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Biogas Production from Tofu Processing Waste and Corncobs with the Addition of Clam Shell Lime

Sulastri Panggabean*[1] and Fauziah[2]

[1] *Study Program of Agricultural and Biosystems Engineering, Faculty of Agriculture, Universitas Sumatera Utara, Medan, 20155, Indonesia*

[2] *Study Program of Agricultural and Biosystems Engineering, Faculty of Agriculture, Universitas Sumatera Utara, Medan, 20155, Indonesia*

*Corresponding Author: sulastripanggabean@usu.ac.id

ARTICLE INFO

Article history:
Received 31 January 2024
Revised 11 June 2024
Accepted 08 August 2024

E-ISSN: 3026-406
P-ISSN: -

How to cite:
Panggabean S and Fauziah, "Biogas Production from Tofu Processing Waste and Corncobs with the Addition of Clam Shell Lime, vol. 2, No. 01, Aug. 2024, doi: 10.32734/jsabe.v2i01.15528.

ABSTRACT

Tofu production process waste has the potential to become raw material in producing biogas because its organic components, but it has a very low pH, which is not suitable for biogas production. Therefore, it is necessary to increase the pH and maintain it to be neutral during fermentation. The number of treatments given were two treatments. The first treatment by adding 3% of NaOH and the second treatment by adding clam shell lime as much as 3 levels (6%, 7% and 8%). From the research, it was found that the highest value of parameters tested was found in the treatment of adding clam shell lime as much as 6% which produced biogas as much as 1633.33 ml with a pressure of 1.0184 bar. The biogas production rate was 842 ml /day. After the combustion test, the resulting flame was blue and can burn for 38.63 seconds.
Keyword: Biogas, NaOH, Clam shell Lime, Tofu, Waste

ABSTRAK

Limbah proses produksi tahu memiliki potensi untuk dijadikan bahan baku produksi biogas karena komponen organiknya, tetapi memiliki pH yang sangat rendah, yang tidak cocok utnuk produksi biogas. Oleh karena itu, pH perlu dinaikkan dan dijaga agar tetap netral selama fermentasi. Perlakuan yang dilakukan sebanyak dua perlakuan. Dimana, perlakuan pertama dengan menambahkan 3% NaOH dan yang kedua dengan menambahkan kapur cangkang kerrang sebanyak 3 taraf (6%, 7%, dan 8%). Dari hasil penelitian diperoleh bahwa nilai tertinggi dari parameter yang diuji pada perlakuan dengan penambahan kapur cangkang kerrang sebanyak 6% yang menghasiklkan biogas sebanyak 1633,33 ml dengan tekanan 1,0184 bar. Laju produksi biogasnya sebesar 842 ml/hari. Setelah uji pembakaran, diperoleh warna nyala api yaitu biru dengan waktu pembakaran selama 38,63 detik.
Keyword: Biogas, NaOH, Kapur cangkang kerang, Tahu, Limbah

1. Introduction

The increase in population every year will have an impact on increasing energy needs. The government needs to increase energy production, especially energy derived from renewable sources. Biogas is one of the potential alternative energies to be developed to reduce the use of fossil energy [1]. Biogas is a process of anaerobic fermentation of organic material to produce gas that is combustible. The gas produced from the fermentation process is mostly methane gas [2].

There are many raw materials that can be used as materials for biogas production, one of which is industrial waste. The tofu industry waste (both liquid waste and solid waste) still contains high organic matter [3] According to [4] tofu liquid waste can be used as material for household scale biogas production. According to [5] tofu industry liquid waste tends to be acidic. Meanwhile, the biogas production process requires neutral pH conditions. In addition, tofu industry waste still has a low C/N ratio which means it needs additional materials. One of the materials that can be used as additional ingredients in biogas production is corn cobs (C/N ratio of 56) [6].

Thus, in this study, the addition of NaOH and clam shell lime to maintain neutral condition of the material during fermentation process was carried out in the production of biogas from tofu processing liquid waste and corn cobs. The purpose of this study was to obtain how much volume, pressure and rate of biogas production, pH before and after fermentation, C/N ratio before and after fermentation, and the color of flame produced from burning the biogas as well as the duration in the addition of NaOH and clam shell lime during fermentation.

2. Materials and method

The ingredients that used and studied to produce biogas in this research were divided into two categories (main materials and complement materials). The main materials as organic materials were from tofu industrial waste (liquid and solid waste) and corn cobs. The complement materials were NaOH and clam shell lime, EM4 (Effective Microorganism-4), and distilled water. In this research used mineral gallons as digesters with capacity of 19 liters that equipped with a pressure measuring device.

This study used an experimental method of 2 treatments and 3 levels of treatment for clam shell lime (total of treatment combination were 4) with 3 replications, namely: 3% of NaOH for treatment P1, 6% of clam shell lime for treatment P2, 7% of clam shell lime for treatment P3, and 8% of clam shell lime for treatment P4. All the ingredients (1000 g of corn cobs; 500 g of tofu dregs; 11,500 ml; EM4 as much as 13 ml; NaOH and clam shell lime solution according to treatments P1, P2, P3 and P4) were being put in to digester (Fig.1) and mixed. The initial pH of the mixture and C/N ratio were measured before and after the fermentation process. During fermentation (21 days), all the research parameters (volume, pressure and environmental temperature) were observed and biogas production rate was calculated using Equation 1.

Figure 1. Digester

$$Biogas\ production\ rate = \left|\frac{gas\ volume\ present\ day\ (ml) - gas\ volume\ previous\ day\ (ml)}{time\ (day)}\right| \quad (1)$$

3. Result and Discussion.

3.1 Biogas volume

The results of organic material fermentation with the help of bacteria in an aerobic condition called biogas. During the fermentation process until completion, the amount of gas produced had been measured every day. To find out how much volume of biogas (Figure 2) produced was by applying Archimedes' law.

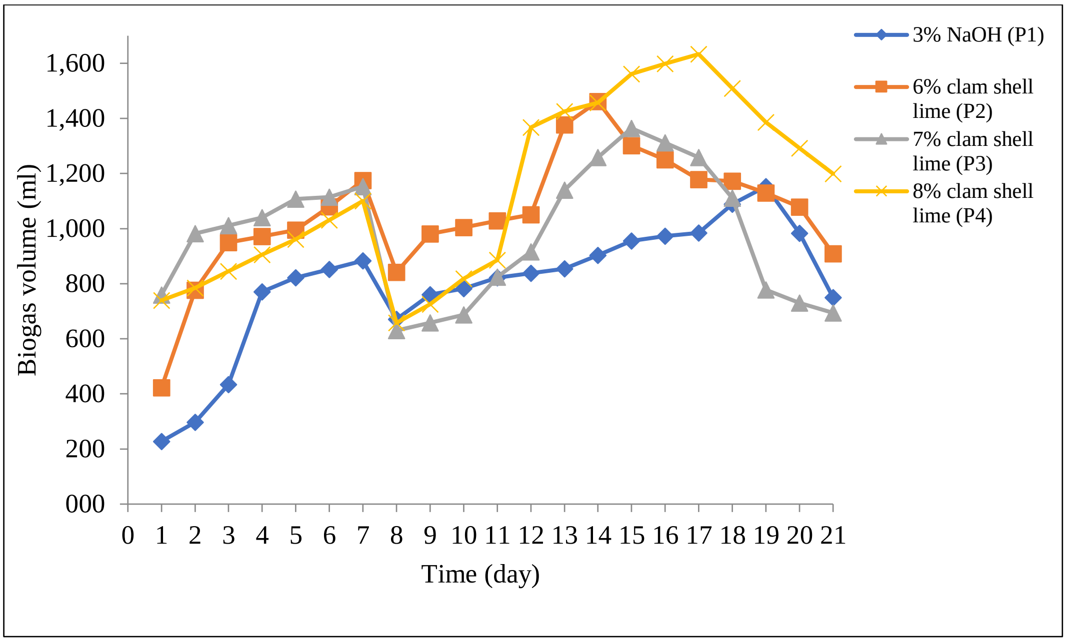

Figure 2. Biogas volume during fermentation

The decrease in volume (Figure 2) on the 8th day was due to the removal of gases carried out on the 7th day of fermentation. According to [7] the gas produced in the first week of fermentation must be discharged because the gas at the beginning is still CO_2 gas while CH_4 gas will be formed in the second and third weeks of fermentation.

The highest biogas volume was obtained in treatment P4, which reached 1,633 ml on the 17th day and the lowest was obtained in treatment P1, which was 1,153 ml on the 19th day. The peak points of biogas formation in each treatment were on 14th, 15th, 17th and 19th day. Each treatment had differences peak point because the optimal point of bacteria in breaking down organic matter in each treatment was different. According to [8], the decrease in bacterial activity is characterized by a decrease in the formation of biogas volume, where in this condition bacteria tend to use the remaining nutrients to survive rather than multiply and form biogas. In treatment P1 where NaOH 3% used to maintain the neutral condition, the bacteria spend a longer time to reach the peak point formed biogas, namely on the 19th day. But when used treatment P2, P3, and P4 (6%, 7% and 8% of clam shell flour), the bacteria reached the peak point formed biogas (on 14th, 15th and 17th day respectively) faster than P1.

The difference of biogas volume that produced in each treatment was due to the type of pH neutralizers in each treatment. In treatment P1, NaOH 3% was used as a pH neutralizer. In treatments P2, P3 and P4, shell clam lime was used, respectively 6%, 7% and 8%. The result obtained when using treatment P1 was lower than treatment P2, P3 and P4. This can be seen from the final pH (at the end of fermentation) in the use of NaOH 3% tend to be acidic so that the biogas produced was far from optimal. According to [8], low biogas production was due to an imbalance in the phases of acidogenesis and methanogenesis which caused by acid bacteria to dominate more so that the biogas production become smaller.

The highest yield of volume was obtained when used 8% clam shell lime. This is because clam shell lime contains 95% calcium carbonate [9]. Where it can be used as a neutralizing material.

3.2 Biogas pressure

The biogas pressure measured every day during fermentation (Figure 3).

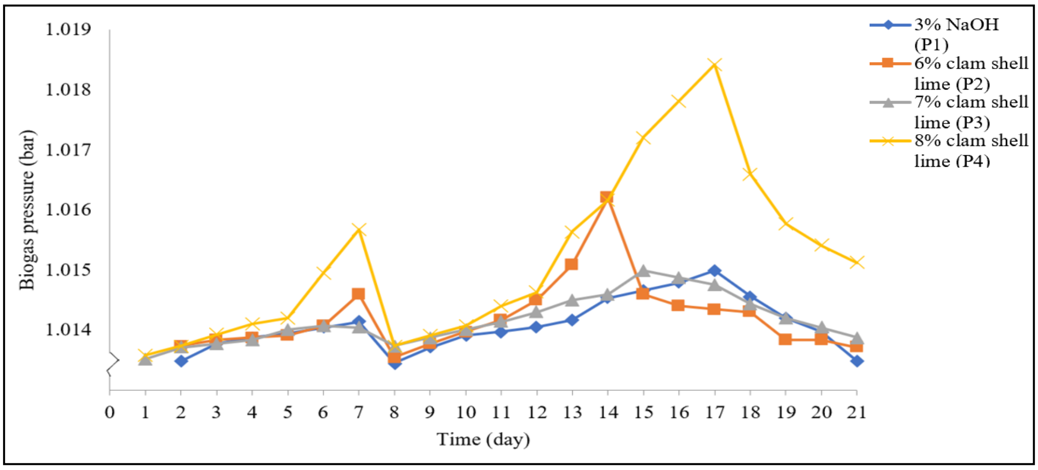

Figure 3. Biogas pressure during fermentation

The highest biogas pressure (Figure 3) occured in treatment P4 which was 1.01842 bar on the 17th day of fermentation and the lowest was in treatment P3 which was 1.01475 bar on the 15th day of fermentation. This difference caused by the optimal point of bacteria in breaking down organic matter was difference. This is because the mixture used in each treatment was different. Where in the use of 3% NaOH bacteria take longer time to break down organic matter into biogas.

In contrast to the use of clam shell lime, where bacteria decomposed organic matter into biogas more quickly so that the peak point reached faster. This means that the content of mixed materials used in each treatment affected the work of bacteria, thus affected the production of biogas. According to [8], the decrease in bacterial activity is marked by a decrease in biogas production so that it affects the pressure produced because the relationship between biogas volume and pressure is directly proportional, meaning that the higher the volume of biogas produced, the higher the pressure of biogas produced and vice versa.

3.3 Biogas production rate

The discussions on the rate of gas formation are divided into two parts. Namely on the first seven days and the 8th day to the 21st day. This is because in the first seven days, the gas formed was uncombustible gas, so it needed to be released. The following (Figure 4) is the rate of biogas formation from the first week of fermentation.

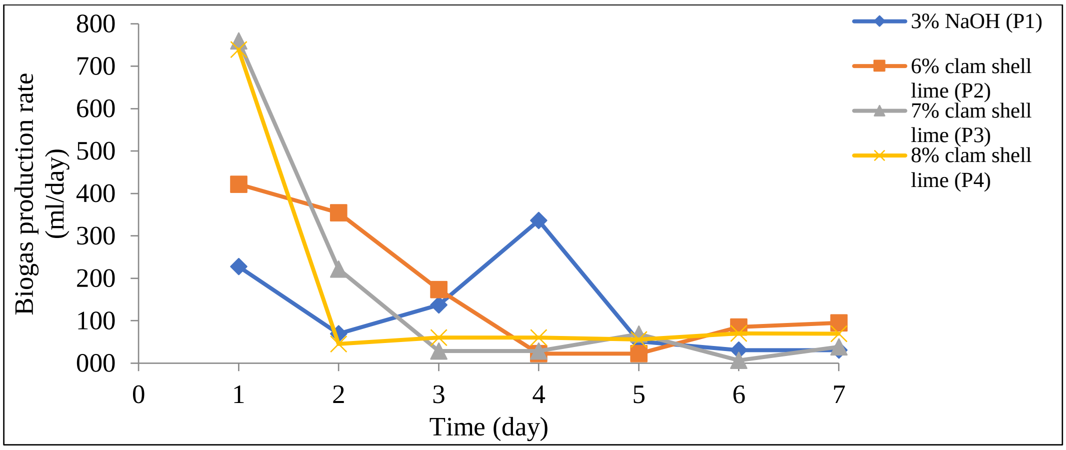

Figure 4. Biogas production rate during fermentation in the first seven days

From Figure 4, it can be seen that the highest gas production rate during 7 days of fermentation was obtained in treatment P3, which was 759.67 ml / day. This is because the volume in treatment P3 on the first day is quite large compared to other treatments. However, on the 6th day, the gas production rate in the treatment P3 got the lowest result, which was 6.67 ml / day. This can be seen from the volume of gas produced on the 6th day had decreased due to bacteria not completely digested organic matter. This is in line with the statement of [10] that stated the decrease in gas production because organic matter has not been fully decomposed by bacteria. The rate of gas production in the second and third weeks of fermentation can be seen in Figure 5.

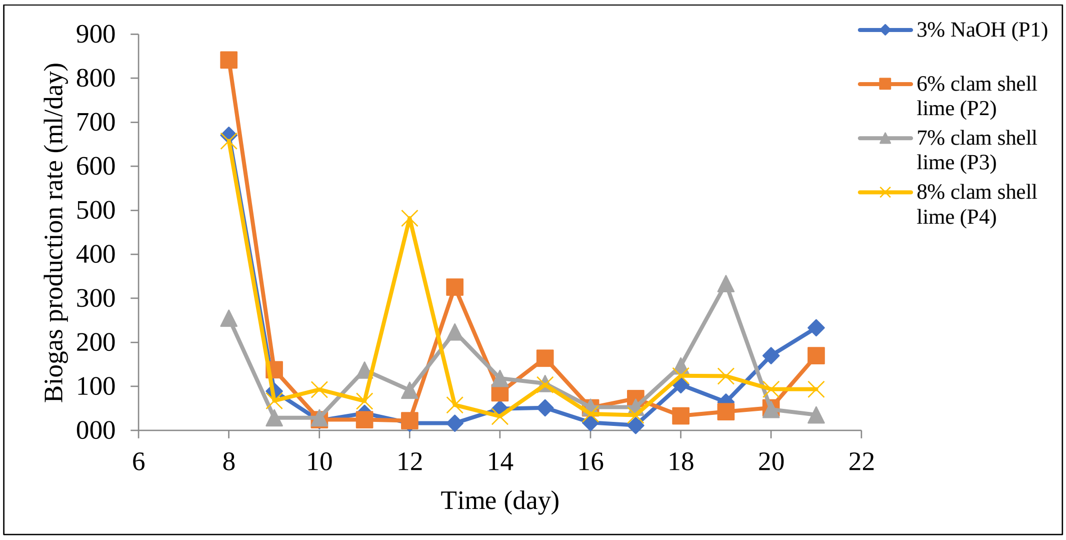

Figure 5. Biogas production rate during fermentation in the second and third week

The highest biogas production rate after gas removal in the first week occurred in treatment P2, which was 842 ml/day on 8th day and on 11th and 12th decreased to 22 ml/day. It can be seen that the volume of biogas produced at the beginning of fermentation after biogas disposal obtained optimal results. This means that the bacteria that work in treatment P2 were relatively fast to convert organics into biogas. On the 17th day the biogas production rate was low when the biogas volume was the highest because gas volume was the amount of gas produced during fermentation time while biogas production rate was the difference in gas volume produced (the previous day and the present day) during fermentation time. So, even though the volume of gas produced is high, the production rate is not necessarily high. Because it could be that the difference in gas production from the previous day is very small. The lowest production rate was obtained at treatment P3 on the 19th day of fermentation, which was 333.67 ml/day. According to [8] bacteria will actively work to convert organic matter into biogas and will decrease when there is a decrease in biogas production.

3.4 pH

pH is a measure of the acidity or alkalinity of a solution. pH is one of the factors that affect biogas production. According to [11] the pH in the digester ranges from 6.8-7, where the pH that works in biogas production ranges from 6-8 and the optimal pH is approximately 7. The initial and final pH measurements of each treatments in this study can be seen in Figure 6.

From Figure 6, it can be seen that the initial pH in each treatment ranged from 6-7, with the highest average pH in treatment P1 which was 7.09 and the lowest was in treatment P2 which was 6.41. At the end of fermentation, the highest average final pH was in treatment 2, which was 6.57, and the lowest was in treatment P1, which was 4.78. The pH value obtained at the end of the fermentation decreased greatly in treatments P1 and considered as very acidic. According to [12] the decrease in pH at the end of fermentation is caused by the production of VFA (volatile fatty acids), where in the process of decreasing pH the acidification process occurs.

According to [13] the acidification process is shown by changing the results from hydrolysis to fatty acids such as propionic acid, acetic acid and butyric. However, things were different with treatment P2. At the end of fermentation, the pH value obtained in the treatment increased from 6.41 to 6.57. According to [14] there is an increase in the pH of the solution due to the decomposition process of organic acids that occured to produce methane and carbon dioxide.

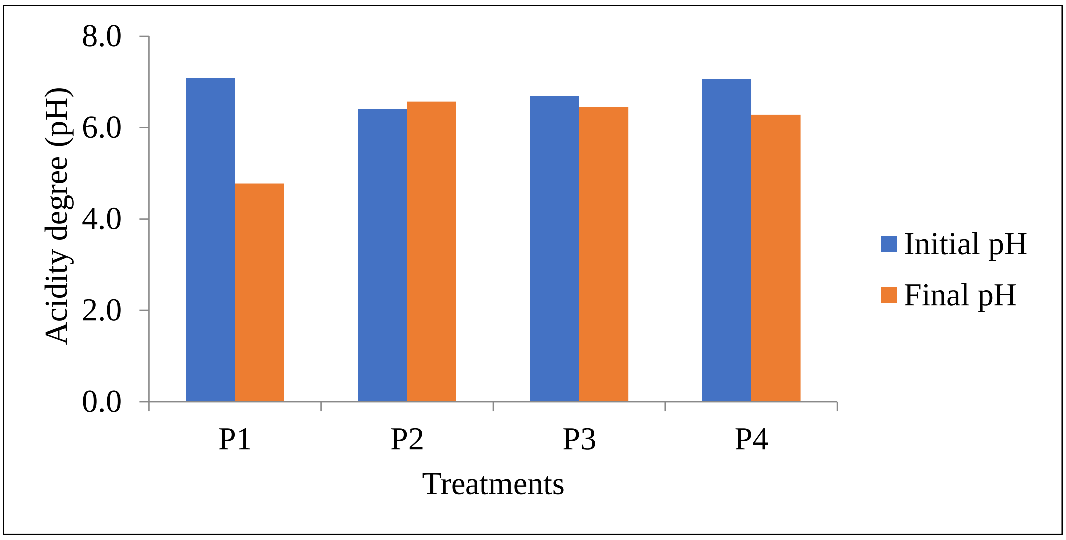

Figure 6. Initial and final pH of the mixture

3.5 C/N ratio

The ratio of carbon (C) and nitrogen (N) in raw materials in the biogas production process is one of the important factors that greatly affect biogas production. The C/N ratio of good materials for the process of anaerobic decomposition of organic matter ranges from 25-30. The calculation of the initial C/N ratio was an indicator of mixed materials to be used as materials in biogas production. While the measurement of the final C/N ratio was carried out as a comparison with the initial C/N ratio. The ratio of initial and final C/N in each treatment can be seen in Figure 7.

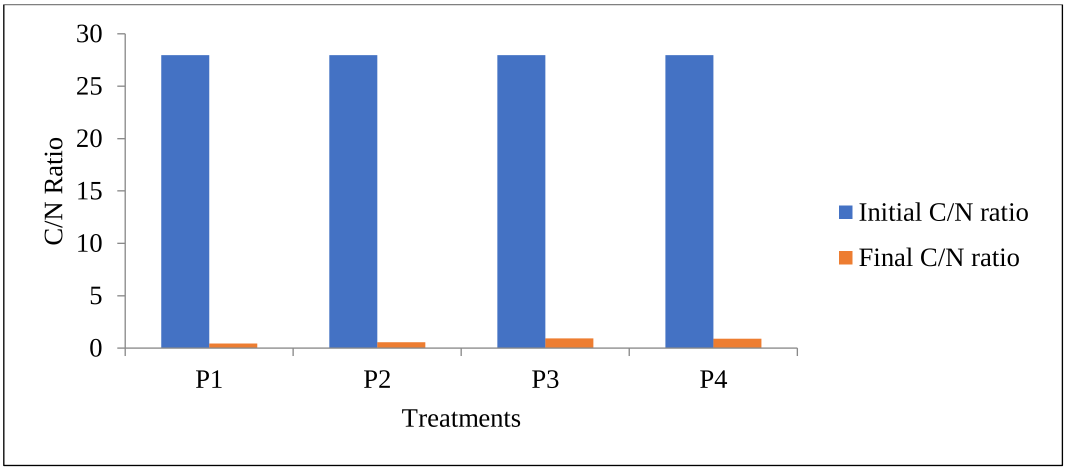

Figure 7. Initial and final C/N ratio of the mixture

From Figure 7, it can be seen that the initial C/N ratio of each treatment was the same, which was 27.95. The final C/N ratio of the material was obtained from laboratory analysis with the highest average final C/N ratio obtained in treatment P3 which was 0.99 and the lowest obtained in treatment P1 which was 0.45. The decrease in the C/N ratio was due to the carbon content had been consumed quickly by bacteria. This can be seen from the final carbon yield obtained in each treatment was very low. The decrease in carbon content in biogas production was due to the carbon had been used by bacteria as an energy source and according to [15] the C/N ratio is too low due to the high nitrogen content produced so that the nitrogen will be released and collected in the form of ammonia.

3.6 Flame

The flame test (Figure 8) was carried out to determine the presence or absence of methane gas content produced in the biogas production process. The duration of biogas burning time in each treatment can be seen in Figure 9.

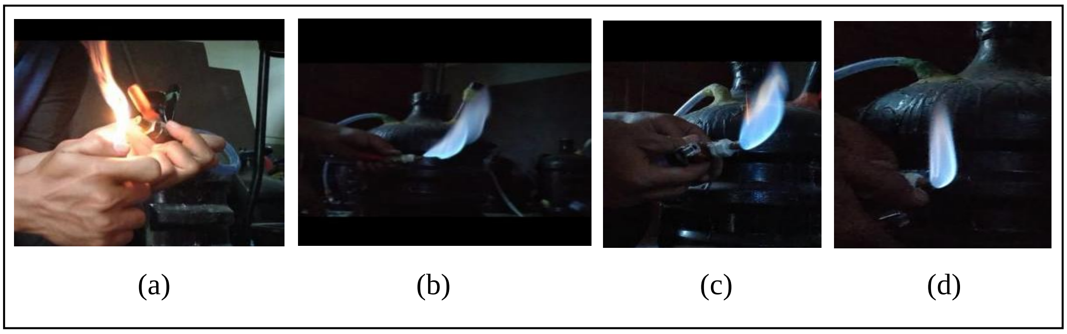

Figure 8. The flame test (a) P1; (b) P2; (c) P3; (d) P4

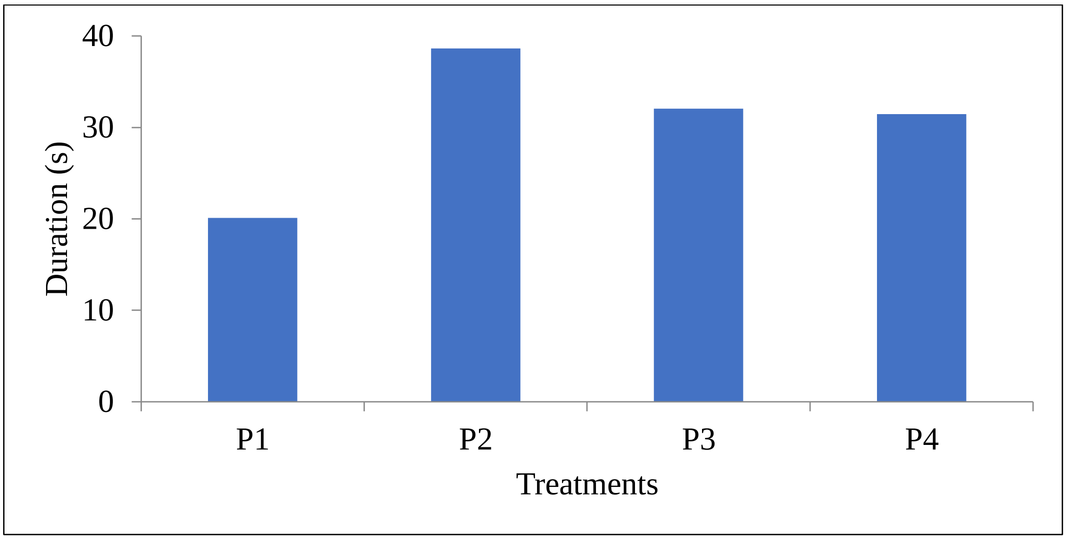

Figure 9. Duration of biogas burning time

From Figure 9, it can be seen that the highest average flame test was in treatment P2, which was 38.63 seconds with the color of the flame produced in blue and the lowest average flame test was in treatment P1, which is 20.11 seconds with the color of the flame produced in reddish. From the results above, it can be seen that the treatment that has high methane gas was in treatment P2 and the lowest was in treatment P1. This can be seen from the color of the fire produced in each treatment. According to [16] the flame that produces blue flames and does not cause black marks indicates that the combustion is perfect.

While the treatments P3 and P4 produced flame for 32.04 seconds and 31.45 seconds respectively and the flame color was blue with a slight reddish. According to [8], the production of methane gas is small because the dominating bacteria are acidic bacteria, not methanogen bacteria, so that the material that decomposes into methane gas is small.

From the research, it can be said that the optimal treatment in producing biogas was in treatment P2 with the addition of 6% clam shell lime. This can be seen from the flame test, and the gas production rate in treatment P2 was higher than the other three treatments and the blue flame color produced indicated that the methane gas produced was optimal.

4. Conclusion.

The highest biogas volume and pressure of the four treatments was in treatment P2, namely a volume of 1633 ml and a pressure of 1.01842 bar. The highest gas production rate of the four treatments was in treatment P2, namely 842 ml/day. The highest flame duration of the four treatments was also in treatment P2, namely 38.63 seconds with the flame color was blue.

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