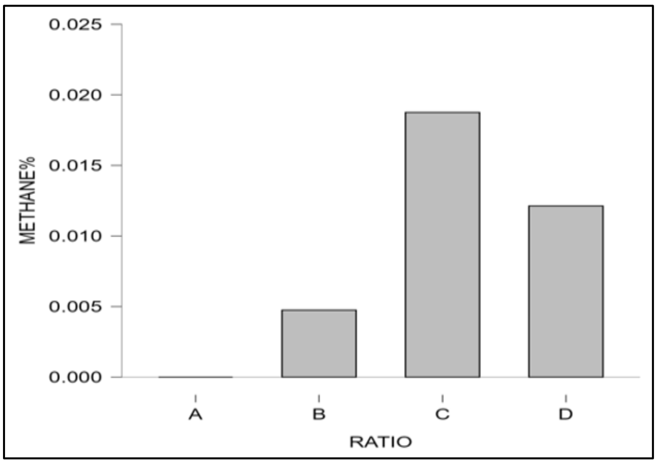

Fig 2 Bar Graph of Methane% across Four Ratios.

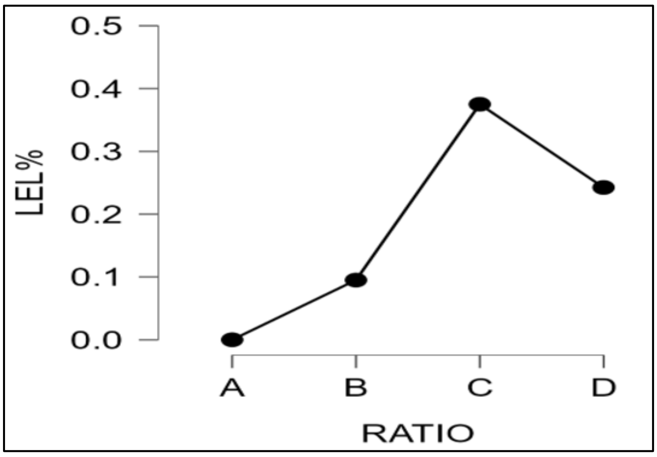

Fig 3 Graph of LEL % across four ratios.

V. CONCLUSION

➢ *Based on the Results and Findings Gathered the Following Conclusions were made:*

- Adding cow manure to mixed fruits and vegetables improves methane yield and biogas production.
- Using only mixed fruits and vegetables cannot produce any significant amount of biogas and methane,
- Having an equal amount of cow manure, mixed fruits and vegetables, and water increases methane yield and biogas production.
- There was a significant difference between the different ratios and their corresponding methane% in a 20-day digestion period.
- The null hypothesis is rejected because the p-value indicates strong difference going lower than the significance level of 0.05.
- Biogas produced from cow manure and mixed fruits and vegetables is an excellent and an eco-friendly alternative to traditional compressed gas.

RECOMMENDATION

The effectiveness of adding cow manure in biogas production from mixed fruits and vegetables was measured in this study as well as comparison of methane yield from the four ratios. Consequently, a series of suggestions are presented:

- Future researchers should design an anaerobic digester that enables a continuous process of digestion by making an opening for which bacterial food is added.
- Future researchers should create another ratio wherein only cow manure and water is in the digester to know it's methane yield.
- Future researchers should design a container wherein biogas is stored, since this study only used rubber tires.
- Future researchers should measure different gases inside the digester to further analyze gas content and further improve the study.
- Future researchers should use a grinder, since it takes a long time to chop mixed fruits and vegetables using a knife only.

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