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Presenter

Evaluation of Biogas Production from Vegetable Waste (Cabbage, Long Beans and Kale) : Utilization and Challenges

in **Tidar International Conference on Engineering and Applied Science (TICEAS)** organized by The Office of Research, Community Service, and Educational Quality Assurance, Universitas Tidar on October 15th, 2022

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Evaluation of Biogas Production from Vegetable Waste (Cabbage, Long Beans and Kale) : Utilization and Challenges

Abstract. Vegetable waste is often found in traditional markets in the city of Yogyakarta. This vegetable waste is often thrown away without further processing, even though vegetables are organic waste that can potentially be processed into products that are beneficial to society, biogas. Biogas is a renewable fuel made from organic waste and can be classified as an environmentally friendly fuel. Biogas production in this study uses vegetable waste in the form of cabbage, kale, and long beans. The vegetable as substrate mixed with cow dung as co-digestion and water. The mixture is then left to ferment for 30 days. The biogas produced was analyzed for volume, methane content, Chemical Oxygen Demand (COD), and acidity (pH). From the observations, cabbage produces more gas volume. The highest methane content is found in kale, 0,5221 ml CH_4/gr COD, this value is still very far from the minimum standard. COD and pH values are measured to see the quality of the waste that can meet environmental standards. This study will discuss what causes vegetable waste not meet the standards for methane content in biogas and how to increase methane levels in biogas from vegetable waste. In addition, it also discussed alternative biological processing of vegetable waste so that it can be utilized by the community and not wasted.

INTRODUCTION

Vegetable waste is one of the problems faced by the Yogyakarta provincial government. Yogyakarta Province has 32 traditional markets that operate every day to improve the community's economy. Based on the regulation of the Mayor of Yogyakarta Number 13 of 2010 states that traditional market activities have the advantage of being able to improve the people's economy through buying and selling activities, but the drawback of traditional markets is that they can indirectly produce organic and inorganic waste. This waste can be in the form of leftover vegetables, fruits, and other food ingredients that are easily decomposed.

Several efforts have been made to overcome vegetable waste that is produced daily in traditional markets in Yogyakarta, one of which is to process the waste into biogas. Vegetable waste is organic waste which is one of the substrates that has the potential to be converted into biogas [1]. Biogas is renewable energy in the form of gas produced from materials or organic waste. Organic waste is waste that comes from living things such as plant waste, human waste, to food waste. The waste includes biomass which can be converted into biogas. Compared to traditional processing methods, such as landfilling, incineration, and composting, anaerobic digestion (AD) is a promising technology in terms of food waste treatment [2].

Anaerobic digestion is a process without involving oxygen that has several stages, the first stage is hydrolysis where there is a simplification of complex organic content, after that there is an acidogenesis stage which produces volatile fatty acids (FVA), the last and most decisive stage is the methanogenesis stage, biogas production process [3]. There are several factors that affect the biogas produced in the AD process, including the process conditions (temperature, pH), C/N ratio and micronutrients (trace elements). If we review the temperature factor, two types of conditions that commonly occur in AD are thermophilic (55-70 ^{o}C) and mesophilic (37 ^{o}C) conditions. Both of these conditions have their advantages and disadvantages, in thermophilic conditions, the reaction rate is faster but the process stability is less due to the acidic conditions in the process. This acidic condition causes the production of biogas to be hampered, because the microorganisms involved in the methanogenesis process can be optimal in neutral conditions, not under acidic conditions. Meanwhile, in mesophilic conditions, the stability and richness of bacteria are higher than in thermophilic and do not require a lot of energy to maintain the temperature, but the methane produced in this process is lower [4]. Based on the temperature conditions that have been described previously, the thermophilic conditions are more suitable for use in the acidogenesis process because the reaction speed in producing acid is quite high. Mesophilic conditions are more suitable for methanogenic processes [5].

Another factor that greatly influences AD is the pH value. Research shows that increasing the pH from 4 to 7 causes positive growth of microorganisms, the increase in the growth of microorganisms in the AD process [6]. The acidogenesis stage has an optimum pH between 5.5-6.5. At a pH value of 7, methanogenesis has an optimum pH condition even though the required pH range for methanogenesis is between 6.5-8.2. At the optimum pH, methanogenesis shows positive growth of microorganisms, if the pH value is below 6.5 and above 8.2 there will be a decrease in the growth of methanogenic microorganisms [7] [8]. The ratio between carbon and nitrogen also affects AD. Research states that carbon can be digested by microorganisms in AD, which is 25-30 faster than nitrogen. So for a good process, the C/N ratio must be maintained at 20-30:1 [9]. To achieve the desired C/N ratio, carbon-rich co-digestion is usually added. In addition to increasing the C/N ratio, the addition of co-digestion is also beneficial in increasing biogas yield [10]. The presence of trace elements is proven to stabilize the process and stimulate biogas production [11]. Several studies have proven that the addition of trace elements, either one type of trace element or a combination of several trace elements has many positive impacts, provided the amount meets the required conditions, so as not to inhibit [12].

This study will explain the comparison of 3 types of vegetable waste (cabbage, long beans and kale) which are processed using AD. The purpose of this study was to determine the types of vegetables that can produce biogas with the highest methane content and to evaluate the challenges that arise from the results of this research. The results of this study are expected to be useful as an alternative review in processing vegetable waste in traditional markets and household scales.

METHODS

This research was conducted in the Chemical Engineering Laboratory of Ahmad Dahlan University. The materials used in this study are substrates in the form of vegetable waste cabbage, long beans and kale. Vegetable waste is obtained from traditional markets in Yogyakarta. Each substrate is fed into a different reactor. Added cow dung as co-digestion. As well as water as a diluent during the substrate mixing and co-digestion process. Table 1 contains details of the composition of each reactor.

TABLE 1. Substrate composition in reactor

reactor	Types of vegetables	Vegetables (g)	Cow dung (ml)	Water (ml)
1	Cabbage	200	100	200
2	Long Beans	200	100	200
3	Kale	200	100	200

The equipment used in this study is an anaerobic reactor and a gasometer to measure the volume of biogas produced. The principle and calculation of gas volume using a liquid displacement gasometer. A partially closed cylinder is submerged in an open box container containing a liquid. Gas is fed into the column through the valve at the bottom of the column which is connected to the digester, when gas enters the column there will be a decrease in liquid in the column that moves to an open box container. The volume of gas is calculated by measuring the change in the height of the liquid in the column and container [13]. Figure 1 is a picture of the anaerobic reactor and gasometer.

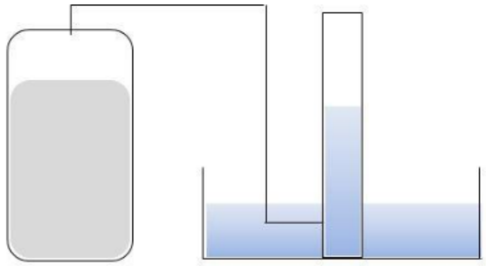

FIGURE 1. Illustration of anaerobic reactor and gasometer

The first step is to reduce the size of the substrate using a chopper and mix all the ingredients (vegetable waste, cow dung and water) into an anaerobic reactor. After all the ingredients are mixed, the reactor is closed and it is ensured that there are no leaks in the reactor or gasometer (figure 2). There are no special settings on the conditions of temperature, pH and pressure in the reactor. So the condition of the reactor is what it is. The measurement of biogas volume is carried out periodically, while the measurement of methane and Chemical oxygen demand (COD) is only at a certain time. As at the beginning and end of the process for measuring COD and pH. Fermentation is carried out in batches within 30 days.

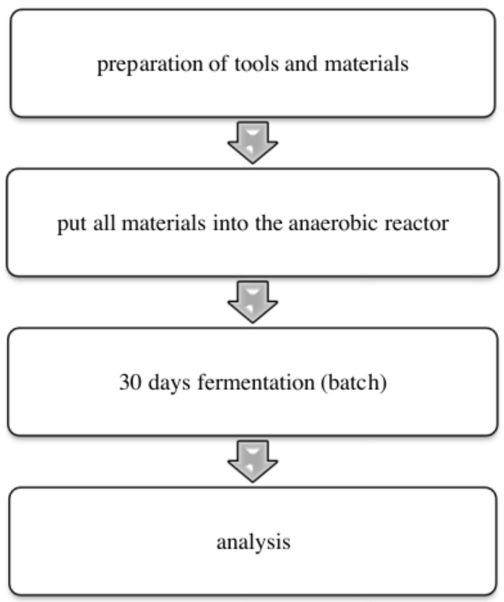

FIGURE 2. Research process

RESULTS AND DISCUSSION

The results of the study showed that kale produced the largest volume of biogas, 5510 ml (figure 3). This amount is five times higher than the volume of biogas produced by long beans and almost 4 times higher than cabbage. When we talk about the volume of biogas produced, of course, many factors affect this result. The addition of cow dung as co-digestion has a good effect on the anaerobic digestion process because it can increase the C/N ratio, although we did not directly check the C/N ratio in the three anaerobic reactors. However, the addition of cow dung has a positive effect on the biogas produced, this result is relevant to the study using some animal manure as co-digestion in anaerobic digestion of food and vegetable waste. The results of the study stated that the addition of manure can increase biogas production by about 50% [14]. The addition of cow dung was carried out for all reactors with the same amount, but produced different biogas results. This is of course due to the characteristics of the vegetable waste. We know that each vegetable has a different nutritional content.

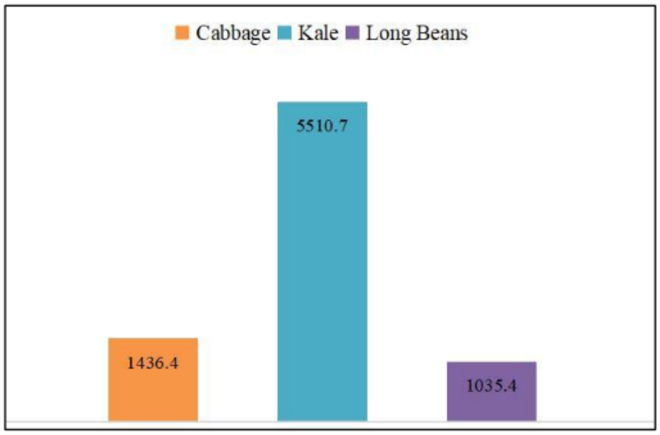

FIGURE 3. Methane volume (ml)

In table 2, the contents of cabbage, kale and long beans are presented. From these data, it can be seen that kale contains iron and calcium. This amount is in the range of values required by anaerobic digestion to increase biogas yield [3]. Other studies have also stated that the presence of iron in the right amount can increase process stability and stimulate methane production [15]. Calcium also has a positive effect in reducing the lag phase and increasing biogas production, the maximum concentration of calcium is 3 g/l, at amounts above 3 g/l calcium can inhibit the process [16]. But keep in mind that the addition of nutrients or trace elements in AD has a different effect on each substrate. In this study, the trace element content is already present on the substrate itself, so there is no need to add more.

TABLE 2. Vegetables nutrition, value per 100 g
Source: USDA National Nutrient database [17]

	Cabbage	Kale	Long beans
Energy	25 kcal	35 Kcal	47 Kcal
Carbohydrates	5.8 g	4.42 g	8.35 g
Protein	1.3 g	2.92 g	2.8 g
Total Fat	0.1 g	1.49 g	0.40 g
Sodium	18 mg	53 mg	4 mg
Potassium	170 mg	348 mg	240 mg
Calcium	40 mg	254 mg	50 mg
Copper	na	0.053 mg	0.048 g
Iron	0.47 mg	1.60 mg	0.47 mg
Magnesium	12 mg	33 mg	44 mg
Manganese	0.160 mg	0.920 mg	0.205 mg
Phosphorus	26 mg	55 mg	59 mg
Selenium	na	0.9 g	1.5 g
Zinc	0.18 mg	0.39 mg	0.37 mg

To see the objectivity of biogas production, we can see in table 4, this result explains how much methane volume can be produced from each gram of degraded COD. The more volume of methane produced from each gram of COD, the better. In this case, kale still has the best results, which is for every gram of COD from degraded kale it will produce 0.5221 ml of methane. Keep in mind that the results presented are pure methane volumes, not biogas which still contains CO_2 . If we look at the overall results of the research, the biogas produced is still very far from the standard methane content it should have. This is due to several things. The first is the non-ideal process conditions, where the temperature during the fermentation process takes place below the mesophilic temperature, ranging from 23-25 ^{o}C. Certainly inhibits the performance of microorganisms. Next is the pH factor, the three reactors show a pH value below neutral, between 4.5 to 6. This indicates that there are still many intermediate products in the form of Volatile Fatty acids (VFA) that may accumulate in the reactor, causing methanogenic microorganisms have a heavy burden to convert into methane, considering pH conditions are not ideal for these microorganisms.

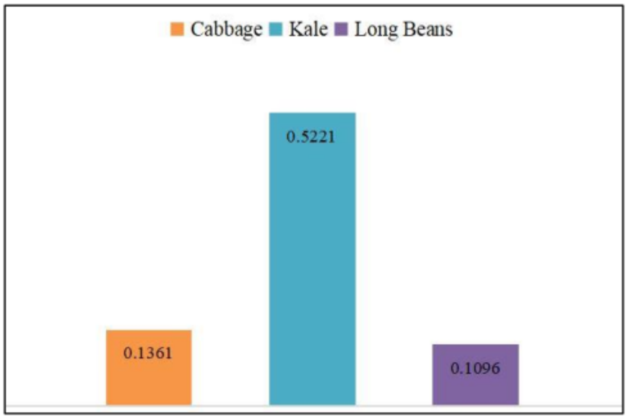

FIGURE 4. Methane volume (ml) / COD (gr)

Although the results obtained are still far from standard, we can still see some opportunities. If vegetable waste is combined and added with appropriate co-digestion, it is possible that the methane produced will be better. In addition, temperature and pH conditioning are also very important. If possible, it is necessary to review how to carry out anaerobic digestion using vegetable waste as a substrate which is divided into 2 stages, each for the process of acidogenesis and methanogenesis. Both can be conditioned according to their respective optimal conditions so as not to interfere with the performance of each of the microorganisms involved.

CONCLUSION

Based on the 3 types of vegetables tested, kale has more potential as a better biogas substrate than cabbage and long beans, but the methane content produced by vegetable waste is still below the methane standard required for combustion. Some opportunities that can be applied are adding co-digestion that is more suitable for the substrate to increase the C/N ratio and dividing the anaerobic process into 2 different stages, acidogenesis and methanogenesis, because the two stages have different characteristics of optimum conditions.

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