International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Optimizing Methane Yield Production from Pig (Sus Scrofa Domesticus) Manure and Corn (Zea Mays) Silage Using A Batch Biodigester

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ABSTRACT
This study aimed to determine the optimization of methane production through co-digestion of pig manure (Sus scrofa domesticus) and corn silage (Zea mays) using a batch biodigester system. A quantitative approach was adopted to ensure that the results would objectively measure and compare the amount of methane production for each treatment ratio. A gas leak detector was utilized to measure the amount of methane production for each treatment ratio. Results showed that Treatments 2, 3, and 4, which were composed of 25% pig manure, 75% corn silage; 75% pig manure, 25% corn silage; and 100% pig manure, respectively, were able to produce a high concentration of 9,999 ppm of methane gas. Treatment 5 was able to produce 9,991 ppm, while Treatment 1 was able to produce 9,182 ppm. ANOVA and Tukey HSD were utilized to ensure that significant differences were present.

Keywords: Batch Biodigester, Co-digestion, Corn Silage, Methane Production, Pig Manure

INTRODUCTION
Methane (CH) emissions have become a major global problem because of its significant impact on climate change (Mar et al., 2022). Over a 100-year period, methane has 28 times greater global warmingpotential compared to carbon dioxide, and it is 84 times more powerful on a 20-year period (Vallero, 2019). This makes it a significant contributor of global warming and climate instability (Moumen et al., 2016).
In a global scale, operations of oil and gas release about 8-12% of the entire total methane emission, resulting around 8 million metric tons per year (Lauvaux et al., 2022). The top methane emitters are China (32.3%), the United States (17.5%), India (16.1%), and Russia (9.7%). Livestock accounts nearly half of

the country's CH_4 emissions from agriculture (Lohan et al., 2023). Rising methane emissions in the Philippines have become a growing concern, especially from paddy rice cultivation. This results to 36% of the country's total 1,026 Gg CH_4 emissions. Furthermore, oil and gas production release about 0.29 Tg/year (Ito et al., 2023). Ignoring these can overestimate seasonal totals by 22% (Weller et al., 2015).3

A recent study by Busilaoco et al. (2025) examined methane emissions from pig dung co-digested with Sargassum polycystum in Davao Oriental. Methane released from untreated livestock manure is apotent greenhouse gas. These emissions contribute significantly to climate change, highlighting the need for effective mitigation strategies.

While pig manure and corn silage are effective substrates for biogas production, there is limited local research on methane emissions and their environmental impacts in Mati City, Davao Oriental. This underscores the need for studies that address both biogas production and its local environmental effects. Biogas production from pig manure and corn silage provides sustainable energy. The efficiency of the substrates was analyzed in this study through their biogas yield and methane content using a batch biodigester. Methane leakage prevention must be focused on for production efficiency (Bakkaloglu et al., 2022).

This study is urgent due to the need for sustainable biogas to address economic and health risk (Mar et al., 2022). Harmful emissions affect both human and animal health, making alleviation important. By prioritizing alternatives to fossil fuels, reducing the rate of global warming is possible.

RESEARCH QUESTIONS

1. Is there a significant difference in methane yield among different concentrations of pig manure and corn silage?
2. What concentration ratio yields the highest biogas production while biogas production is measured at 3-day intervals during the 30-day anaerobic digestion of pig manure and corn silage in a batch biodigester?

METHODS

Study Design

This study employed a quantitative experimental research design integrating in Optimizing Methane Yield Production from Pig Manure and Corn Silage using a Batch Biodigester. The design aimed to determine whether the varying concentrations of the feedstock and substrate combination have a significant difference in methane yield that was measured at 3-day intervals during the 30-day anaerobic digestion in a batch biodigester.

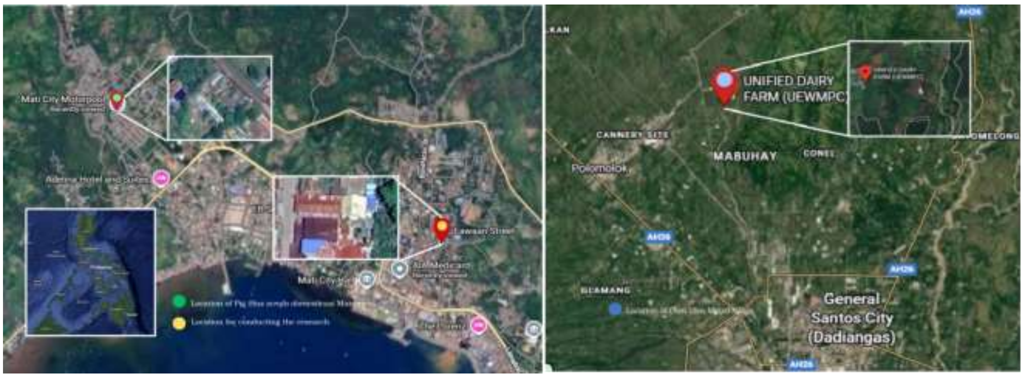

FIgure 1. Map of the Study Site

The construction of the batch biodigester in this study began with the utilization of five individual gas containers for five different substrates to assess the methane yield of each substrate, with each container serving as the main reactor vessel. Three holes were drilled into each drum to serve distinct functions, and each drum was fitted with a separate gas container: an inlet pipe hole at the top for loading the feedstock, an outlet pipe hole at the bottom for removing the digestate, and a gas outlet hole at the top for collecting the produced biogas (Obileke et al., 2020). The holes were securely sealed using epoxy clay and silicone sealant, which were carefully applied around each connector to ensure that the entire system was airtight and leak-proof.

Following the sealing process, PVC pipes were connected to the corresponding connectors. These included an inlet pipe that extended upward and fitted with a wide-mouthed funnel. The pipes were double-checked to ensure the prevention of leakage, thereby ensuring effective and hygienic loading of the substrates. The gas outlet pipe was then connected to a flexible hose, which linked to a gas storage tank used to collect the produced biogas (luno et al., 2024). All pipe joints were sealed with PVC glue and wrapped with PTFE tape. Any detected leakages were rectified by resealing or adjusting the fittings until the system became fully leak-proof. Furthermore, this setup was carefully constructed to provide a robust and secure environment conducive to optimizing methane yield from pig manure and corn silage feedstock during anaerobic digestion.

Figure 2. Experimental Setup of the Batch Biodigester (A, B)

The researchers prepared the substrates through a sequential process. Corn silage was chopped into 7 mm pieces, while pig manure was collected from the Livestock Auction Market in Mati City, Davao Oriental. The combined materials were weighed, after which the manure was filtered using a 1-5 mm stainless steel mesh sieve and finally mixed with water to create a slurry. Corn silage obtained from Unified Dairy Farm was chopped into 7 mm pieces and fermented for 8 weeks to maximize yield. Fresh pig manure from the Livestock Auction Market was sieved to ensure stable digestion.

Each biodigester consisted of 5 kg of substrate mixed with diluted wastewater. To ensure the stability in digestion, pig manure was filtered to remove large debris through the bulking technique. The manure was then filtered by a 1- 5mm stainless steel mesh sieve (Breza-Boruta et al., 2024). Both organic materials were used for the purpose to maintain its organic integrity (Busilaoco, 2025). The substrates were then individually mixed with water to a uniform slurry, which ensured proper consistency and facilitation of effective anaerobic digestion during the biogas production process. To ensure the proper distribution of nutrients and measurements are exact with the substrates, a weighing scale was used before mixing all the substrates together. The study evaluated five substrate treatments which varied proportions of pig manure and corn silage, with each treatment totaling 5kg. T1 used 50% pig manure (2.5kg) and 50% corn silage (2.5kg); T2 had 25% pig manure (1.25kg) and 75% corn silage (3.75kg);T3 contained 75% pig manure

(3.75kg) and 25% (1.25kg) corn silage; T4 was 100% pig manure (5kg). The formulations are designed to assess the impact of different substrate compositions on the target biogas production.

Figure 3. Substrate Preparation (A, B, C)

The loading and inoculation of the batch biodigester was commenced by carefully pouring the prepared mixture of pig manure and corn silage feedstock into every 5 drums through the inlet pipe, and using a funnel to facilitate smooth transfer and minimize spillage (Bong et al., 2017). The 5 individual drums were filled up to three-quarters of their total capacity, which intentionally left adequate headspace that allowed for biogas accumulation during anaerobic digestion. Once the substrates and inoculum were added, the biodigester lid was sealed tightly to maintain an airtight environment, and all valves were securely closed to prevent Each biodigester unit was clearly labeled with its specific substrate ratio that ensured accurate identification and monitoring throughout the experimental process.

Figure 4. Biodigester Loading

The study followed a 3-day interval biogas production measurement, monitored regularly throughout the 30-day digestion period. All measurements were carefully and systematically recorded for analysis, following strict and standardized procedures to ensure accuracy and reliability. Methane yield was measured using a HABOTEST® HT601 gas leak detector. The biogas samples were collected by manually squeezing the gas storage tank to release the gas through the faucet opening. A rubber balloon was securely attached to the faucet, and as biogas flowed into it, the balloon was immediately sealed to prevent gas leakage. The sealed balloon containing the biogas sample was then taken for measurement (Busilaoco, 2025). The unit of measurement utilized was parts per million, which determines the number of parts of a specific gas or substance for every one million parts of the total biogas (Soehartanto et al., 2025).

Data Analysis

The methane yield data from the five treatments (50% PM–50% CS, 25% PM–75% CS, 75% PM–25% CS, 100% PM, and 100% CS) were analyzed. Mean daily methane values were calculated during the 30-day experiment, with readings taken every 3 days. Duplicate readings from the HABOTEST Gas Leak Detector were averaged to reduce errors. Incomplete data were removed from the group averages.A one-way ANOVA was used to test if there were differences in methane yield among the treatments. When differences were found, Tukey HSD was applied to compare each treatment. The results showed that the mixed treatments (25% PM–75% CS, 75% PM–25% CS, and 100% PM) produced higher methane yields than the single-substrate treatments.

RESULTS

Table 1.2 represents the average mean of the daily methane production over 30 days. The highest methane yields came from T2 (25% Pig Manure + 75% Corn Silage), T3 (75% + 25%), and T4 (100% Pig Manure), each producing 99,990 ppm total and 9,999 ppm/day. In contrast, the 50-50 mix (T1) yielded much less, likely due to microbial inhibition, while pure Corn Silage (T5) was the least effective. Overall, the best strategy is to avoid a 50-50 ratio and instead use manure-heavy or manure-corn blends above 25% to maximize biogas production.

Table 1. Total and Mean Daily Biogas Production of Different Pig Manure – Corn Silage Ratios Over 10 Days

Treatment	Substrate Composition	Total Biogas Production (ppm)	Mean Daily Biogas Production (ppm/day)
T1	50% Pig Manure : 50% Corn Silage	57,211	5,721.10
T2	25% Pig Manure : 75% Corn Silage	**99,990**	**9,999.00**
T3	75% Pig Manure : 25% Corn Silage	**99,990**	**9,999.00**
T4	100% Pig Manure	**99,990**	**9,999.00**
T5	100% Corn Silage	49,143	4,914.30

Table 1.3 presents the results of the analysis of variations among the treatment groups. Since the p-value is less than 0.05, the null hypothesis is rejected, indicating that there is a statistically significant difference in methane yield among the five treatment groups despite the apparent differences in measured values.

Table 2. One-Way Analysis of Variance (ANOVA) for Biogas Production Across Different Substrate Ratio

Source of Variation	df	F	p
Between Groups	4	17.47	< .001

Source of Variation	df	F	p
Within Groups	145	—	—
Total	149	—	—

*Significant at 0.05

Table 1.4 represents that Tukey's Honestly Significant Difference (HSD) post hoc comparison evaluates pairwise differences in mean daily biogas production among the five treatment groups with varying ratios of pig manure (PM) and corn silage (CS): T1 (50% PM:50% CS), T2 (25% PM:75% CS), T3 (75% PM:25% CS), T4 (100% PM), and T5 (100% CS). The Tukey HSD post hoc test showed that T1 (50% Pig Manure + 50% Corn Silage) and T5 (100% Corn Silage) had no significant difference in mean biogas production (p = .886). Similarly, T2 (25% + 75%), T3 (75% + 25%), and T4 (100% Pig Manure) were statistically comparable (all p = 1.000). In contrast, all other treatment comparisons had p-values below 0.001, confirming real differences in production levels. Overall, the analysis indicates that while some feedstock combinations yield similar biogas output, others differ significantly, supporting the use of Tukey HSD for identifying specific group differences after ANOVA.

Table 3. Tukey Hoc Test Comparison of Mean Daily Biogas Production

Group 1	Group 2	Mean Difference (ppm)	p	Significant
T1 (50% PM : 50% CS)	T2 (25% PM : 75% CS)	4,277.90	< .001	Yes
T1 (50% PM : 50% CS)	T3 (75% PM : 25% CS)	4,277.90	< .001	Yes
T1 (50% PM : 50% CS)	T4 (100% PM)	4,277.90	< .001	Yes
T1 (50% PM : 50% CS)	T5 (100% CS)	−806.80	.886	No
T2 (25% PM : 75% CS)	T3 (75% PM : 25% CS)	0.00	1.000	No
T2 (25% PM : 75% CS)	T4 (100% PM)	0.00	1.000	No
T2 (25% PM : 75% CS)	T5 (100% CS)	−5,084.70	< .001	Yes
T3 (75% PM : 25% CS)	T4 (100% PM)	0.00	1.000	No
T3 (75% PM : 25% CS)	T5 (100% CS)	−5,084.70	< .001	Yes
T4 (100% PM)	T5 (100% CS)	−5,084.70	< .001	Yes

DISCUSSION

Effect of Substrate Composition and Methane Production

The results showed that substrate composition significantly affected methane production in the batch biodigester, with Treatments 2 (25% pig manure + 75% corn silage), 3 (75% pig manure + 25% corn silage), and 4 (100% pig manure) producing the highest methane concentration of 9,999 ppm, while Treatment 1 (50/50 mixture) and Treatment 5 (100% corn silage) produced slightly lower values of 9,182 ppm and 9,991 ppm, respectively (Fuksa et al., 2023). This demonstrates that combining pig manure and corn silage creates favorable conditions for methane-producing microbes, supporting previous studies showing that co-digestion enhances biogas yield by balancing nutrients, improving the carbon-to-nitrogen (C/N) ratio, and increasing microbial activity (Kupryaniuk et al., 2025; Wang et al., 2020). Optimal methane production is influenced by C/N ratio, with recommended ranges of 25–34, as higher or lower values may reduce microbial efficiency (Ma et al., 2020; Ning et al., 2019). Mixed substrates also promote more diverse and active methanogenic communities, enhancing methane generation compared to single substrates (Kong et al., 2019). However, variations in substrate composition, small-scale batch biodigester conditions, and environmental factors such as temperature, pH, and ammonia accumulation may limit methane yield compared to ideal commercial standards (Poulsen et al., 2016; Kadam et al., 2024).

Process Optimization and Practical Implications

Variations in process parameters such as substrate concentration and treatment ratios significantly influence methane yield in biodigester systems (Sidi Habib et al., 2024). In this study, mixed concentrations of pig manure and corn silage produced higher methane levels than single-substrate treatments, with T2 (25% pig manure, 75% corn silage) and T3 (75% pig manure, 25% corn silage) showing optimized performance due to balanced nutrients and enhanced microbial activity, while T4 (100% pig manure) also generated high methane concentrations because of its strong biodegradability (Gaworski et al., 2017). These treatments exceeded the detector limit of 9,999 ppm, confirming that co-digestion can improve microbial stability and methane production efficiency. The findings suggest that a strict 50:50 ratio is not always necessary, since higher pig manure concentrations can increase methane yield due to the presence of active methanogenic microorganisms (Mutungwazi et al., 2023), while corn silage contributes starches that support microbial growth (Fuksa et al., 2023). However, the lower output from the 50:50 mixture indicates that balanced carbon-to-nitrogen ratios alone do not guarantee optimal performance, as certain combinations may disrupt microbial processes through ammonia or volatile fatty acid accumulation (Zamanzadeh et al., 2017). Converting manure through biodigesters also reduces environmental impacts by transforming waste that would normally release methane into renewable energy for farms and communities (Ferreira et al., 2024). Although the study demonstrates the effectiveness of pig manure and corn silage co-digestion for improving methane production, limitations such as the 30-day batch digestion period, the use of a gas detector with a maximum limit of 9,999 ppm, and the absence of long-term and large-scale economic evaluation suggest that further research is needed to confirm performance under practical biogas plant conditions.

CONCLUSION

This study has been able to successfully identify the optimal combination of pig manure and corn silage substrates to enhance biogas production in a biodigester. The results clearly indicate that the composition of the substrate has a major influence on methane production. The optimal ratio of the substrate can be used to improve methane production and the efficiency of the biodigester.

The optimal methane production was obtained in Treatments 2 (25% pig manure and 75% corn silage), 3 (75% pig manure and 25% corn silage), and 4 (100% pig manure) at a concentration of 9,999 ppm, which is the highest biogas production. Treatment 1 (50% pig manure and 50% corn silage) also used a mixture of substrates, but the concentration of methane was lower at 9,182 ppm, while Treatment 5 (100% corn silage) produced 9,991 ppm. These results clearly indicate that different ratios of substrates result in the production of varying amounts of methane.

The results clearly indicate that co-digestion is an efficient process for the development of renewable energy resources in agricultural regions. The optimal ratio of the substrate in co-digestion not only results in the maximum production of methane but also helps in the efficient management of waste. Furthermore, it also helps in the reduction of greenhouse gases and makes the environment sustainable.

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