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Water Hyacinth Extract Addition Towards Tofu Wastewater Degradation by Anaerobic Treatment

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***Abstract*—Indonesian tofu industries produce wastewater with high amounts and concentrations of organic compounds that pollutes the environment. Biological treatment of anaerobic and aerobic systems can degrade organic compounds and produce appropriate effluents for disposal into the environment. Anaerobic degradation process is highly determined by C/N ratio of the substrate. Tofu wastewater has a low C/N ratio (5.90), therefore other organic materials that have a higher C/N ratio should be added. This study aims to determine the effect of adding water hyacinth extract towards anaerobically degradation of tofu wastewater. Anaerobic systems utilize microorganisms found in cow rumen with mixture substrate of tofu wastewater and water hyacinth extract at volume ratio of 1.25:0.75. Addition of water hyacinth extract produced mixed C/N ratio of 10.49. Anaerobic bioreactor with active volume of 20 L, operated at hydraulic retention time (HRT) for 20 days. With influent COD load of 6,000 mg/L, the anaerobic system was able to remove COD by 92.8% or produced effluent with COD of 431.04 mg/L. Producing biogas accounted for 17,325 mL with highest concentration of methane gas of 56.9% for 35 days. Activated sludge method as an advanced treatment of aerobic systems is recommended to be added to complete the treatments in fulfilling the effluent standard to be discharged into the environment.**

Keywords—tofu wastewater, water hyacinth, anaerobic treatment, cow rumen, biogas

I. INTRODUCTION

Tofu is a traditional food product made from soybeans, favored by almost all Indonesian people. Most tofu industries in Indonesia are in the form of small scale industry with simple technology. Therefore, the efficiency of resource use is still very low and the level of waste production is relatively high [1]. In 2010, total number of tofu industry in Indonesia reached 84,000 business units with an average capacity production of more than 2.56 million tons per year and capable of producing liquid waste of 20 million cubic meters per year [2].

Liquid waste produced by the tofu industry has high organic content, with a BOD value of 6,000-8,000 mg/L, a COD value of 7,500-14,000 mg/L, temperatures reach 40-46^{o}C, and pH at 5-6 [2,3]. From these characteristics, tofu industrial wastewater will cause pollution if discharged directly into the environment, so processing needs to be done to meet the quality standards set by the Ministry of Environment.

Treatment of liquid waste with high COD values is generally carried out anaerobically. Besides being able to reduce the organic content at a cost cheaper operations, anaerobic processes also produce biogas, which can be used as a source of renewable energy [4]. Biological anaerobic systems provide only 70-80% processing efficiency, effluent still contains high levels of organic pollutants [5]. Therefore, an additional aerobic process was conducted after the anaerobic process in order to obtain the lowest organic content value and fulfill standard environment before the waste is discharged.

The C/N ratio is an important factor in the anaerobic process because it determines microbial activity and biogas production [6]. The optimal C/N ratio in anaerobic processes is between 20-30 [7], while tofu liquid waste has a C/N ratio of 5.19 [8]. Other organic materials, namely water hyacinth, having a high carbon content and low nitrogen content were added, resulting in a C/N ratio to increase to become 26.6 [9].

Water hyacinth is a type of weed that grows very fast, so that it can have a negative impact due to the nature of the water hyacinth that grows covering the surface of the water causes the oxygen content to decrease. The use of water hyacinth as a mixture of tofu liquid waste can reduce water damage caused by water hyacinth. Utami [1] conduct research on the addition of water hyacinth as a catalyst in processing tofu industrial wastewater anaerobically and get that water hyacinth can speed up the process of decomposing organic matters in tofu liquid waste to be biogas. Comparison of composition between tofu waste and water hyacinth giving the best results is 1.25: 0.75 with COD efficiency of 92.65%.

Stirring can increase biogas production by the intensive contact between bacteria and the substrate achieved by mixing thoroughly in the tank. There are two types of stirring, namely mechanical stirring and stirring the circulation [10]. Improper mechanical stirring can lead to a biotic community that supports the process of acetogenesis and methanogenesis to be destroyed by excessive friction as a result of excessive stirring so that negatively affects the anaerobic decomposition process [11]. Operating the reactor by applying substrate circulation can stabilize pH, uniform temperature, and remove organic substances bigger in the reactor [12]. Therefore, this research used a substrate circulation system and addition of water hyacinth to increase C/N ratio in this anaerobic process.

II. Research Methodology

A. Materials and Methods

Tofu wastewater and water hyacinth were obtained from a tofu home industry and fish pond in Bandung. Cow rumen, used as microbial starter, was obtained from a slaughterhouse in Bandung. Characteristics of tofu wastewater, water hyacinth, and catlle rumen, as well as total nitrogen were examined in Center for Material and Technical Products in Bandung. COD, pH, volume and gas composition were tested in water and wastewater treatment Laboratory in Politeknik Negeri Bandung, West Java, Indonesia.

Total volume of the anaerobic reactor is 25 L with an active volume of 20 L. Influent flow rate was set to obtain a hydraulic retention time of 20 days. Stirring is conducted by circulating the contents of the reactor and operation conditions are maintained at room temperature. The volume ratio of tofu wastewater and water hyacinth is 1.25:0.75. Water hyacinth extract was obtained by chopping and smoothing using a bender and juicer and addition of water at a weight ratio of 2:13, continued by filtering it using a jersey cloth.

B. Preliminary Research

Seeding and acclimatisation were done before the main experiment was conducted. The seeding process begins with preparing the cow rumen, namely by diluting the rumen using water with a ratio of 1: 2 then filtering and feeding the mixture into the biodigester. Fourty grams of glucose was added into the biodigester every 3 days. The seeding was carried out until more than 2,000 mg/L MLVSS were obtained.

Acclimatization was done by gradually replacing glucose with tofu wastewater. The mixture of tofu wastewater and water hyacinth extract was diluted and glucose was added to obtain 6,000 mg/L mixture concentration. 1L/day of this mixture was then fed into the biodigester. The tofu waste composition in the feed was increased by 5-10% every 3 days until the feed is completely replaced by the mixture of this wastewater.

At this stage the pH and volume of gas were measured every day. pH, COD, MLSS, and MLVSS measurements were done every 3 days. Testing of the gas composition formed was also carried out. The acclimatization process was carried out until a constant COD decrease was obtained.

C. Main Experiment

Anaerobic processing was carried out by feeding tofu wastewater (COD approximately 6,000 mg / L) into the reactor as much as 1L/day. Substrate circulation was carried out every day for 30 minutes before sampling and after feeding the wastewater. At this stage the pH and volume of gas formed were measured every day and measurements of pH, COD, MLSS, and MLVSS were done every 3 days. Measurements of the formed gas composition were carried out every 7 days.

III. Results and Discussion

A. Characteristics of Raw Materials

Characteristics of cow rumen, tofu wastewater, water hyacinth extract, and mixture of tofu wastewater and water hyacinth extract are shown in Table 1.

TABLE I. Charteristics of Raw Materials

Parameter	**Unit**	**Characteristics**			
		Cow rumen	***Tofu waste - water (1)***	***Water hyacinth extract (2)***	***Mixture of (1) and (2)***
Temperature	C	27	35	25	25
pH	-	6.80	5.45	6.25	5.75
COD	Mg/L	8,538.3	10,267.6	8,106.4	8,464.4
Water content	%	99.57	99.67	99.48	99.63
TSS	%	4,300	3,300	5,200	3,700
% organic C	%	26.79	53.64	35.96	47.01
Total P	%	11.14	9.09	2.71	4.48
Total N	%	0.02	0.01	0.01	0.02
C/N	-	2.40	13.27	13.27	10.49

Table 1 shows that cow rumen has pH of 6.80. The pH of rumen is in the range of 6.0 – 6.8 [13]. The pH value is a factor, which is very important, where the optimum pH for anaerobic treatment is in the range of 6.60 - 7.60. Anaerobic microorganisms naturally grow on in anaerobic ecosystems, one of which is the rumen of the cow so that it can be used as a source of methanogenic bacteria.

C/N ratio of the original tofu wastewater is 5.90 whereas C/N ratio after addition of water hyacinth into tofu wastewater becomes 10.49. The optimum C/N ratio in anaerobic degradation is in the range of 20-30 [6]. Even though it does not reach the optimum C/N ratio in anaerobic systems, the addition of water hiacynth increases the C/N ration of the mixture.

Teghammar et al. [14], if the C/N ratio in organic matter is high, it will cause low methane gas production due to the fast nitrogen consumption by methanogenic bacteria, causing less nitrogen available for bacterial growth. If the C/N ratio is low, nitrogen will be released and gather to form ammonia so that it

will increase the pH value in the anaerobic system. A pH value higher than 8.5 can poison the anaerobic bacteria.

B. Seeding

Seeding was carried out for 27 days by giving regularly nutrition in the form of glucose as a substrate once every three days. Glucose is used since it is the main of carbon which is easily degraded by bacteria [15].

COD parameter measurements were done to see if the nutrients in the form of organic matter in the substrate can meet the nutritional needs for the growth of microorganisms. During the seeding process, the fluctuation in COD value occur. In the seeding process, there is additional nutrition in the form of glucose which is added regularly, once every three days into the bioreactor. This causes the COD values flctuated to return to high values after the addition of nutrients. The appropriate COD value for anaerobic processing ranges between 2000 mg/L to 20,000 mg/L [16].

The measured COD value of the initial substrate is 8,538.32 mg/L. This concentration still falls within the range of COD concentration requirements for the anaerobic process. Thus it can be said that the organic matter in the substrate is high enough to provide nutrients in the form of organic matter to microorganisms that are being cultured.

From day 0 to day 16 there was an increase in growth until it reached MLVSS of 2,865 mg/L. On the 20th day there was a decrease in MLVSS however it was not drastic, namely a decrease from 2,865 mg/L to 2,595 mg/L. This is because the nutrition was not given on the set day so that the late nutrition causes the population of microorganisms to decrease. On the 23rd day to the last day of the 27th day of seeding, there was an increase in MLVSS up to 3,000 mg/L. At that time (day 20 to day 27) nutrition was again added periodically, i.e. once every three days.

The pH range, from day 0 to day 17, has not reached the optimum pH range for methane gas formation. This shows by % CH_4 obtained of only 9.9%. On the contrary, from the perspective of the growth of microorganisms, this pH range is sufficient to support the growth of microorganisms. To maintain pH conditions it was added sodium bicarbonate (Na_2CO_3) into the feed before the feed was fed into the anaerobic reactor. At the seeding stage, the biogas product accumulated as much as 780 mL with a composition of 9.9% CH_4; 9.4% CO_2; and 0.3% O_2; and 0% H_2S.

C. Acclimatisation

The addition of glucose to the waste aims to prevent shock loading because there is more complex organic materials in the wastewater and more difficult to degrade than glucose which is nutrition in the seeding process. Loading shock will cause an increase in acid formation without being balanced with methane formation, so that the pH will decrease and inhibit the degradation process and reduce biogas production.

pH measurements during acclimatisation were in the range of 6.08 - 7.14. During the acclimatization stage, the pH of the substrate in the reactor tends to increase. This increase in pH indicates that there was activities of microorganisms in the reactor [16]. A good pH range for the formation of methane gas is 6.8 - 7.2 [17]. The pH values during the acclimatization stage were in this pH range from day 0 to day 20. This condition is in line with the detection of total gas that had accumulated during the acclimatization stage. The volume of gas accumulated during the acclimatization stage was 3,770 mL with a methane gas concentration of 10.7%.

At the acclimatization stage, observing COD parameters is very crucial to check whether the acclimatization stage has been obtained. Decrease in COD value shows that microorganisms have been able to degrade organic compounds in the wastewater. Active microorganisms and starting to grow can be assumed by a decrease in the COD concentration [16]. During the acclimatization, from day 0 to day 20, COD continued to decline. During this stage, microorganisms were able to remove COD up to 53.3%. The acclimatization stage can be stopped when the fluctuation of COD removal is not more than 10% [18]. From COD data, it can be seen that the decrease in COD from day 14 to day 20 has stabilized so that the acclimatization stage was stopped on the 20th day.

Biomass has an important role in the operation of anaerobic reactors as organisms that actively degrade organic compounds. The effluent, resulting from anaerobic reactors, is very dependent on the bacteria involved [19]. The portion of organic materials in MLSS is non-microbial organic materials, microbes live and die, and destroyed cells [20]. Organic materials are represented by MLVSS. During the acclimatization stage, MLVSS fluctuations occur with the lowest value amounted to 1,931.11 mg/L and the highest value was 2,995.00 mg/L. During this acclimatization stage, MLVSS was still in the range of good MLVSS values for anaerobic processes, namely 2,000 - 3,000 mg/L [21].

D. Main Experiment

The optimum residence time for anaerobic waste treatment is 15-20 days [22]. The loading rate, given during this study, was 6 kg COD/m^3/day and at 20 days of residence time. A good loading rate for anaerobic waste treatment is 5-10 kg COD/m^3/day [22]. At this main experiment, several parameters were measured, namely pH, MLVSS, COD, as well as the volume and composition of biogas, with data collection for 35 days.

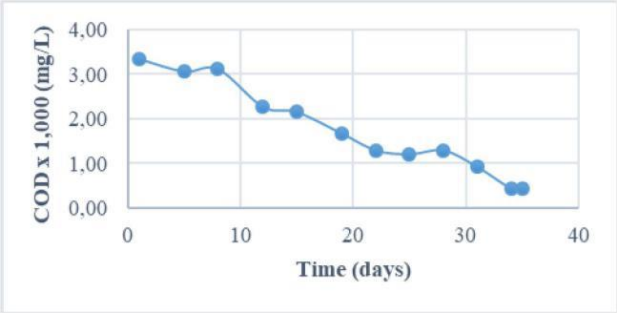

Fig. 1. COD reduction during anaerobic degradation.

The process of degradation of organic compounds in tofu wastewater run well in this anaerobic process. With influent COD of 6,000 mg/L, it can remove up to 92.82% COD with the final COD value of 431.04 mg/L (Fig. 1). It can be seen in this Figure that COD value tends to decrease, but on day 34 to day 35, COD reduction is not significant. It indicates that the anaerobic system has been steady. This is in line with the MLVSS parameters shown by this Fig. 2, where the MLVSS values fluctuate very much at the beginning of the process and started to stabilize on day 31 to day 34.

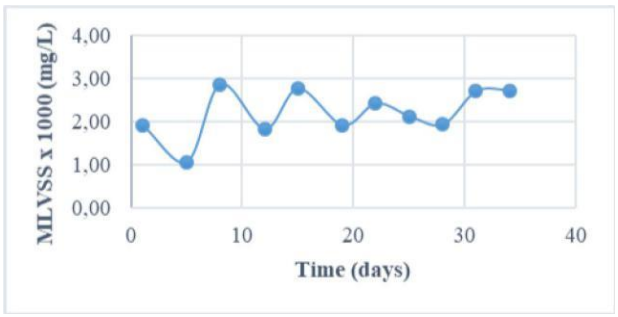

Fig. 2. MLVSS measurements during anaerobic degradation.

In the Fig. 3, it can be seen that during the process, the pH is still maintained at the optimum pH condition for anaerobic processing, namely 6,60 - 7.60. Although it is still in the optimum pH range for anaerobic process, a significant increase in pH on day 25 has an effect to decrease the content of methane gas in the biogas produced. The optimum formation of methane gas occurs when the pH is in the neutral range, namely 6.8 to 7.2 [17].

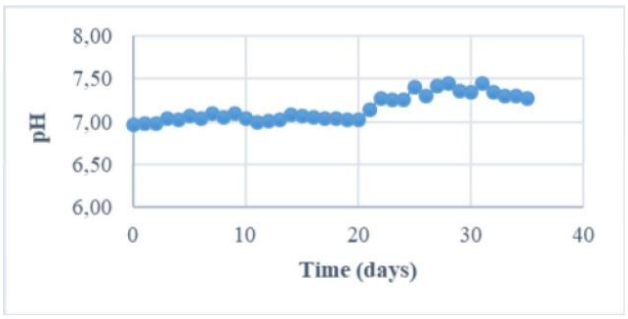

Fig. 3. pH measurements during anaerobic degradation.

In Fig. 4, it can be seen that from day 0 to day 21 it occurs an increase in methane gas content in the resulting biogas, namely from 26.3% to 56.9%. Then along with increasing pH, biogas production decreased and the composition of methane gas in biogas was lower, namely 49.1% on day 28. The composition of methane gas in methane gas increases again on day 35 as pH begins to fall back. During this period, volume of total gas measured was 17,325 mL.

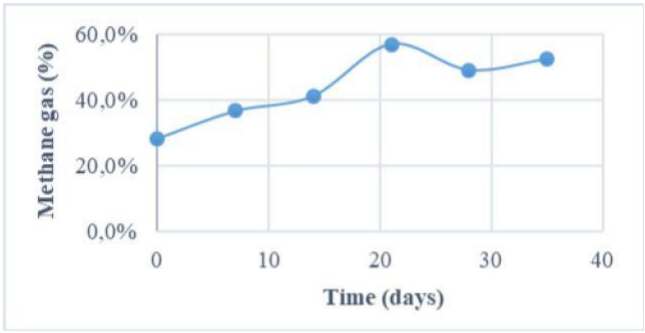

Fig. 4. CH_4 compositions during anaerobic degradation.

From all parameter measurements, it can be concluded that this anaerobic process could be conducted well to degrade tofu wastewater by addition of water hyacinth extract. To obtain lower COD parameter in fulfilling the effluent standard to be discharged into the environment, an advanced treatment of aerobic systems (activated sludge) is recommended to be added.

IV. Conclusion

The anaerobic system was able to remove COD by 92.8% or produced effluent with COD of 431.04 mg/L. Producing biogas accounted for 17,325 mL with highest concentration of methane gas of 56.9% for 35 days. Activated sludge method as an advanced treatment of aerobic systems is recommended to be added to complete the treatment in fulfilling the effluent standard to be discharged into the environment.

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