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Analysis of the Biogas Potential of Organic Waste from Keranggot Market and Household Waste in Cilegon City

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Abstract

Organic waste from traditional markets and households represents a significant environmental challenge but also offers potential as a renewable energy source through biogas production. This study aimed to evaluate the chemical composition and gas production potential of organic waste collected from Keranggot Market and household sources in Cilegon City. Proximate analysis was conducted to determine pH, moisture content, crude fiber, fat, carbohydrate, and protein levels, while total organic carbon (TOC) was measured using the dry combustion method. Gas composition (N_2, O_2, H_2, CH_4, and CO_2) was analyzed by gas chromatography after storage in drum containers for one and two weeks. The results showed that the waste samples had an acidic pH (5.18), high moisture content (3.00%), high crude fiber content (55.01%), moderate fat (6.76%) and protein levels (5.56%), and a total organic carbon content of 19.11%. The calculated C/N ratio was approximately 21.5, which falls within the optimal range for anaerobic digestion. Gas analysis revealed the presence of methane (1.10%) and carbon dioxide (6.71%) after two weeks of storage, confirming the onset of anaerobic decomposition. These findings suggest that organic waste from Keranggot Market and household sources in Cilegon City has potential as a feedstock for biogas production, although pretreatment may be required to overcome the high lignocellulosic content.

Keywords: *Biogas, organic waste, ration C/N*

1 Introduction

The growing population and economic activity in Cilegon City have led to an increase in organic waste production, both from traditional markets and households. Keranggot Market, as one of the main markets in Cilegon, generates a significant amount of organic waste that is often not managed optimally [1]. Previous studies have shown that the organic waste from Kranggot Market is predominantly composed of vegetable scraps, fruits, and other food residues, which have high potential for reuse, particularly in the production of renewable energy such as biogas [2].

Efforts to manage organic waste at Kranggot Market still face various challenges, such as poorly integrated waste management systems, a lack of waste processing facilities, and low awareness among vendors and the community about the importance of organic waste reutilization. Most of the waste still ends up in the final disposal site (landfill), which poses a risk of environmental pollution and contributes to increased greenhouse gas emissions due to anaerobic decomposition processes at the landfill [3].

On the other hand, the demand for sustainable energy sources continues to rise due to the depletion of fossil fuel reserves and increasing awareness of the environmental impacts of their use [4]. One potential solution that can be implemented is the utilization of organic waste as raw material for biogas production [5]. Biogas is an environmentally friendly and renewable alternative energy source that offers dual benefits: reducing the volume of waste while simultaneously generating energy that can be used for household needs and small-scale industries [6].

This study aims to analyze the potential of waste from Kranggot Market and household waste

as raw materials for biogas production. By understanding the composition and organic content of the waste, this research will evaluate the effectiveness of waste to biogas conversion and its longterm economic benefits. Furthermore, the study is expected to provide recommendations for more optimal organic waste management strategies for Kranggot Market and the surrounding community, thereby supporting the implementation of sustainable renewable energy and reducing negative environmental impacts.

2 Method

2.1 Chemical material

Distilled water, H_2SO_4 (pro analysis grade), NaOH, n-hexane, HCl (pro analysis grade), KI, $Na_2S_2O_3$, Luff-Schoorl solution, phenolphthalein (PP), potassium sulfate, mercuric oxide.

2.2 Sample collection and preparation

The sampling of organic waste was conducted at Keranggot Market and from household waste in Cilegon City. A total of 4 kg of organic waste was collected from Keranggot Market, while another 4 kg was obtained from household sources. The collected samples were subsequently mixed and cut into small pieces.

2.2 Fermentation procces

Fermentation was conducted in airtight drums. The samples were introduced into the drums and incubated for 14 days under anaerobic conditions. Upon completion of the fermentation period, the generated gas was collected and subsequently analyzed using Gas Chromatography (GC).

2.3 pH determination

A 1 g portion of the dried waste sample was weighed and placed into a 100 mL beaker, followed by the addition of 100 mL of distilled water. The mixture was stirred until homogeneous. The pH meter electrode was immersed into the sample solution and allowed to stabilize before recording the pH value [7].

2.4 Water content determination

The empty crucible was weighed and recorded as W0. Approximately 2 g of the dried waste sample was placed into the crucible, weighed, and recorded as W1 (crucible + initial sample). The crucible containing the sample was then dried in an oven at 105°C for 24 hours or until a constant weight was achieved. After cooling in a desiccator for 15 minutes, the crucible was reweighed and recorded as W2 (crucible + dried sample) [8].

2.5 Crude fiber analysis

A 1 g sample was weighed and recorded as W1, then placed into a 250 mL beaker and added with 100 mL of 0.30 N H_2SO_4. The mixture was shaken until homogeneous, then heated and boiled for 30 minutes. After cooling, the mixture was filtered using Whatman No. 41 filter paper. The residue was rinsed with hot distilled water (±300 mL), transferred into a beaker, and the filter paper was washed with 0.30 N NaOH solution (±100 mL), heated, and boiled again for 30 minutes. The Whatman No. 41 filter paper was dried in an oven at 105 °C for 1 hour, weighed, and labeled with an identification code. The filtrate was refiltered using the same filter paper, and the residue was rinsed with hot distilled water (±300 mL) followed by the addition of 25 mL acetone. The filter paper together with the residue was folded and placed into a pre-weighed porcelain crucible. The crucible was then dried in an oven at 105 °C for 8 hours, cooled in a desiccator for ±15 minutes, and weighed (W2). The crucible containing the sample was placed in a furnace at 600 °C for 4 hours. After the furnace was turned off, the sample was left inside for approximately 4 hours. The sample was then cooled in a desiccator and weighed (W3) [9].

2.6 Fat content analysis

A 10 g sample was weighed (W), wrapped in filter paper, and tied in a hanging position. The sample was placed into a Soxhlet apparatus and connected to a boiling flask of known weight (W1). A volume of 250 mL hexane was added into the flask. Extraction was carried out for 1 hour or until the solvent became clear. The boiling flask containing the extract was then dried in an oven at 105 °C until the odor of hexane disappeared. The flask was subsequently cooled in a desiccator and reweighed (W2) [10].

2.7 Determination of carbohydrate content

A 5 g sample was weighed and placed into a 250 mL ground-glass Erlenmeyer flask. The sample was added with 25 mL of 3% HCl and refluxed for 1 hour. After cooling, the solution was

neutralized using 30% NaOH with phenolphthalein (PP) as indicator, followed by the addition of a small amount of 3% acetic acid until the solution was slightly acidic. The solution was then transferred into a 500 mL volumetric flask, diluted to the mark, and filtered. A 10 mL aliquot of the filtrate was pipetted into a 500 mL Erlenmeyer flask, followed by the addition of 25 mL Luff-Schoorl solution, 15 mL distilled water, and several boiling chips. The mixture was heated to boiling and refluxed for 30 minutes (counted from the onset of boiling). After cooling, 25 mL of 20% KI and 25 mL of 25% H_2SO_4 were slowly added. The solution was immediately titrated with 0.1 N sodium thiosulfate solution using starch as an indicator until the endpoint was reached. A blank determination was carried out using the same procedure. The reducing sugar content was calculated based on the difference in titration volumes between the sample and the blank according to the Luff-Schoorl method [11].

2.8 Determination of protein content

A total of 2.00 g portion of the ground sample was weighed and placed into a Kjeldahl flask. Subsequently, 7.5 g of potassium sulfate, 0.35 g of Cu, and 1.5 mL of concentrated sulfuric acid were added. The mixture was heated in a fume hood until the fumes ceased, then heating was continued until the solution became clear. Heating was maintained for approximately 30 minutes, after which it was stopped and the solution was allowed to cool. Then, 100 mL of distilled water was added into the Kjeldahl flask. The flask was immediately connected to a distillation apparatus, heated slowly until the two liquid layers mixed, and then more rapidly until boiling commenced. The distillate was collected in an Erlenmeyer flask containing 50 mL of 0.1 N standard HCl solution and 5 drops of 0.1% methyl red indicator. Distillation was stopped after approximately 75 mL of distillate had been obtained. The excess unreacted 0.1 N HCl was titrated with 0.1 N standard NaOH solution until the color changed from red to yellow. A blank determination was carried out using the same procedure [12].

2.9 Nitrogen, Hydrogen, oxygen and methane determination

The analysis of nitrogen, hydrogen, oksigen and methane gas was carried out using gas chromatography (GC) Shimadzu type 2030, with detector FID, sampling method GSV, quantification approach of external standard, carrier gas helium (He), initial 80 deg C hold 13 minutes, rate 20 deg C/min untuil 220 deg C hold 5 min and detector type TCD. The concentrations of nitrogen, oksigen, hydrogen and methane gas produced were measured in percentage (%).

2.10 *Total organic carbon (TOC)*

Total organic carbon (TOC) was determined using the dry combustion method with a TOC analyzer. Dried and homogenized organic waste samples (≈50 mg) were weighed into a quartz boat and combusted at high temperature under an oxygen flow with a catalyst. The TOC content was expressed as the percentage of carbon on a dry weight basis.

3 Result and Discussion

The organic waste samples from Keranggot Market consisted of vegetable residues from the vendors, while the household waste samples consisted of vegetables and food scraps. The proximate analysis of organic waste samples collected from Keranggot Market and household waste in Cilegon City is presented in Table 1.

Table 1 Proximate analysis result of organic waste sample

Parameters	Result
pH	5.18±0.01
Water content (%)	3.003±0.025
Crude fiber content (%)	55.013±0.015
Fat content (%)	6.763±0.021
Carbohydrate content (%)	5.570±0.02
Protein content (%)	5.563±0.015

The pH value of the sample was 5.18 ± 0.005, indicating that the waste matrix tends to be acidic. Such acidity is commonly associated with the decomposition of organic matter, particularly due to the presence of organic acids produced during microbial activity [13].

The water content was relatively low at 3.003 ± 0.025%, suggesting that the samples had undergone partial drying or that the materials contained were predominantly solid in nature. Low moisture content can influence microbial activity during biodegradation processes and may affect the efficiency of biogas production [14].

The crude fiber content was found to be significantly high at 55.013 ± 0.015%, which reflects the predominance of lignocellulosic

materials in the waste, such as vegetable residues, fruit peels, and other fibrous components. A high fiber fraction generally indicates resistance to microbial degradation, as lignin and cellulose are more recalcitrant compared to simple carbohydrates [15].

The fat content of the sample was 6.763 ± 0.021%. This moderate fat level suggests the presence of lipid-rich residues, possibly derived from household food waste. Fats can contribute to higher calorific value; however, excessive fat content may inhibit microbial fermentation due to the accumulation of long-chain fatty acids.

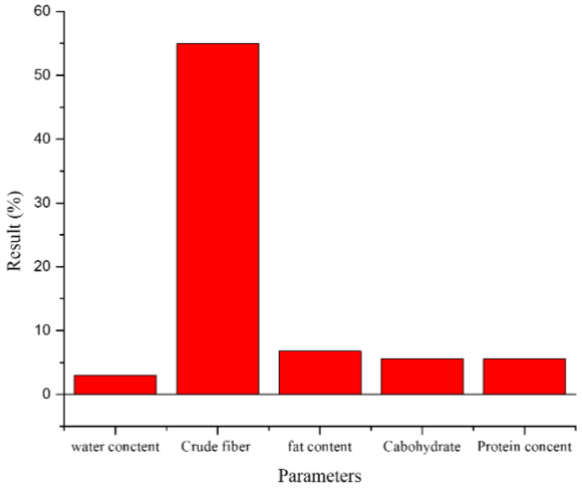

Figure 1 The water, crude fiber, fat, carbohydrate and protein content of sample

The carbohydrate content was relatively low at 5.570 ± 0.020%. Carbohydrates are generally more easily degraded by microorganisms, contributing to faster energy release during the decomposition process. The low carbohydrate fraction in this study indicates that the majority of easily degradable substrates may have already been consumed or decomposed prior to sampling.

Similarly, the protein content was 5.563 ± 0.015%, which is considered moderate for organic waste. Proteins provide a source of nitrogen for microbial growth; however, during degradation, they can also lead to the release of ammonia, potentially affecting the pH balance in anaerobic digestion systems [16].

Based on Figure 1, the proximate composition indicates that the organic waste samples were dominated by fibrous components with relatively low levels of carbohydrates and proteins. This composition suggests that pretreatment methods such as size reduction, hydrolysis, or microbial inoculation may be required to enhance biodegradability and improve biogas production efficiency [17].

The concentrations of nitrogen, oxygen, and hydrogen were determined after the samples had been stored in a drum container for one week, whereas the concentrations of methane and carbon dioxide were determined after two weeks of storage. The chromatogram of oxygen, hydrogen, and nitrogen concentrations is presented in Figure 2, while the chromatogram of methane and carbon dioxide is presented in Figure 3.

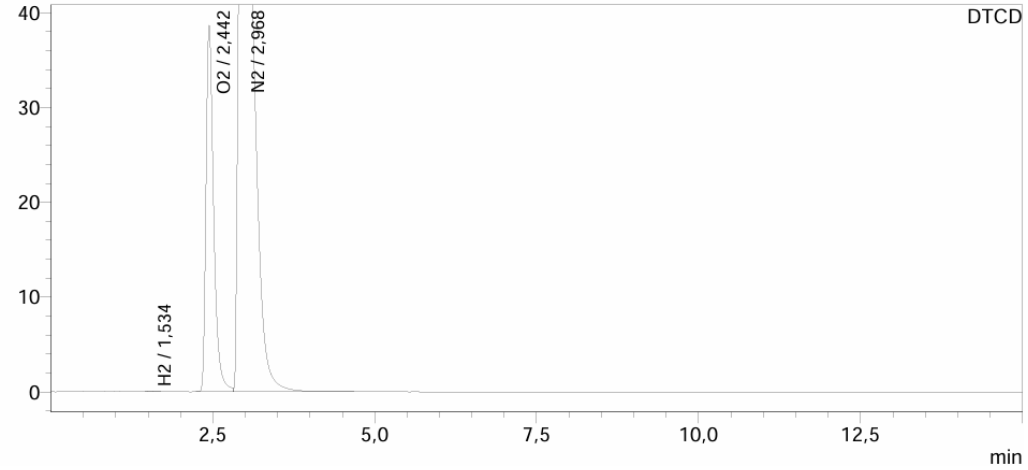

Figure 2 Chromatogram of H_2, O_2, and N_2 using GC analysis

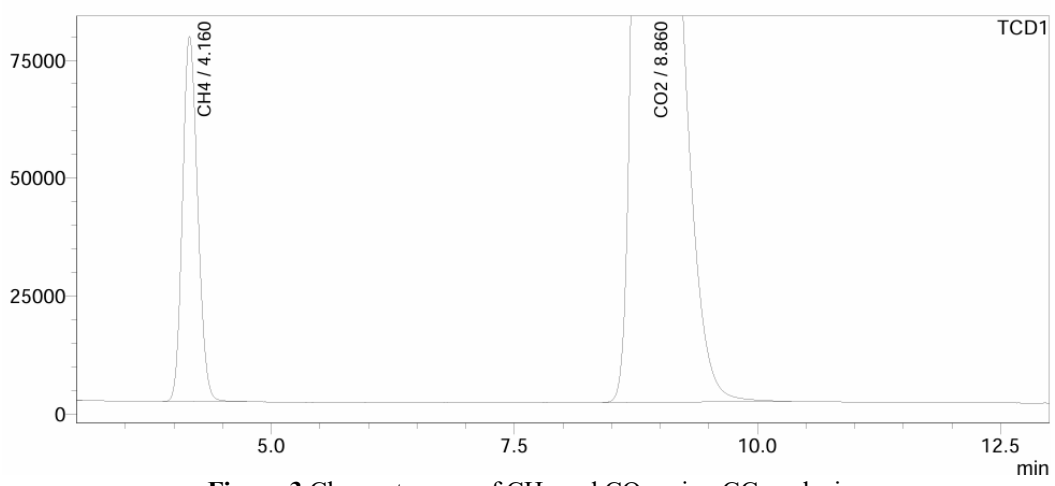

Figure 3 Chromatogram of CH_4 and CO_2 using GC analysis

Table 2 The composition of H_2, O_2, N_2, CH_4 and CO_2 using GC analysis

Name	Retention time	Area	Concentration (%)	Height
H_2	1.534	114	0.001	17
O_2	2.442	318930	16.284	38634
N_2	2.968	1124338	76.905	72914
CH_4	4.160	840456	1.102	77405
CO_2	8.860	7153575	6.708	280641

The gas composition analysis of organic waste samples from Keranggot Market and household sources in Cilegon City is presented in Table 2. The concentrations of nitrogen, oxygen, and hydrogen were measured after one week of storage, while methane and carbon dioxide were analyzed after two weeks of storage.

Nitrogen was found to be the dominant component, with a concentration of 76.905%, indicating that the headspace of the drum was primarily composed of inert nitrogen gas. This high proportion suggests limited anaerobic activity during the early stages of storage, as nitrogen typically remains unreactive under such conditions [18]. Oxygen was detected at a concentration of 16.284%, which shows that the system was not yet fully anaerobic during the first week. The presence of oxygen indicates that aerobic microbial activity may have initially dominated the decomposition process. Hydrogen was present only in trace amounts (0.001%), suggesting minimal hydrogen-producing microbial activity or rapid consumption of hydrogen by methanogens during the early phase.

After two weeks, methane and carbon dioxide were detected at 1.102% and 6.708%, respectively. The presence of methane confirms that anaerobic conditions had begun to establish, enabling methanogenic microorganisms to metabolize organic matter. However, the relatively low methane concentration indicates that methanogenesis was still in its early stages, likely due to the high fiber content of the waste, which slows down microbial degradation. Carbon dioxide was detected at a higher concentration compared to methane, which is typical during the initial anaerobic digestion process, as CO_2 is produced more rapidly through the breakdown of carbohydrates, proteins, and lipids before methane production becomes dominant [19].

Overall, the gas profile suggests that the decomposition of organic waste from both market and household sources was in the transition phase from aerobic to anaerobic conditions. The high nitrogen and oxygen levels after one week, combined with the later appearance of methane and carbon dioxide, reflect a gradual shift in microbial activity [20]. These findings imply that extending the incubation period and optimizing anaerobic conditions could enhance methane production, thereby improving the potential of organic waste as a biogas feedstock.

The measurement of total organic carbon (TOC) using a TOC analyzer showed that the organic waste samples from Keranggot Market and household sources in Cilegon City contained 19.11% total carbon. This value falls within the range commonly reported in previous studies, which indicated that the total carbon content of organic waste samples is typically between 18–20% [21].

The consistency of the obtained results with earlier findings suggests that the organic waste analyzed in this study has a comparable composition to similar types of municipal and market-derived organic waste. The relatively high carbon content highlights the potential of this substrate as a source of energy in anaerobic digestion processes, as well as its possible application in composting, where carbon availability plays a crucial role in the carbon-to-nitrogen (C/N) balance required for effective microbial activity.

The carbon-to-nitrogen (C/N) ratio of the organic waste samples from Keranggot Market and household sources in Cilegon City was calculated to be approximately 21.5. This value was obtained from a total carbon content of 19.11% and a nitrogen content of 0.89%, the latter being derived from the protein content (5.563%) using a conversion factor of 6.25.

A C/N ratio in the range of 20–30 is generally considered favorable for microbial decomposition, as it provides a balanced supply of carbon as an energy source and nitrogen as a nutrient for microbial growth. The ratio observed in this study indicates that the organic waste has a suitable composition for biodegradation and can potentially support efficient microbial activity in composting or anaerobic digestion processes.

Compared with the ideal C/N ratio for biogas production, which is typically between 20 and 30, the value of 21.5 falls within the optimal range. This suggests that the organic waste mixture does not require significant adjustment of carbon or nitrogen inputs to improve microbial activity. However, it should be noted that the high crude fiber content (55.01%) may slow down the overall degradation rate despite the favorable C/N ratio, as lignocellulosic components are more resistant to microbial breakdown.

Overall, the C/N ratio obtained in this study confirms that the combination of organic waste from market and household sources in Cilegon has potential as a raw material for renewable energy production through anaerobic digestion, as well as for use in composting applications.

4 Conclusion

The results of this study indicate that organic waste derived from Keranggot Market and household sources in Cilegon City has potential as a raw material for biogas production. The proximate analysis showed a total carbon content of 19.11% with a C/N ratio of approximately 21.5, which falls within the optimal range (20–30) for anaerobic digestion. Gas analysis further confirmed the onset of anaerobic activity, with detectable concentrations of methane (1.10%) and carbon dioxide (6.71%) after two weeks of storage. Although the high crude fiber content (55.01%) may limit the rate of biodegradation, the overall chemical composition supports the feasibility of microbial conversion into biogas. Therefore, organic waste from market and household sources in Cilegon can be considered a promising feedstock for renewable energy generation through biogas technology.

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