



INFLUENCES OF MIXED COMPOSITION OF CHICKEN MANURE AND WATER HYACINTH (*Eichhornia crassipes*) AND ALKALI PRETREATMENT TO ENHANCE BIOGAS PRODUCTION ON ANAEROBIC DIGESTER

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ABSTRACT

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant species that considered as weeds, lead to accelerate eutrophication and sedimentation on the river. Water hyacinth has a potential to be used as a renewable energy source to produce biogas, because it has content of lignocellulose. Lignocellulose need to be pretreated to break down lignin to produce hemicellulose, cellulose and lignin. Chicken manure is added as a source of nutrients and microorganisms to degrade hemicellulose and cellulose to produced biogas. The purposes of this study were to determine the effect of pretreatment and composition of chicken manure and water hyacinth mixed to produce biogas volume. This study was used reactors with a capacity of 6 liters each. Research carried out by a batch process for 30 days. The research variables were the composition of water hyacinth and chicken manure, and pretreatment and without pretreatment of water hyacinth. The ratio of water hyacinth to chicken manure was 90:10; 70:30 and 50:50 (%w/w). The concentration of total solids of the mixture variation in this study was 10%. Pretreatment of water hyacinth was done by soaking NaOH 3% for 5 days at room temperature and then used as raw material. The results showed the highest production of biogas generated by a mixture of water hyacinth and chicken manure 70:30 (%w/w). The cumulative gas volume produced during 30 days was 439 mL. It is a slightly higher than the biogas produced in the same mixture without pretreatment which produced 366 ml biogas. A maximum methane concentration was 20% with pretreatment and 6% without pretreatment.

Keyword: biogas, chicken manure, pretreatment, total solid, water hyacinth.

1. INTRODUCTION

Biogas is gas produced from the decomposition of organic matter by anaerobic bacteria to produce methane (CH₄), carbon dioxide (CO₂), and other gases. Wastes with high moisture content, such as manure, food processing wastewater, and sewage sludge, are usually treated by liquid anaerobic digestion handles feedstocks with solid concentrations between 0.5% and 15% [1]. Dilution of organic material cannot increase the biodegradability of feedstock or the fundamental efficiency of the anaerobic digestion system [2]. Production of biogas through anaerobic process were influenced by several important factors, among which is the C/N ratio. The process would take place properly if the C/N ratio ranging between 17-30 [3; 4], where at this ratio availability of C as the carbon source and N as a nutrient source can be met. High concentrations of carbon and nitrogen will affect the balance ratio of C/N on the material which affects the activity of anaerobic bacteria [5]. Production of total ammonia nitrogen and volatile acid excess would hinder the process of formation of biogas [4].

Water hyacinth is composed of lignocellulose in the form of cellulose, hemicellulose and lignin. The high content of cellulose and hemicellulose has the potential to be used as an alternative fuel [6]. Utilization of water hyacinth as raw materials for biogas takes a long time, so lignocellulose need to break down prior to the formation of biogas. Pretreatment can be process by physical and chemical treatment. Chemical pretreatment can be performed by using acid and alkali, where pretreatment

with dilute NaOH extraction could be effectively removed lignin [7; 8]. NaOH pretreatment could reduce lignin content without affecting the other components, increasing the surface area, and can break the bonds between lignin and hemicellulose [7].

Chicken manure contained relatively higher concentrations of N, P and K in fresh manure, it is confirmed that this material provides a more readily available source of soluble nutrients [9]. Protein in chicken manure is a good source of nitrogen in the form of organic nitrogen or inorganic nitrogen. The content of C, N, P and K in chicken manure were 57.7; 8.57, 82.48 and 79.2 mg/g dry solid respectively [9]. Free nitrogen in biogas processing will form the compound ammonia (NH₄), which would lower the C/N ratio. Therefore, the addition of solids/cellulose containing carbon (C) in the form of water hyacinth can increase the content ratio of C/N on chicken manure to increase the production of biogas.

Substrate concentration is the important environmental and operational factors in biological processes [10]. Many studies have been conducted to determine the effect of the ratio of raw material composition. Substrate concentrations high enough at the beginning of the experiment can generate sufficient volatile organic acid as well, so it can be converted into biogas [4]. Due to the characteristics of each raw material that can be digested different from one to another, it is necessary to study the weight ratio of water hyacinth and chicken manure to produce optimum biogas. The purposes of this study were to determine the effect of pretreatment



and composition ratio of water hyacinth and chicken manure to produced optimum biogas volume.

2. MATERIALS AND METHODS

This study was used six reactors with a capacity of 6 liters each. Research carried out by a batch process

for 30 days. The research variables were the composition of water hyacinth and chicken manure, and pretreatment and without pretreatment of water hyacinth. The ratio of water hyacinth to chicken manure was described on Table-1.

Table-1. Research variables.

Treatment	Raw materials (% w/w)	Water hyacinth (gram)	Chicken manure (gram)	Reactor
Pretreatment	90:10	550	75	P(10)K90
	70:30	450	225	P(10)K70
	50:50	350	375	P(10)K50
Non pretreatment	90:10	550	75	T(10)K90
	70:30	450	225	T(10)K70
	50:50	350	375	T(10)K50

The concentration of total solids of the mixture in this study was 10%. Pretreatment of water hyacinth was carried out by soaking NaOH 3% for five (5) days at room temperature, modified Sun et al. research [7], which found optimum pretreatment NaOH 1,5% for six (6) days. After pretreatment, water hyacinth pH was neutralized by using H₂SO₄. Water hyacinth and chicken manure poured to reaktor, and then mixed with water until volume 5 Liters. Temperature and pH measured every day. Slurry stirred once a day by shaking the reactor. Volatile solid measured once every 5 days. Biogas volume measured by calculating increase water in the manometer. Measurement the methane concentration of the biogas using Gas Chromatography (GC) Hewlett Packard (HP-series 6890).

3. RESULTS AND DISCUSSIONS

3.1 Anaerobic digester operating conditions

3.1.1 C/N Ratio conditions

The initial of C/N value ratio have a range (19.10 - 34.58) as can be seen in Table-2. Refers to ideal conditions criteria of growth and activity microorganisms, all the reactors comply to ideal conditions [3; 4].

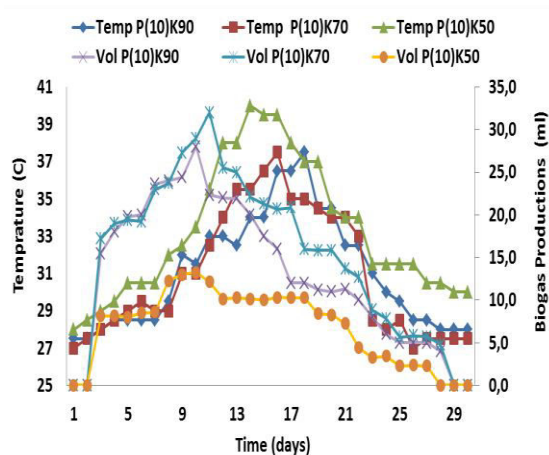
Table-2. C/N ratio conditions.

Reactor	Initial C/N Ratio	End C/N Ratio	Decreased (%)
P(10)K90	24.66	11.23	54.46
P(10)K70	23.25	9.21	60.22
P(10)K50	19.10	12.31	36.55
T(10)K90	30.82	18.79	39.03
T(10)K70	29.41	14.22	51.65
T(10)K50	26.74	16.65	37.73

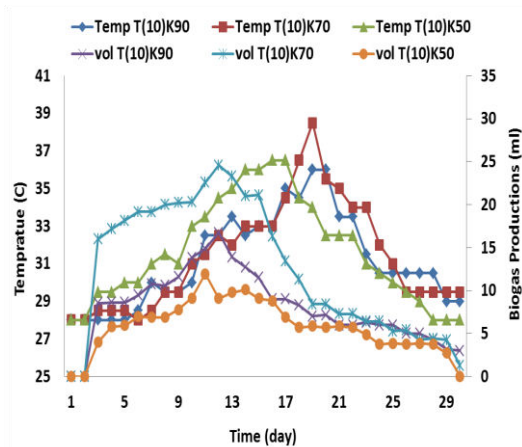
In the end of the experiment, C/N ratio in all reactor were decreased. It implies that in all reactor, degradation of substrate by microorganism were occurred. The lowest end C/N ratio was occurred on reactor P(10)K70 by decreased C/N ratio 60.22%. This showed pretreatment can release cellulose, lignin and hemicelluloses from libgocellulose bond, increased porosity of substrate, so the microorganisms will be easier to degrade the organic material [10].

Temperature conditions

The increasing temperature indicated degradation of the substrate in the reactor. In this study the digestion process occurred on mesophilic range (25°C-40°C) slightly lower than the results of other studies. Methane production depended on the incubation temperature, which the peak total biogas production was obtained at 45 and 55°C [10]. On the third day of the study, the temperature of all reactors increased. its because the population of microorganisms were still on lag phase. After 15 days temprature and then decreased slowly as can been seen in Figure-1. The highest biogas formation with the pretreatment in the reactor P(10)K70 was 32 mL and the temperature conditions 32,5°C on 11th day. Since day 12th, the biogas formation on reactor P(10)K70 decreased until the end of the experiment, but the temperatures remained increased until day 16th. The highest biogas formed in the reactor without pretreatment T(10)K70 was 24.5 mL, or with pretreatment was 1.3 more than with pretreatment.

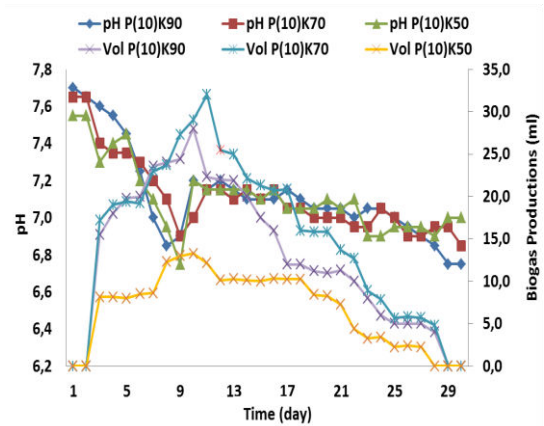


(a) with pretreatment

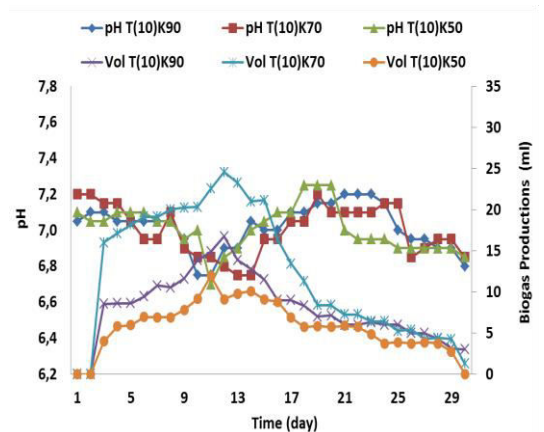


(b) without pretreatment

Figure-1. Temperature condition with and without pretreatment vs biogas production.



(a) with pretreatment



(b) without pretreatment

Figure-2. pH conditions.

pH Conditions

Certain types of microorganisms cannot grow at a pH that is not suitable for its growth. The growth of microorganisms will determine the amount of biogas produced. The fermentation bacterial and methane bacteria can live in the pH range 6, 5 - 8.00. During digestion process, the pH range in each reactor was 6.65 to 7.7 as can be seen in Figure-2, where the pH change was not significant. This results same to other research, where pH values of the rest treatments reached 7.7-7.9 with significantly increased methane production [7]. It is appropriate to microorganisms growth. The pH decrease followed by an increase in the formation of biogas.

In the first day to 10th day, almost all reactor has pH decreased. The pH decreased in the first 10 days was acetogenesis and asidogenesis phase. It was happened cause the degradation of substrate and the formation organic acids by fermentative bacteria. The increase pH reactor while entering methanogenesis phase marked by reduced the acidity of the mixture. After the mixture into a well buffer condition, the pH will stable by itself.

Well buffer is a condition where the pH will remain stable even if the material is inserted again into the reactor. Almost all of the pH reactor is in stable condition at 15th day to 30th day, except in the reactor T(10)K50, T(10)K70 and T(10)K90 was increased. This happens because there is still decomposition of organic acids to CO₂, methane and NH₃. It was increases pH. Degradation substrate in the reactor was running slowly. It was show by C/N ratio still remain high at the end of experiment. After 15 days, pH increased, but still in safe range for biogas formation. The maximum methane production potential and VS degradation rate optimum were obtained when the initial pH was 7.5 [11].

Figure-2(b) shows pH conditions in the reactor without pretreatment, all reactor has decreased pH from 7.2 to 6.9, that followed by increase the biogas formation from 1st day to 12th day. On 12th day until 30th day, all the reactors get decreased biogas formation, but the pH of reactor still increased until 19th day. On 20th day to 30th day, the pH in all reactors getting decreased. The pH increases gradually occur because the bacteria utilize the degradation products susbtrat such as acetic acid, CO₂, and hydrogen formed in asidogenesi phase, then the pH will slowly rise to pH normal. The decreased biogas production



was happen because there is competition between the bacteria for use a nutrient substrate. The death rate of bacteria was faster than formation cells rate. So that the rate of organic matter decomposition into biogas was decreased. Formation of the highest gas contained in the reactor P(10)K70 with 24 ml occurring at pH 6.8 at 12 days.

3.2 Effect of composition on biogas production

Biodegradable volatile solid is part of the volatile solid that can be used to form acid bacteria in the acidification phase and form the methane in methanogenesis phase [12]. In reactors by pretreatment, the highest percentage was in the reactor P(10)K70 was 26%. While the reactor without pretreatment, the highest percentage in the reactor T(10)K70 was 23%. It shows that the pretreatment will produce the highest biodegradable volatile solid. Water hyacinth pretreatment have effectiveness in breaking the substrate size and eliminate the lignin so that the substrate is easier to be degraded by anaerobic bacteria [13].

Raw material is a source of nutrients for the bacteria in the biogas reactor. From the raw material can

be seen the highest biogas produced for 30 days. Table-3 shows the highest production of biogas generated by a mixture of water hyacinth and chicken manure 70:30 (%w/w). The cumulative gas volume produced at reactor P(10)K70 was 439 ml and at reactor T(10)K70 was 366 ml. The best composition of water hyacinth with chicken manure produces the highest biogas was (70:30 %w/w). Production of biogas at composition (70:30 %w/w) was higher than (50:50 %w/w) because the available nutrients and the bacteria in that reactor was balance.

3.3 Effect of pretreatment effect on biogas production

Figure-3 showed the highest production of biogas generated by pretreatment with NaOH and generated by a mixture of water hyacinth and chicken manure (70:30 %w/w). The highest cumulative gas volume produced by pretreatment at reactor P(10)K70 was 439.1 mL. The biogas produced in the same mixture without pretreatment at reactor T(10)K70 was 366.7 mL. It is a little fewer than the biogas produced in the same mixture by pretreatment. The result showed the water hyacinth pretreatment by soaking with NaOH 3% can increase the production of biogas.

Table-3. Composition effect to biogas productions.

Reactor	Raw materials (%w/w)	Water hyacinth (gram)	Chicken manure (gram)	Biogas volume (ml)
P(10)K90	90:10	550	75	383.8
P(10)K70	70:30	450	225	439.1
P(10)K50	50:50	350	375	193.5
T(10)K90	90:10	550	75	240.0
T(10)K70	70:30	450	225	366.7
T(10)K50	50:50	350	375	198.7

Cumulative gas volume produced by pretreatment at reactor P(10)K70 was higher than P(10)K90. Although the sources of nutrients more available, but not all bacteria are able to digest the nutrients properly. Contact between the bacteria with the substrate may not homogenous, so that the formation of biogas is not optimal. Biogas produce at composition (70:30 %w/w) is higher than (50:50 %w/w) because the available nutrients and bacteria in that reactor was balanced. Water hyacinth pretreatment using NaOH made a higher biogas production. Pretreatment can smoothing the physical condition of the water hyacinth so easily processed by anaerobic bacteria.

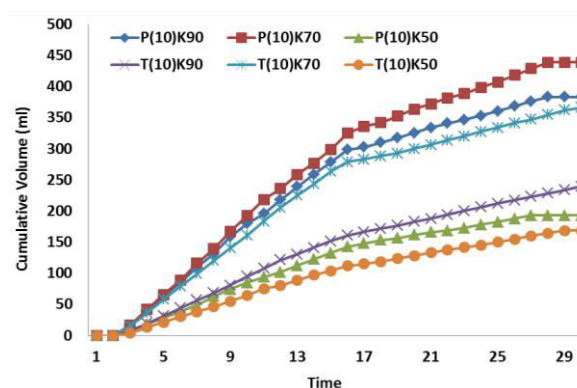


Figure-3. Pretreatment effect to cumulative biogas production.

Table-4 show the highest cumulative gas volume and methane concentrations of biogas generated by a mixture of water hyacinth and chicken manure 70:30 (%w/w) and with pretreatment. The cumulative gas volume produced at reactor P(10)K70 was 439 ml and the



methane levels was 20%. The cumulative gas volume and methane levels produced in the same mixture without pretreatment at reactor T(10)K70 was 366,7 ml and the methane level was 7%. The result showed, water hyacinth pretreatment by soaking with NaOH 3% for 5 days at room temperature and a mixture of 70:30 (%w/w) can increase the production of biogas and methane concentrations.

3.4 The rate of volatile solid degradation

Volatile solid (VS) is the content of organic compounds which can be degraded by anaerobic bacteria. Volatile solid is the substrate (food source) for non-methanogenic microorganisms that work in the early stages of biogas production. VS degradation and biogas production can be seen in Figure-4. VS degradation in the reactor P(10)K90, P(10)K70, and reactor P(10)K50 were 66%, 72%, and 59% respectively. When compared with the production of biogas each reactor, it can be concluded the higher the rate of decline in VS, the higher the production of biogas.

Table-4. Concentration of methane in biogas product.

Reactor	Raw materials (%w/w)	Biogas volume (ml)	Methane (%)
P(10)K90	90:10	383.8	12
P(10)K70	70:30	439.1	20
P(10)K50	50:50	193.5	6
T(10)K90	90:10	240.0	3
T(10)K70	70:30	366.7	7
T(10)K50	50:50	198.7	1

The composition of water hyacinth and manure chicken 70:30 (% w/w) produces higher volatile solid degradation. This can be achieved because the number of microorganisms, carbon and nutrients in a reactor at a ratio which met the requirements of the growth of microorganisms to degrade organic matter. To determine the degradation rate of volatile solid can be seen from the value of b in the linear equation obtained as can be seen in Table-5.

Table-5. Volatile solid degradation equation.

Reactor	Raw materials (%w/w)	VS degradation equation	R ²
P(10)K90	90:10	$Y = -2393X + 24099$	0.98
P(10)K70	70:30	$Y = -2639X + 21466$	0.98
P(10)K50	50:50	$Y = -2044X + 18005$	0.97
T(10)K90	90:10	$Y = -1333X + 20102$	0.99
T(10)K70	70:30	$Y = -2128X + 17777$	0.99
T(10)K50	50:50	$Y = -1222X + 18421$	0.92

Compare to all reactors, the highest rate of volatile solid degradation with pretreatment was achieved in the reactor P(10)K70, which is b value of -2639. Activity volatile solid anaerobic bacteria highest degrade on day 12 which is characterized by the formation of biogas highest daily volume. The rate of degradation of volatile solid in the reactor P(10)K70 produce the highest daily biogas volume of 160 ml on day 12, as can be seen in Fig.4. On day 6 to day 12 increased degradation of volatile solid characterized by the increase of daily biogas volume. Anaerobic bacterial activity decreased from day 18 to day 30. This is showed by decreased of daily biogas product.

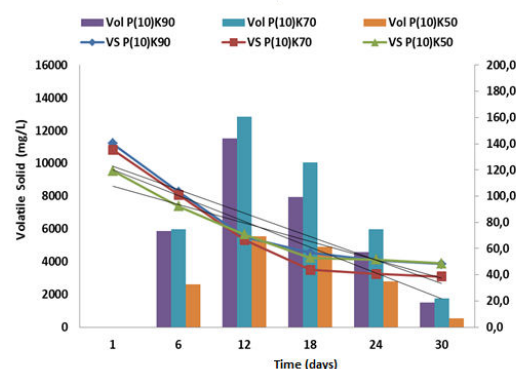


Figure-4. Volatile solid degradation and biogas production.

Bacterial activity is characterized by decreased production of biogas daily volume. The formation of biogas daily on days 18 to 125mL. Daily biogas formation on day 24 amounted to 74 mL. Daily biogas formation on day 30 amounted to 22 mL.

4. CONCLUSIONS

The highest production and methane concentration of biogas generated by a mixture of water hyacinth and chicken manure 70:30 (%w/w) with 3% NaOH for 5 days at room temperature. The highest cumulative gas volume 439 ml and methane concentration 20% of biogas generated at reactor P(10)K70.

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