RASĀYAN *J. Chem.*
Vol. 9 | No. 2 |133 - 138 | April - June | 2016
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

EFFECT OF ORGANIC LOADING ON PRODUCTION OF METHANE BIOGAS FROM TOFU WASTEWATER TREATED BY THERMOPHILIC STIRRED ANAEROBIC REACTOR

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ABSTRACT
The objective of this study was to examine the effect of organic loading on the change of produced methane biogas and some wastewater parameters (i.e., pH, COD, MLSS, MLVSS, and ammonia) of the thermophilic stirred anaerobic reactor in treating tofu wastewater. The composition of the biogas produced was also measured. The reactor was studied at different organic loadings ranging from 65 to 162.5 g COD. The temperature in the reactor was maintained at 55ºC. In general, the reactor showed a good performance in utilizing tofu waste, producing significant amount of methane biogas. The production of biogas changes with the change of organic loading rates. The biogas comprised methane (79.5%), CO_2 (20%), and CO (0.5%). Based on the results of the analysis, since there were no corrosive materials, the biogas produced could be used directly for electricity or to power a generator. Other parameters such as pH, COD, MLSS, MLVSS, and NH_3-N were changed during the process.
Keywords: Organic Loading, Tofu Waste, Methane, Thermophilic Stirred Anaerobic Reactor.

INTRODUCTION
In Indonesia, tofu is one of the most popular commodities. In 2009, around 0.92 ton of soybeans was used to produce tofu[1]. The tofu industry uses a huge amount of water since producing 540 kg of tofu requires 500 kg of soybeans and 11,000 L of water. This process produces around 9,000 L of wastewater [2, 3]. More than 90% of the water used is wasted [4]. This huge amount of waste could cause serious environmental issues. Some of the issues that could be caused by wastewater from tofu production are ecosystem damage, extinction of certain organisms, decreased quality of water, and many others.
Wastewater from tofu production has a value of COD of around 6,500–8,500 mg/L[5]. High COD contentcauses the wastewater to have the potential to be converted into biogas. Biogas can be produced from various anaerobic process[6]. The biogas produced might be directly used for its heat energy, electricity, and many others [7].
Various methods have been used to process tofu wastewater, such as the upflow anaerobic filter process (UAFP), upflow anaerobic sludge blanket (UASB), anaerobic attached-film expanded-bed reactor (AAFEB), anaerobic fluidized bed reactor (AFBR), anaerobic mixed microflora under thermophilic conditions[8,9], and thermophilic stirred anaerobic (TSA) reactor. TSA is a type of anaerobic reactor with a stirrer that keeps the condition within the reactor homogeneous. This reactor uses thermophilic anaerobic bacteria and operates within the temperature range of 45ºC–55ºC.
The objective of this research is to investigate the influence of organic loading on the performance of the TSA reactor by analyzing the amount of methane produced and some other parameters (i.e., pH, COD, MLSS, MLVSS, and ammonia).

EXPERIMENTAL
Waste of Tofu
The tofu waste used in this research was taken from a factory in Banda Aceh City, Aceh Province,

Indonesia. The waste contained a value of COD of as much as 6,500–8,500 mg/L, TSS of 600–2,000 mg/L, VSS of 400–1,300 mg/L, and NH_3-N of 60–300 mg/L.

Thermophilic Stirred Anaerobic (TSA) Reactor

TSA is one of the anaerobic reactors that use thermophilic bacteria to degrade the organic component in waste. This reactor also uses a stirrer to increase its efficiency, reduce the value of the effective hydraulic retention time (HRT), and increase kinetic reaction[3]. In this research, TSA operated within the temperature range of 45ºC–55ºC and a stirring rotation speed of as much as 3 rpm; the reactor operated in a batch condition. The TSA reactor used was made of stainless steel with a capacity of 80 L. The schematic diagram for thermophilic anaerobic stirred reactor is shown in Fig.1. Methane thermophilic bacteria were acclimated to tofu waste for about 3 months, thereby ensuring good bacteria growth. The amount of bacteria-rich tofu waste with was kept constant at 80 L. The variations of COD loading used were 65 g, 97.5 g, 130 g, and 162.5 g of COD. In this research, a COD loading of 65 g meant that 10 L of acclimated tofu waste was removed from the TSA reactor and 10 L of fresh tofu waste (COD of 6500 mg/L) was added into the reactor, so the waste volume in the reactor was kept constant at 80 L. The methane gas produced was measured periodically at different COD loadings. Other parameters such as MLSS, MLVSS, COD, and NH_3-N were measured every day to observe the activity of anaerobic bacteria within the reactor and the performance of the reactor in reducing these values in the waste.

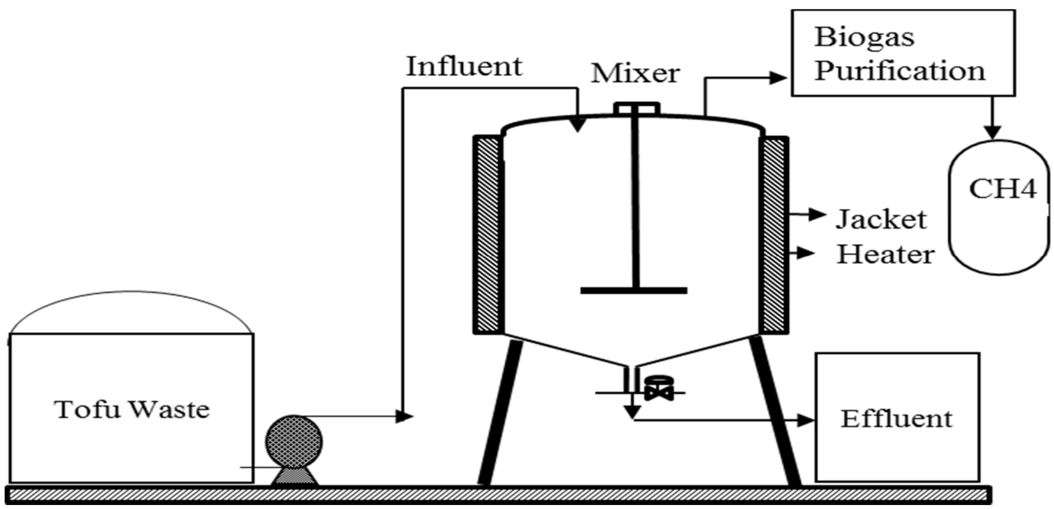

Fig.-1: Schematic diagram for ThermophilicAnaerobic Stirred Tank Reactor

RESULTS AND DISCUSSIONS

Performance of the TSA Reactor

Generally, the TSA reactor performed well in changing the organic compounds in tofu waste into biogas. Analysis of the results showed that the produced biogas contained methane (79.5%), CO_2 (20%), and CO (0.5%). There was no corrosive substance in the biogas produced, so it can be used directly as electrical energy for a generator. Figures 2–7 show that the organic loading value influences the value of pH, COD, MLSS, MLVSS, and NH_3-N within the tofu wastewater that had been processed using the TSA reactor. The tofu wastewater that had been processed using the TSA reactor could be used as a starter to make a compost.

COD loading influenced the gas methane produced. The higher was the value of the COD loading rate, the higher was the production of methane gas produced (Figures 2 and 3). The carbon content in tofu wastewater would be converted by anaerobic bacteria into biogas through hydrolysis, acidogenesis, acetogenesis, and methanogenesis [10]. At the start of the process, anaerobic bacteria require around 5–6 days to reach the process of methanogenesis. Once it reaches optimal condition, the production process of biogas slowly decreases as a result of the increasing production of volatile fatty acids (FVAs) that could hinder the process of methanogenesis. The higher is the COD loading rate, the higher is the amount of CH_4 produced on day 18 (Figure 3). Anaerobic bacteria use the organic content from tofu waste as a substrate and then turn it into biogas through various processes and mechanisms.

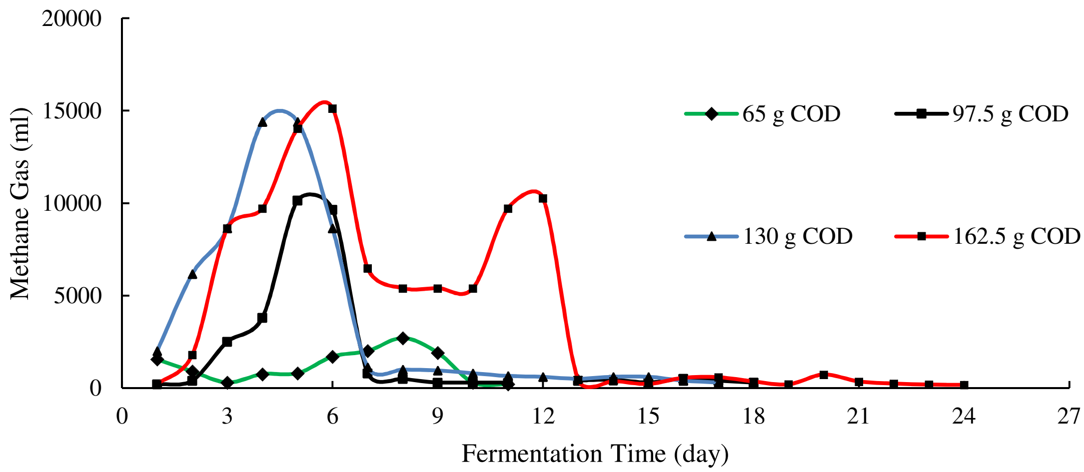

Fig.-2: Methane gas produced during the process at different COD loadings.

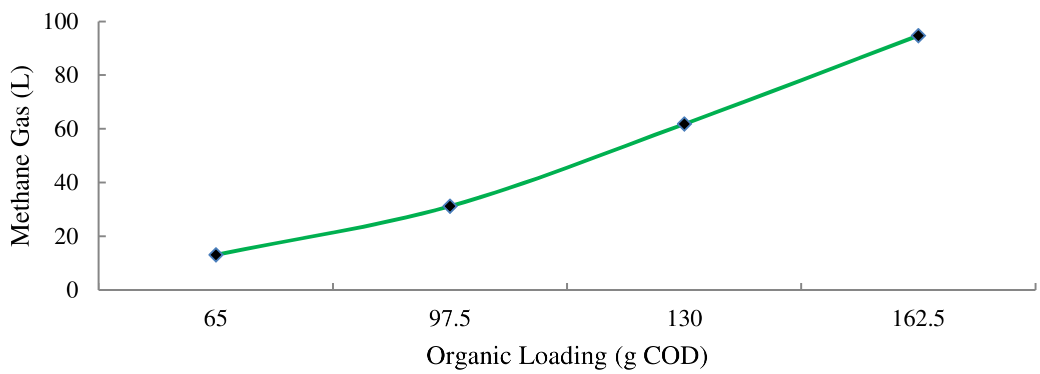

Fig.-3: Total methane gas produced on day 18 with the variations of COD loading.

Chemical Oxygen Demand (COD)

The value of COD of the tofu wastewater from the tofu factory before it plunged into the TSA reactor ranged from 6,500 to 8,500 mg/L, and it could decrease to around 1,000 mg/L (Figure 4). The value of COD decreased to around 80%–85%. The value of COD decreased because some of the organic substance was into $CH_4$and othercompounds. At aCODloadingrateof 130 g, COD removal was 85.6%.The value of COD decreased through some stages. On the first week, the value of COD decreased drastically, while on the second and third weeks, it decreased constantly.

The decreasing COD value was influenced by the stages of metabolism of bacteria. On the first week, the processes of hydrolysis and acidogenesis occurred, so the value of COD decreased drastically. The next stage was the process of methanogenesis, which turned the organic substance in wastewater into methane. This process was influenced by the pH and the activities of bacteria [11-13].

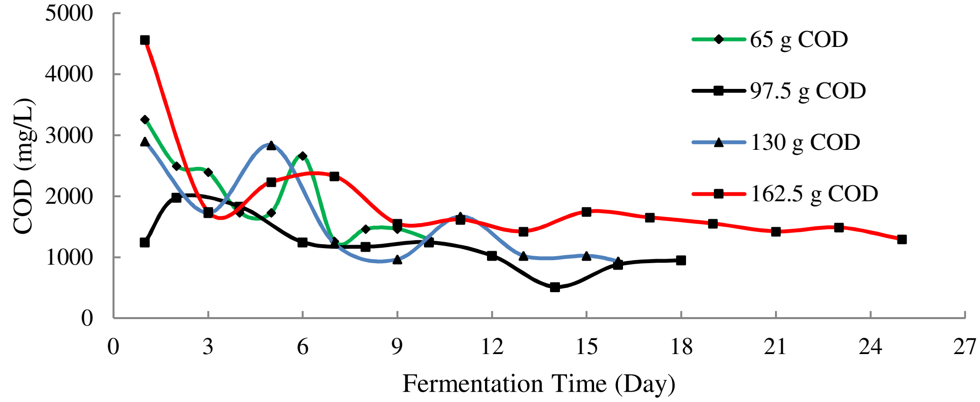

Fig.-4: The influence of the COD loading on the change of value of COD.

Mixed Liquor Suspended Solids (MLSS)

Different COD loading rates produced a decrease in different value of different MLSS, as shown in Figure 5. By using the TSA reactor, the value of MLSS, which was around 1,900–2,000 mg/L, decreased to 80–500 mg/l. The value of MLSS was one of the parameters used to determine the number and the activity of microbes, the change of MLSS value that signaled the existence of microbe metabolism in the reactor [14].

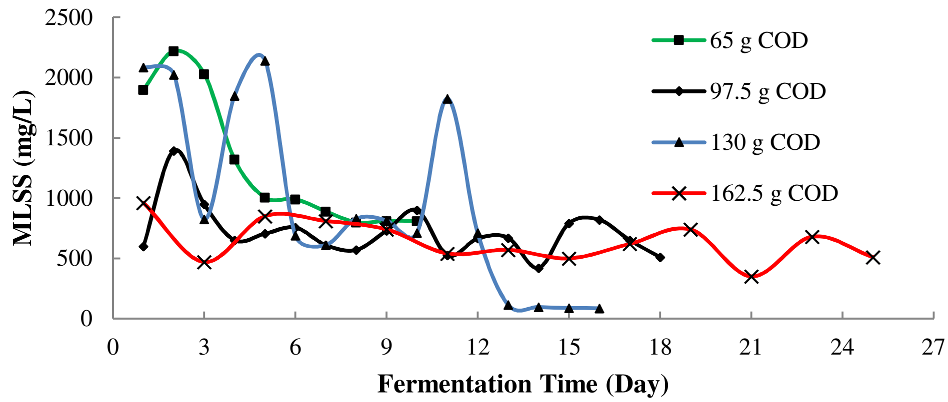

Fig.-5: The influence of the COD loading rate on the change of the value of MLSS.

Besides being influenced by the COD loading rate, the decrease in the value of MLSS was also influenced by the process of stirring. The research conducted by Zabranska et al.[15] showed that the process of stirring could increase the efficiency of the reactor by up to 40% because of homogeneity and the short-circuiting effect.

Mixed Liquor Volatile Suspended Solids (MLVSS)

MLVSS is a part of MLSS, and it can be used as a parameter to determine microbe activity [9]. The decreasing value of MLVSS is directly proportional to the decreasing value of MLSS. The value of certain types of MLVSS in the reactor shows the existence of biomass production by the bacteria[16,17]. The influence of the COD loading rate on the change of value of MLVSS is shown in Figure-6.

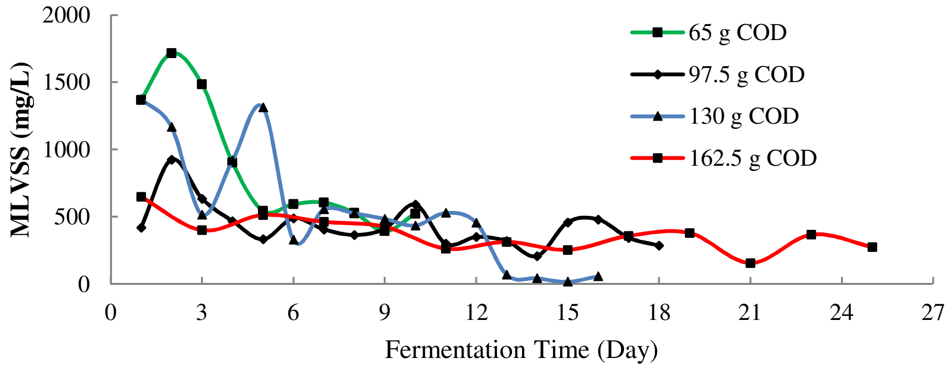

Fig.-6: The influence of the COD loading rate on the change of value of MLVSS.

NH_3-N

Figure 7 shows the influence of the COD loading rate on the change of value of NH_3-N. The value of NH_3-N increased as time progressed as a result of the process of hydrolysis in the organic component because of the loss of ammonia and nitrogen. Different COD loading rates showed different values of NH_3-N. The higher was the value of the COD loading rate, the higher was NH_3-N produced because of the higher amount of organic component that could be turned into ammonia and nitrogen [18].

In this research, an insignificant decrease in the value of NH_3-N occurred. The decreasing value of NH_3-N was influenced by the type of bacteria used in the TSA reactor. The concentration of NH_3-N in the TSA reactor remained within the range of 50–350 mg/L. The presence of ammonium in the process did not influence the amount of biogas produced [11].

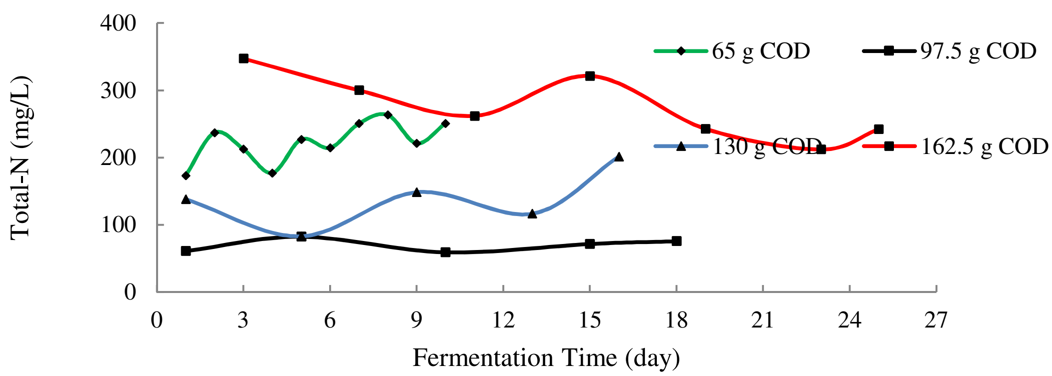

Fig.-7: The influence of the COD loading rate on the change of value of NH_3-N.

pH

Basically, concentration of hydrogen ion plays an important role in the biological processes[19].In this research, the pH value increased through time because of the activity of the bacteria. The increasing pH value was not too high within the range of 0.2–0.5 from 6.9–7.4. The value of pH remained neutral inobtaining optimal condition. The value of the COD loading did not influence the pH of the tofu waste.

CONCLUSIONS

The result of the research showed that the variations of COD loading produced different reactor performances. It showed that COD loading influenced the activity of thermophilic anaerobic bacteria in producing biogas. It also showed that the production of biogas increased along with the increasing amount of COD loading. The best value of COD loading was 162.5, and it can produce 94.71 L of biogas. The biogas produced contains methane (79.5%), CO_2 (20%), and CO (0.5%). The high composition of CH_4 and the low CO_2 can be used directly to run a generator.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from the Ministry of Research, Technology, and Higher Education of Indonesia, under grand research from the International Research Collaboration and Scientific Publication. Publication Grant No. 035/SP2H/PL/Dit.Litabmas/II/2015.

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[RJC-1397/2016]