Optimization of biogas production from water hyacinth by liquid anaerobic digestion (L-AD) using response surface methodology

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Abstract. In this biogas research from water hyacinth, we are using Central Composite Design and full factorial design. Enzyme (X1), C/N ratio (X2) and total solid (X3) is three experimental variables were selected as controlled factors. Performed on a laboratory scale and at room temperature with 16 runs for 60 days measured every two days. The variables were set at 3-9% for Enzyme concentration, C/N at between 20-50, and concentration of TS between 5-15% (LAD condition). Based on the research that has been done, the optimum conditions for the biogas production process from water hyacinth in Liquid State Anaerobic Digestion (LAD) conditions use Response Surface Methodology (RSM) in the variable range are the C/N ratio 30-40, 6% enzyme, and for TS was not significant factor. Following the run in the central composite experimental design, these values correspond to run number 10 with variable C/N ratio 35, enzyme 6% and TS 1.59% with biogas production 202.51 mL/g TS.

1. Introduction
Biogas have a significant potential as a source of energy latest because the womb methane CH₄ his own they received a heat engine 50 mJ/kg. Methane CH₄ that has one carbon in every chain, can produce combustion that is environmental friendly than the serial fuel long carbon. This is because the amount of CO₂ put which is produced during the combustion of fuel serial short carbon is more a little. Biogas is flammable gases (flammable) resulting from the process of fermentation organic materials are bacterium by anaerobic derived from an agricultural waste, animal husbandry and of human waste. The material that can be used as raw materials of manufacture for biogas that is biodegradable material like biomass, dirt, the results of the activity of garbage solid urban and others [1].

One of material used in this research is a waste product the hyacinth. Biogas obtained from the results of the decipherment of water hyacinth without oxygen are anaerobic. Water hyacinth that containing a great the water level in its body which is approximately 90 % is a profit in making use of as a result of biogas through a yeast process fermentation with methane formulation bacteria besides figures to be womb a compound of carbon dioxide and nitrogen high between 30-35. Breed of this fast causing a plant water hyacinth it has turned into a weed water. A very fast the water hyacinth growth but also that it caused many problems, among others speed up silting in the rivers or lakes, decreasing

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the production fish, has created a difficulty for an irrigation channel, and cause the evaporation of water to 3 to 7 times greater than the evaporation of water out on the open water [2].

In the process of biogas there are renewable biomass material as of aquatic plants used for cleansing of waste water or invasive species in lakes and the rivers can be harvested and implemented in the process of L-AD. L-AD can be operating at concentrations Total Solids which are different. The process comparison between of L-AD with TS fewer than 15 % classified as Liquid State Anaerobic Digestion (L-AD), are suitable for waste by high water content include cesspool mud and waste flood. Therefore, that water L-AD need a lot to handle waste low water as biomass containing lignocellulose. On the other experiment that discuss, a Solid State Anaerobic Digestion are (SS-AD) operating on Total Solid more than 15 % so it is more suitable to digest lignocellulose on biomass [3], [4].

Microorganism’s activity that play a role during the process of fermentation depends for C/N Ratio. On anaerobic are the ratio of \( c / n \) optimal about 20-30. The ratio of \( c / n \) high on the material organic will causing the production of methane that is low. The problem is that of material by C/N Ratio are only containing nitrogen in a low. The increase has caused consumption nitrogen that is fast by bacteria methanogen and result in the yield applied for biogas down because of nitrogen lack available for the growth bacteria. That is why to increase the level of nitrogen on the material, organic matter has accompanied containing nitrogen that is as high as the excrement of an animal. While, if the C/N ratio very low to cause of ammonia accumulating and could raise its pH digester amounted to 8.5 who is poisonous against bacteria methanogen [5]. This is a reason why not need other material containing carbon or high fibre, as grass, straw, the husks and foliage. The trick is to mixing organic matter with material containing carbon until achieved the C/N ratio term.

Water content known as one of important parameter anaerobic process are. Hence, the womb total solid used define two types of them are anaerobic process, wet are Liquid Anaerobic Digestion are to the womb TS 15 % and dry are Solid-State Anaerobic are to TS 15 %. If temperature between 4-60°C and temperature kept constant gas will be produced. The high temperature was expected to fast but are becoming less of bacteria would the temperature had an influence on the process of digestion anaerobic of organic matter and the production of gas. Digestion lasted well at a temperature of 30-40°C for the condition of mesophilic and at a temperature of 45 to 60°C for the condition are thermophilic. The speed of fermentation down in the 2008 second temperature under 20°C. Most bacteria mesophilic optimal temperature reached at 35°C, but to bacteria are thermophilic at a temperature of 55°C. At a temperature of are thermophilic the activity of microorganisms resulted higher 25 to 50 % to produce more biogas yield [6].

The range are the condition of the neutral pH 7-7.5 who is favourite field most microorganisms. The process of biogas there are types of microorganisms and pH different for each microorganism. An optimal growth pH between 6.8 - 7.6 are the condition for the optimal bacteria methanogen and at pH under 6.6 the growth of bacteria methanogen would decrease, while bacteria with hydrolysis process and acetogenesis will work at between pH 5.5-6.6. If pH values dropped below 6.5, so the production of an organic acid by bacteria hydrolytic can result decrease in more noticeably pH and the process of fermentation will stop [7].

2. Materials and Methods

Biogas research has been conducted for 60 days located in The Engineering Laboratory Waste Processing Chemical Engineering and Environmental Engineering Laboratory, the building in college together of Engineering Faculty, Diponegoro University. Namely by preparing in the implementation stage research reactor in accordance with draught which has been made (Fig. 1 and Fig. 2) drum-shaped plastic volume 2 liters a number of seventeen reactor (Duplo) [8]. By controlling the reactor in the extent of the contents of or reactor by determining variable free the C/N ratio: 20, 35, 50; Enzyme: 3%, 6%, 9% and Total Solid 5%, 10%, 15%, and the rumen: water ratio is 1:1, for rumen cow fluid as inoculum was obtained from slaughter house in Pedurungan, Semarang [9].
This research was done on a laboratory scale. Biogas production process was operated on bio digester with volume of 1.5 liters. Bio digester made from a polyethylene bottle plugged in tightly rubber plug and fitted with a valve on the top of bio digester to measure the biogas. Water hyacinth that used on the reactor up to 16 is water hyacinth that not through pre-treatment, while 17 reactors is control reactor that uses water hyacinth by concentration of the TS 5%. The research was done for 60 days with the method of measurement in the form of a method of displacement of water every once in two days.

![Figure 1. Detailed reactor design.](image1)

![Figure 2. Schematic diagram of biogas measurement in laboratory.](image2)

2.1. Biogas analysis
The research studies were used water hyacinth as the principal ingredient of making biogas. The implementation of this research with the processing organic waste removal of water hyacinth (bio waste) and rumen fluid. Then examined the composition of TS, water content, and C/N Ratio. After that composition are calculation and determination of enzyme variation, C/N Ratio and TS content and preparation of an anaerobic a batch or reactor. The substrate will be mixed with inoculum and water according to the TS concentration as well as the technical urea to adjust the C/N Ratio variation and the Enzyme added accordingly. Other preparing samples can be incorporating into the reactor, seal tightly for anaerobic conditions, and ready for operation. In this super-special stage, we observed the structure groups of water hyacinth before and after of them using. During the processes, observed the volume of biogas produced each time intervals of 2 (two) days. Water hyacinth that used on the reactor up to 16 is water hyacinth that not through pre-treatment, while 17 reactors is control reactor that uses water hyacinth by concentration of the TS 5%. The research was done for 60 days with the method of measurement in the form of a method of displacement of water every once in two days.

The biogas volume is calculating by passing the gas into a water-filling measuring cup by utilizing the gas properties of pressing in all directions from the or reactor (Boyle’ s Law), so that when the valve will be open, or gas from reactor directly moves into the measuring cup to observe the difference volume. The biogas the volume of observation scheme was presented in Fig. 2. Observations will stop after no more biogas is forming. After that, data analysis using Response Surface Method to obtain optimum position in biogas production in cardiac condition.
2.2. Response surface methodology
Variables are set between 3-6% enzyme concentration variation, C/N ratio 20-50, and TS 5-15%. The parameters are optimize using a technique called Response Surface Methodology. A Central Composite Design with full factorial design employ in this regarding. Three independent variables namely, enzyme (X1); C/N ratio (X2); and TS content (X3) as control factors and Yi was set at response variable, with Equation 2. The lower, upper, and center point of the design were code as -1, 1, 0 and α, where + 1 denotes high level, -1 low level, α = 2 n/4 (n=number of variables or factors) is the star point, and 0 corresponds to the center point. The result points of design to provide curvature estimation for the model. From experimental design used, 16 experiments are need and data will be resulting. Statistical analysis of the model was performed in the form of analysis of variance (ANOVA). For each variable, which the quadratic models were represented as contour plots (2D) and surface plots (3D) [10].

\[ Y_i = \beta_0 + \beta_{11}X_{11} + \beta_{22}X_{22} + \beta_{33}X_{33} + \beta_{12}X_{12} + \beta_{13}X_{13} + \beta_{23}X_{23} \]

Did calculation material is in accordance with predetermined variables and prepare us bio digester needed. The substrate was mixing with inoculum, water, enzyme, and technical urea to adjust the C/N Ratio variation and Total Solid. After the sample was preparing, can be inserting into the bio digester, then sealing tightly to get the cardiac condition without oxygen or anaerobic, and ready for operation. During the operation, biogas production was measured every two days. Furthermore, the observation was stopped after the biogas was no longer formed.

| Run | Enzyme (%) | C/N ratio | TS (%) | Biogas production (mL/g TS) |
|-----|------------|-----------|--------|-----------------------------|
| 1   | 3          | 20        | 5      | 120.8                       |
| 2   | 9          | 20        | 5      | 111.3                       |
| 3   | 3          | 50        | 5      | 104.1                       |
| 4   | 9          | 50        | 5      | 100.9                       |
| 5   | 3          | 20        | 15     | 21.66                       |
| 6   | 9          | 20        | 15     | 15.56                       |
| 7   | 9          | 50        | 15     | 24                          |
| 8   | 3          | 50        | 15     | 22.2                        |
| 9   | 6          | 35        | 10     | 52.3                        |
| 10  | 6          | 35        | 1.59   | 202.51                      |
| 11  | 6          | 35        | 18.41  | 16.53                       |
| 12  | 3          | 9.77      | 10     | 46.125                      |
| 13  | 6          | 60.2      | 10     | 44.05                       |
| 14  | 1          | 35        | 10     | 42                          |
| 15  | 11         | 35        | 10     | 3.425                       |
| 16  | 6          | 35        | 27.5   | 42.275                      |

3. Results and discussions
3.1. Optimize the TS, C/N ratio, and enzyme against the biogas from water hyacinth use Response Surface Methodology (RSM) in LAD
This research having aims to determine the ratio TS, C/N ratio and the enzyme use RSM. TS concentration (Total Solid) 5-15 % [11], the ratio of C/N 20-50 % and enzyme 3-9%. At this stage, a model quadratic served as meanwhile the contours of (contour of the plot) two dimension (2D). The production of biogas maximum indicate by the surface area of the smaller in the diagram contour. The
level of significance the influence of factors MC, C/N Ratio, and TS presented in the form of the chart of pare to chart as are presented in Fig. 3.

**Figure 3.** Significant factor of enzyme, C/N ratio, and total solid against the production of biogas.

The pare to principle (also known as a rule restore us) said that for many the incident, around 80% than the effect caused by 20% of the cause. From the Fig. 4 pare to chart shows the significance of the influence of TS is directly proportion to the results of production of biogas, microbial consortium the said / enzyme is directly proportional to the results of the production of biogas, and the C/N Ratio is directly proportional to the production of biogas.

A picture pares to chart indicating the level of significance for each variable whether it is being linearly and quadratic, as well as the relations between 2 variables. The total solid are linearly and quadratic as well as the C/N Ratio are linearly influence significantly to the production of biogas (p<0.05).While to the ratio of C/N having the character of quadratic and the concentration of microbial consortium said (mc) be it the is linear and quadratic did not influence on the biogas production (p>0.05) [10]. In addition, diagrams on Fig. 4. Above can be seen that factors TS having the character of linear having influence the highest against the production of biogas.

**Figure 4(a).** The 2D contours of TS and C/N ratio to biogas production at concentrations MC.
Figure 4(b). The 3D contours of TS and MC against biogas production at concentrations the C/N ratio.

Figure 5(a). The 2D Contours of C/N ratio and MC against biogas production at concentrations TS.

Figure 5(b). The 3D contours of the C/N ratio and MC against biogas production at concentrations TS.
In Fig. 4 shows that the concentration of the ratio of C/N optimum position for the production of biogas is between 30-40. On other illustration namely in Fig. 5, the concentration of enzyme optimum position for the production of biogas was 6%. In Fig. 6 also shows that the C/N Ratio optimum position for the production of biogas is between 30-40. On other illustration namely in Fig. 5, the concentration of TS optimum position for the production of biogas is around 2%. Based on the response the surface that was displayed on a Fig. 4 and Fig. 5 found the condition of optimum position to the factors of TS not significant on biogas research of water hyacinth in this. Of a number of things that has been related is in accordance with the outcome of several study to show that the concentration of TS for the production of biogas optimum position at concentrations below 10 %, the experimental work on this is an L-AD water hyacinth on the condition of the concentration of TS among defeat at 2-0 %.

4. Conclusion
Based on the research that has been done, the optimum conditions for the biogas production process from water hyacinth in Liquid State Anaerobic Digestion (LAD) conditions use Response Surface Methodology (RSM) with variable ranges of 5-15% TS, C/N ratio of 20-50, and enzyme 3-9%.
Optimum conditions in the variable range are the C/N ratio 30-40, 6% enzyme, and for TS was not significant factor. Following the run in the central composite experimental design, these values correspond to run number 10 with variable C/N ratio 35, enzyme 6% and TS 1.59% with biogas production 202.51 mL/g TS.

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6. References

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