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Effects of Nutrients Ca and K on Anaerobic Digestion of Food Waste

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ABSTRACT

We often find food waste daily, especially on household and restaurant scales. Using food waste for helpful something, biogas is an alternative to reduce wasted waste and produce renewable energy. The anaerobic digestion process is a process that decomposes organic material into biogas with the help of microorganisms in conditions without oxygen. Adding nutrients in the anaerobic digestion process can positively affect biogas-producing microorganisms. One of the nutrients or nutrients studied this time is Ca and K. The provision of nutrient Ca has a positive effect, namely a significant increase in biogas production compared to without the addition of nutrients. However, adding K does not positively impact biogas production is inhibited. Excessive amounts of nutrient K can inhibit the process by inhibiting microorganisms in breaking down intermediate products into biogas. The largest volume of biogas produced for five days came from the reactor with the addition of nutrient Ca, which was 15072 cm^3, while the control reactor and reactor with the addition of nutrient K produced biogas of 1648.5 cm^3 and 15.7 cm^3. The addition of nutrient Ca increases biogas production more than nine times.

1. Introduction

Waste is still one of the most common problems found in people's lives, especially food waste. Food or food is a basic human need to survive. The higher the population growth, the more food waste produced also has the potential to continue to grow. Food waste originating from households is the main contributor to the accumulation of food waste. According to a study by Bappenas and several other institutions, Indonesia disposes of 23-48 million tons of food waste per year in the period 2000-2019, equivalent to 115-184 kilograms per capita per year. Processing food waste that is increasingly piling up is a big task for the entire community. In Indonesia, the processing of food waste has not received special treatment, even though if this problem is handled properly, it can produce something useful [1].

Food waste is organic waste. There are many ways to treat organic waste, but one method that has several advantages is the anaerobic digestion process. Anaerobic digestion is a biological process of organic material without oxygen [2]. The process occurs in the form of the digestion of organic material converted into methane gas or what we often refer to as biogas. The existence of this process not only treats waste but can also convert waste into an energy source.

The anaerobic digestion process results in biogas consisting of methane gas and carbon dioxide gas. The formation of methane gas through several stages of the process. The first stage is hydrolysis. In this process, the digestion of insoluble organic materials such as carbohydrates, fats, and proteins occurs. The second stage is the acidogenesis stage. At this stage, the digestion results of the previous stage (hydrolysis) in the form of amino acids, sugars, and peptides are converted into alcohol and fatty acids. Then the last is the methanogenesis stage, namely the process of forming methane gas and carbon dioxide [3].

The most sensitive microorganisms to interference (inhibition) are methanogenic bacteria whose job is to form methane gas so that the presence of inhibition will directly interfere with methane gas production [4]. Nutrients are divided into two, namely, micronutrients and macronutrients. The function of nutrients in the biogas formation process is to facilitate the growth of bacteria involved in the process so that more gas is obtained. Substrates with high organic material content can be decomposed properly using an anaerobic digestion process at a relatively low cost, but the methane produced is not yet optimal. Slow bacterial growth also impacts the volume of biogas produced and the length of residence time.

One of the methods used to optimize biogas production is by accelerating the growth of bacteria involved in the process. Living things need nutrients to grow better, as well as microorganisms in the anaerobic digestion process. Each nutrient has its influence on the process. The addition of different nutrients can produce different effects. The effect depends on the concentration of the given nutrient because if it is too high, it will interfere with the process. So it is necessary to study the literature to determine the appropriate concentration of nutrients to obtain optimal results.

This study seeks to increase biogas production from food waste processing by adding a nutrient to the process. The nutrients used are nutrients needed by microorganisms in relatively small amounts, often referred to as trace elements. The trace elements that will be used in this study are Ca and K. Adding these trace elements is expected to optimize the growth of microorganisms so that the biogas produced can increase. There is an optimal concentration of nutrients (trace elements) to produce methane gas which is also optimal; for Na, the optimum concentration is between 100-200 mg/L, for K of 400 mg/L, Ca of 200 mg/L, and Mg of 720 mg/L [4]. This study aimed to determine the appropriate trace element as a nutrient for microorganisms in the anaerobic digestion process of food waste in terms of the growth of microorganisms and biogas production.

2. Research Methodology

2.1. Materials

Food waste as the substrate used comes from household food waste with the composition specified in Table 1. The active digester effluent used is cow dung. The active effluent digester of cow dung was taken from the cattle ranch area of Arjawinangun village, Cirebon. Micronutrients/trace elements using Ca and K from $Ca(OH)_2$ and KCl.

The variables used in this study were the types of nutrients or traced elements, Ca and K. Both nutrients were also compared for their effects on the substrate without adding nutrients. Table 2 summarizes the variables used in this study. The reactor and gas meter used is shown in Figure 1.

Table 1. Composition of bacterial starter and food waste substrate (% volume)

Bacteria starter	
Cow dung	100%
Food waste substrate	
Water	40%
Rice	40%
Various vegetable	10%
fruits	5%
meat and bones	5%

Table 2. Composition of materials in the reactor

	Reactor with the addition of nutrient Ca	Reactor with the addition of nutrient K	Reactor without adding nutrients (control)
Substrate	Food waste	Food waste	Food waste
Co digestion	Cow dung	Cow dung	Cow dung
Nutrient	Ca	K	-
Residence time	5 days	5 days	5 days

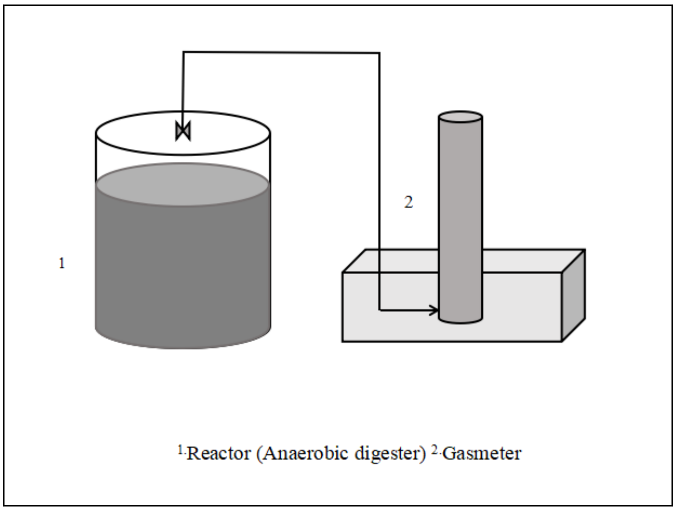

Fig. 1. Reactor and Gasmeter

2.2. Procedures

The food waste substrate and the active digester effluent of cow dung were fed into the reactor in a ratio of 3:1. Before the substrate is put into the reactor, physical pretreatment is carried out on the solid phase food waste substrate, reducing the particle size, by pulverizing it using a blender. The particle size is not made uniform considering the conditions at the time of application in the field do not allow for more detailed checks regarding the substrate size. Reducing the particle size of the substrate in the initial treatment before the anaerobic digestion process begins has been shown to increase the decrease in COD [5]. Esposito (2011) also stated that the larger the particle size, the lower the COD and the biogas production [6].

A Gasometer is a tool used to measure gas production from a connected reactor [7]. The experiment uses three types of reactors, the first is a control reactor, and the rest is a reactor with the addition of trace elements Ca and K. The control reactor is a reactor that does not add trace elements, the symbol (R-Control) is used. Meanwhile, R-Ca and R-K are reactors with added Ca and K, respectively.

The variables in this study were the types of trace elements, namely Ca and K, with adjusted levels. These two types of trace elements will be compared for their performance in increasing biogas production from food waste. In addition, the control reactor was used as a comparison without the addition of trace elements. Observation of gas volume is carried out every day.

The results of the anaerobic digestion process in the form of gas are measured using a series of tools called a gasometer. Gas measurements are carried out every day within the same time span.

3. Results and Discussion

The selection of pretreatment on the substrate affects the results of anaerobic digestion, so it is necessary to choose a pretreatment following the desired goal. The advantage of physical or mechanical pretreatment (size reduction) is that it is easy, simple to implement, and increases the final yield of the anaerobic digestion process in the form of COD removal and biogas production [8,9].

The anaerobic digestion process is a natural biological process when bacterial communities work together to obtain stable and regular fermentation through the assimilation, transformation, and digestion of organic matter contained in sewage and wastewater into biogas [10]. Anaerobic digestion processes can be carried out at mesophilic and thermophilic temperatures with a relatively neutral pH (not too acidic and not too alkaline).

Three anaerobic reactors observed the amount of gas (volume) produced daily. Table 2 contains the specifications of the three reactors operated: the control anaerobic reactor, the Ca anaerobic reactor, and the K anaerobic reactor. The biogas results are presented in Figure 2.

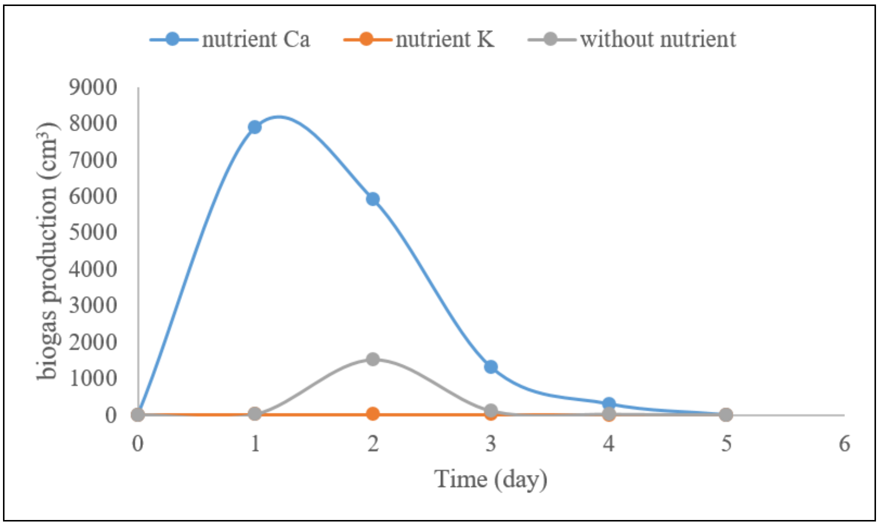

Fig. 2. Everyday biogas production

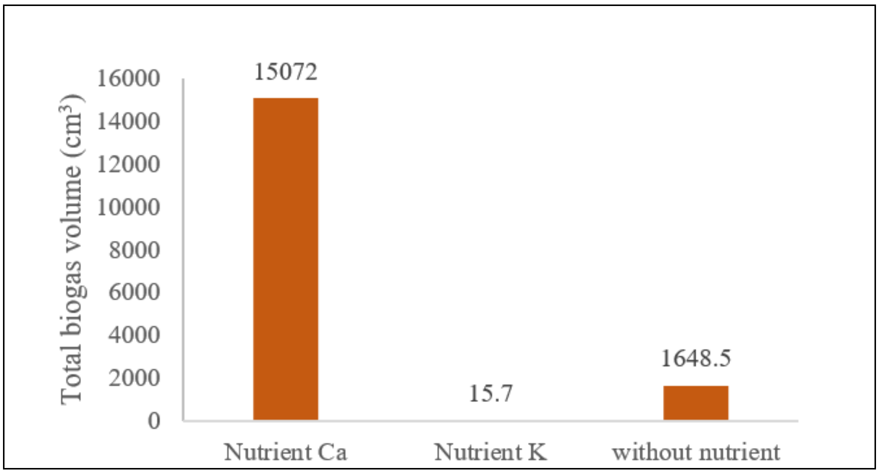

Fig. 3. Total biogas production

Biogas is immediately produced on the first day of fermentation due to the co-digestion incubation process for the previous three days. On the first and second days, the anaerobic process went well, as evidenced by the amount of biogas production, which was higher than the next day. Before the substrate is put into the anaerobic reactor, the starter bacteria in the form of cow dung are first incubated under anaerobic conditions so that the bacteria are active and ready to digest the given substrate.

Day 3 began to show a decrease in biogas production for the three reactors. The decrease in biogas produced could be caused by the decrease in the amount of substrate [11]. Food waste is waste with not too high organic material content so that the amount of substrate available for bacterial digestion is also only available in limited quantities. If the substrate is depleted, the bacteria will no longer find food to break down, so the activity of these bacteria is reduced to produce biogas.

When viewed from the total amount of biogas produced from the three anaerobic reactors (Figure 3), the anaerobic Ca reactor produced the highest amount of biogas. The control anaerobic reactor produces 1648 cm^3 of biogas. In the anaerobic K reactor, very little biogas is produced. This is because of the inhibition of K in methane-producing bacteria, so that the intermediate product in the anaerobic process cannot be properly converted into biogas. The dosage of nutrients for anaerobic digesters is essential to maintain their performance because the high metal concentrations are toxic for microorganism's growth [12]. The previous research reported the effect of K is weaker than the other metals on biogas production. It was reported that a low concentration (<400 mg/L) of K can enhance the production of biogas, while at a high concentration, K can be inhibitory because this condition causes potassium ions to enter passively, which can neutralize the membrane potential [13]. We can see the content of K and Ca in the composition of the substrate (in 100 grams) which is presented in Table 3. The table shows that the substrate also contains K and Ca. K content in the substrate is greater than the Ca content. The total amount of K in the substrate is high enough when we added, K nutrient of 200 mg/L into the anaerobic reactor resulted in a fairly high amount of K in the reactor. This causes toxicity in biogas production in the reactors.

Good biogas production in anaerobic Ca reactors indicates a positive effect of Ca cations which act as nutrients or trace elements. The Ca concentration given at the beginning of the process was following the previously studied amount of 200 mg/L [4]. It is not known exactly how much Ca concentration can harm the anaerobic decomposition process. Still, it is proven from this experiment that the concentration of Ca present in the substrate and added as much as 200 mg/L does not cause a negative effect, it increases biogas production positively. The function of nutrients in the biogas formation process is to facilitate the growth of bacteria involved in the process so that more gas will be obtained. Still, if the nutrients are inappropriate or excessive, then these nutrients will inhibit the process by inhibiting the bacteria in the anaerobic process. Further studies need to be carried out to see the effect of Ca and K on the anaerobic digestion process of food waste. The effect of nutrition on pure culture differs from that of mixed culture in terms of behavior. Also, it is quite difficult to determine the need for mixed cultures using complex substrates. Thus, it is necessary to determine the metal requirements based on certain complex substances [15].

Table 3. K and Ca in the composition of the substrate (in 100 grams) [14]

Substrate	K content in 100 gram substrate	Ca content in 100 gram substrate
Cooked rice	38 mg	25 mg
Chicken Meat	358.9 mg	14 mg
Vegetable (spinach)	456.4 mg	166 mg
Fruit (aple)	130 mg	6 mg
Water	0 mg	0 mg

4. Conclusion

Food waste has the potential to be processed into biogas by an anaerobic digestion process. The addition of nutrient Ca has a positive effect on biogas production. Still, the addition of nutrient K does not have a positive effect because the results are under the reactor without the addition of nutrients due to the inhibition of the methanogenic process. The largest volume of biogas produced for five days came from the reactor with the addition of nutrient Ca,15072 cm^3, while the control reactor and reactor with the addition of nutrient K produced biogas of 1648.5 cm^3 and 15.7 cm^3. The addition of nutrient Ca increases biogas production more than nine times.

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