



Effect of Discontinuing Sodium Bicarbonate on Fermentation Process of Palm Oil Mill Effluent

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The aim of this research is to investigate the effect of discontinuing sodium bicarbonate on the fermentation of palm oil mill effluent to biogas. This research was conducted in a two liters continuous stirred tank reactor at thermophilic temperature of 55 °C. Fresh palm oil mill effluent from Adolina mill without further treatment was used as feed. The result showed that at hydraulic retention time of 6 days and discontinuing of sodium bicarbonate addition, there was no significant effect on the production of biogas, change of pH, volatile solid and total solid degradation, except alkalinity. By discontinuing sodium bicarbonate, biogas production was in the range of 4-6 L/day, while by adding sodium bicarbonate was 6-10 L/day. About 45 % of volatile solid degradation by discontinuing of sodium bicarbonate addition was obtained during the digestion, while by using sodium bicarbonate was 55 %. pH of digester was relatively stable with average value was 6.7 and alkalinity was 2000 mg/L.

Keywords: Anaerobic, Biogas, Palm oil mill effluent, Sodium bicarbonate, Thermophilic, Hydraulic retention time.

INTRODUCTION

Palm oil industry in Indonesia is growing rapidly. This is shown from the total area of oil palm plantation in Indonesia that increased to 9,074,621 ha and crude palm oil (CPO) production was 23.5 million tons in 2012 [1]. It makes Indonesia become one of the countries with largest production of crude palm oil. As the consequence, new problem appears where more wastes are generated. One kind of the wastes produced by palm oil mill in large numbers is palm oil mill effluent (POME). Fresh palm oil mill effluent coming out from fat pit is hot (80-90 °C), typically has biological oxygen demand (BOD) of 20,000-25,000 mg/L, chemical oxygen demand (COD) of 40,000-50,000 mg/L and pH 3.8-4.5. Generally for one tonne of fresh fruit bunch (FFB) produces about one ton of palm oil mill effluent [2].

Nowadays, anaerobic digestion process becomes a popular method to treat palm oil mill effluent. This method involves a group of microorganism digesting organic matters to produce methane and carbon dioxide as major components in biogas. One of the key factors to successfully control the stability and efficiency of an anaerobic reactor is pH [3].

In the anaerobic process, the pH conditions required by methanogenic bacteria are in the range 6.5 to 7.5 [4]. To maintain this pH in the range of conditions required by microorganisms to live, the alkalinity is usually adjusted by

adding carbonates. There are several types of carbonates that commonly used such as, sodium bicarbonate, sodium carbonate, sodium hydroxide, magnesium oxide and lime. The sodium bicarbonate is the most commonly used chemical in anaerobic process, because its high solubility and lack of the need for CO₂ neutralization make it easy to use with little risk [5].

Some studies about anaerobic process for the treatment of palm oil mill effluent have used NaHCO₃ to adjust the pH within the optimum range for anaerobic microbial growth [6-10]. Choi *et al.* [11] reported that 10 g/L of NaHCO₃ was added to the fresh palm oil mill effluent before it was fed into the anaerobic hybrid reactor (AHR). Palm oil mill effluent pH increased to 7.1 from an initial level of 3.9. Then, after the 7th week, NaHCO₃ was not added anymore. Chan *et al.* [12] also reported in their experiment to treat palm oil mill effluent using sequencing batch reactor (SBR), without pH adjustment the operating pH increased from 7.4 up to the values ranging between 8.33 and 9.14 and then it remained constant. No research has been conducted in order to investigate the effect of NaHCO₃ on the digestion performance from the fermentation of palm oil mill effluent. For this purpose, a series of experiments by performing the termination of addition NaHCO₃ was conducted, therefore the effect on biogas production, changes in pH and alkalinity were known.

EXPERIMENTAL

The material used in this study was palm oil mill effluent taken from a fat pit of palm oil mill's wastewater treatment facility belongs to Adolina palm oil mill PTPN IV, North Sumatera, Indonesia. The characteristics of palm oil mill effluent used in the experiment are shown in Table-1. While, anaerobic digested wastewater taken from anaerobic pond of the same treatment facility was used as inoculum. As supporting materials were NaHCO_3 , hydrochloric acid solution, metallic solution of trace metal; FeCl_2 , $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ and $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$. The addition of FeCl_2 is to minimize H_2S production and the addition of $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ and $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ are required for anaerobic microbial metabolism.

TABLE-1
CHARACTERISTICS OF PALM OIL MILL EFFLUENT

Parameters	Values
pH	4.5
Total solid (mg/L)	42,173
Volatile solid (mg/L)	33,390
Chemical oxygen demand (mg/L)	42,000
Biological oxygen demand (mg/L)	23,000
VFA (mg/L)	4,510
Oil and grease (mg/L)	3,700

General procedure: The anaerobic digestion of the experimental laboratory set-up for the fermentation of palm oil mill effluent is shown in Fig. 1. The fermentation was performed in a 2 L capacity transparent jar digester (EYELA, Model MBF 300ME) which was provided with double walled water jacket to control the temperature, valves for sampling, conduit for discharge and feeding, turbine propeller and alarm indicator bulb anticipating temperature disorder. A data logger (KEYENCE, Model NR-250) was connected to computer to enable automatic recording of temperature and pH, provided by censoring equipment attached to digester [13].

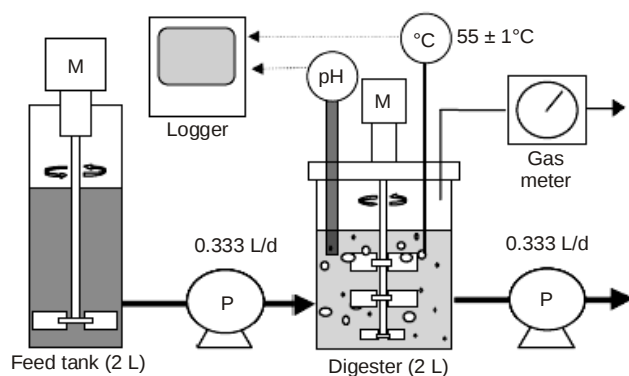


Fig. 1. Anaerobic digestion of the experimental laboratory set-up

This research was performed by two mayor steps; loading up and main experiment.

- The loading up process took about 12 days to reach hydraulic retention time of 6 days. During the loading up, 2.5 g/L NaHCO_3 , 0.49 mg/L $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ and 0.42 $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ were added into the feed tank
- After hydraulic retention time 6 days was reached the addition of NaHCO_3 was stopped, except the addition of $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ and $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$.

Experimental design of this experiment was shown in Fig. 2.

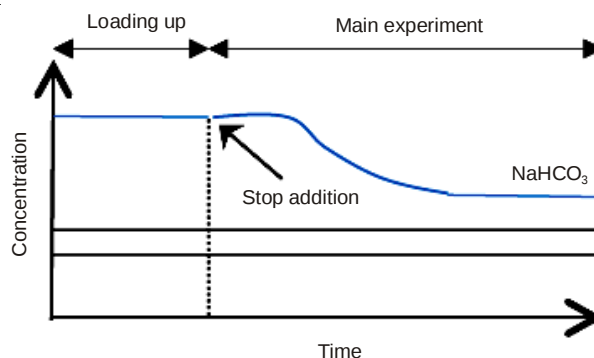


Fig. 2. Experimental design

During the experiment, feeding and discharging were carried out automatically six times in a day, having an interval of four hours (intermittent).

Detection method: Loading up was carried out based on the increased production of biogas which measured by using a wet gas meter (SHINAGAWA, Model W-NK-0.5B). If biogas production raised by 20 % then the loading up was increased by 20 % as well, until hydraulic retention time 6 days was achieved. Concentrations of H_2S and CO_2 in the biogas were measured by using a suction gas injector (GASTEC, type GV-100S) and inspection tube (GASTEC, 25-1600 ppm). Temperature and pH were measured using a connected thermocouple and pH probes and then acquired in a data logger (KEYENCE, Model NR-250). To ensure the accuracy, pH electrode was calibrated once in two weeks. The measurement of total solid, volatile solid, alkalinity and pH value were in accordance with standard methods for the examination of water and wastewater [14].

RESULTS AND DISCUSSION

Biogas production: The measurement of biogas production during the fermentation process was carried out by using a wet gas meter (SHINAGAWA, Model W-NK-0.5B). During the loading up, 2.5 g/L NaHCO_3 was added to the digester, since palm oil mill effluent used in this study was acidic with a pH around 4.5.

Fig. 3 shows biogas generation during the fermentation process. As shown in Fig. 3, biogas generation increased from the 1st day to the 11th day where the initial hydraulic retention time was 60 days. The biogas production increased as hydraulic retention time decreased. The biogas production increased from 3.02 L/day to 9.01 L/day as hydraulic retention time decreased from 20 days to 6 days. The increase of biogas production was due to the higher loading rate with shorter hydraulic retention time.

After hydraulic retention time 6 days was reached on the 11th day and stable data were achieved, shown by the stable production of biogas on the 40th to 50th day, the addition of NaHCO_3 was stopped. After the addition of NaHCO_3 was stopped on the 50th day, the gas generation decreased gradually, although, until the 65th day the gas production was relatively high, in the range of 7 to 8 L/day. This high biogas production

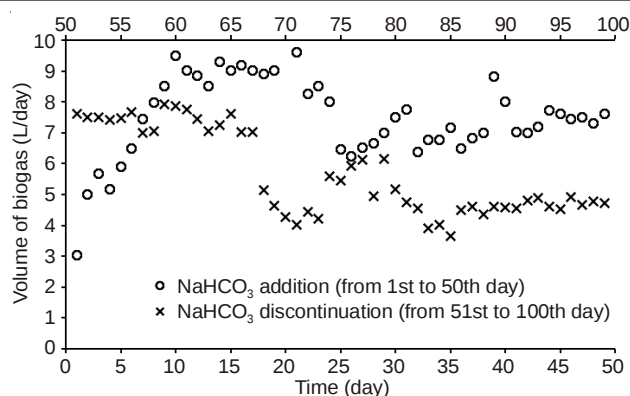


Fig. 3. Effect of the addition and discontinuation of NaHCO_3 on biogas production

could still be obtained because biogas producer microorganisms were still stable since environmental condition was sufficient for the needs in the activity of methanogenic bacteria. From the 66th day biogas production kept on decreasing until the 70th day and then fluctuating until the 85th day indicating that the performance of the digester was not stabilized during this period. Although no troubles were occurred to the equipment or controller of the digester.

From the 86th day until the 100th day of the experiment, biogas production was stable at about 4.5 L/day, decrease 36 % from the highest biogas production. This is giving indication that microorganism condition has been stable.

Effect of discontinuation of NaHCO_3 on alkalinity:

Alkalinity is a measure of the capacity of water to neutralize acids. In wastewater treatment, alkalinity is an important parameter in determining the amenability of wastes to the treatment process and control of processes such as anaerobic digestion.

Fig. 4 shows the profile of alkalinity by adding and discontinuing NaHCO_3 in the fermentation of palm oil mill effluent. Alkalinity increased from the 1st day to the 75th in the range of 4000 to 5000 mg/L and then relatively stable at the value of 5000 mg/L. For discontinuing NaHCO_3 system, the highest alkalinity value was achieved at the beginning of the process, on the 51st day. It was occurred because there was still supply of bicarbonate. After that, alkalinity values decreased, indicating sodium bicarbonate was reduced in the digester, as the consequence the microbes in digester might not work as good as at the beginning of the process.

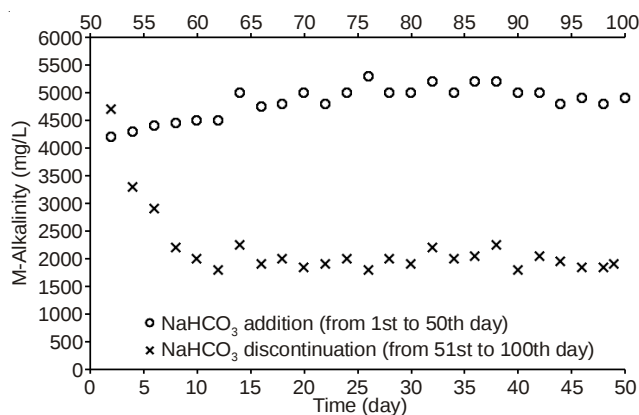


Fig. 4. Effect of the addition and discontinuation of NaHCO_3 on alkalinity

From the 58th day until 100th day, the average alkalinity values by discontinuing NaHCO_3 was 2000 mg/L, which is the lower limit of appropriate alkalinity values for effective anaerobic digestion process [15].

Effect of discontinuation of NaHCO_3 on pH: In the anaerobic process for biogas production requires a condition for the methane-forming microorganisms to live and multiply. One of the conditions that must be maintained is the pH of the anaerobic treatment system. The pH must not be allowed to fall below 6.2 as it begins to impede the methanogenic bacteria, or in the range of 6.5 to 7.5 [16]. To maintain the pH in the range required by microorganisms in order to live, then the alkalinity should be maintained by adding NaHCO_3 .

During the early period of this experiment, 2.5 g/L NaHCO_3 was added to the fresh palm oil mill effluent before it was fed into the digester. The palm oil mill effluent pH increased to approximately 7.1 from an initial level of 4.5. No significant difference of pH values was occurred, from the 1st day until the 50th day of the fermentation process for system by adding NaHCO_3 .

Fig. 5 shows the profile of pH inside the digester by discontinuing NaHCO_3 . Sodium bicarbonate was not added anymore after the 50th day. By discontinuing NaHCO_3 , pH of digester decreased slightly but not significantly. They were still in the range that is allowed for the anaerobic fermentation (6.5 to 7.5). Average pH value was 6.7.

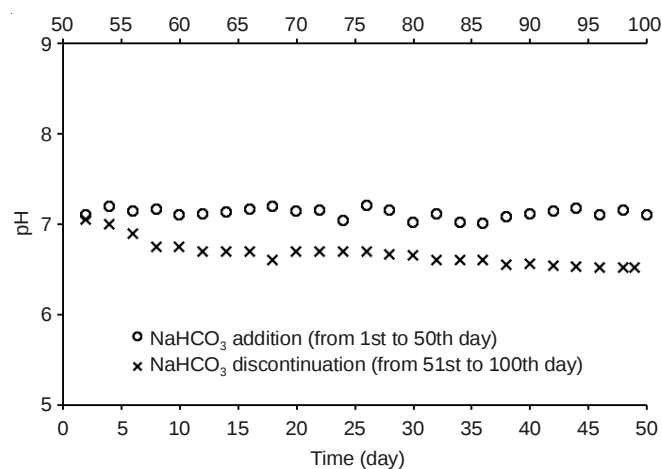


Fig. 5. Effect of the discontinuation of NaHCO_3 on pH

Volatile solid and total solid degradation in the digester:

Volatile solid is the solid part of wastewater that turned into a gas phase on the acidification and methanogenesis stages in the fermentation of organic waste and biogas production. It can be referred to the percentage of volatile solid.

Fig. 6 shows the effect of discontinuing NaHCO_3 on the volatile solid degradation. As shown on Fig. 6, the average results of the volatile solid degradation by discontinuing NaHCO_3 was 45 %, while by adding NaHCO_3 was 55 %. It is known that the system by discontinuing NaHCO_3 still resulted good volatile solid degradation.

Total solid is the amount of organic and inorganic solids contained in the liquid waste. Fig. 7 shows the effect of discontinuing NaHCO_3 on total solid degradation. From Fig. 7 it shows that total solid values from the both graphs basically

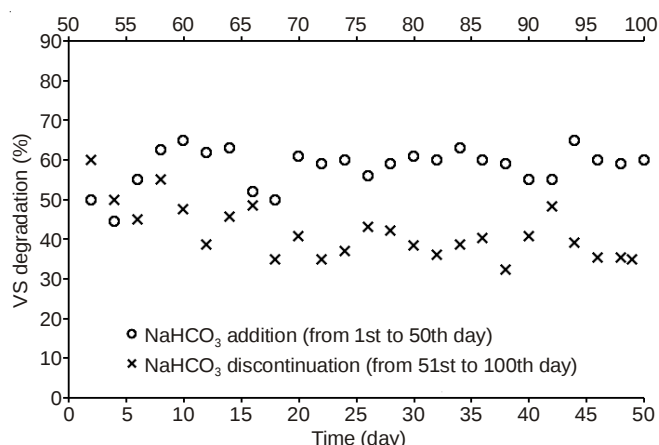


Fig. 6. Effect of the addition and discontinuation of NaHCO_3 on volatile solid degradation

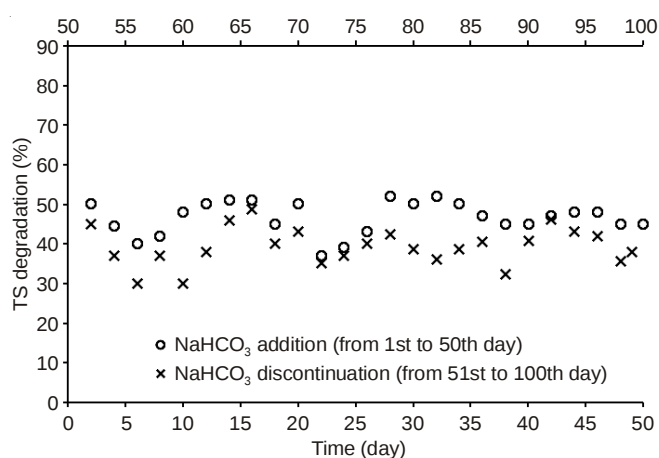


Fig. 7. Effect of the addition and discontinuation of NaHCO_3 on total solid degradation

have almost similar trend. However, the result obtained by adding NaHCO_3 has total solid profile slightly higher than by discontinuing NaHCO_3 . From the experiment, average value obtained for total solid degradation by adding NaHCO_3 was 47 % while by discontinuing NaHCO_3 is 39 %.

Conclusion

The termination of addition of sodium bicarbonate to the fermentation process of palm oil mill effluent although decrease the digester performance such as reduction of biogas production, alkalinity values, pH level and degradation of volatile solid and total solid, but they were still in the range of appropriate values for the good anaerobic fermentation.

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