Biogas Production from POME By Using Low Intensity Sonic Wave

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***Abstract*— Ultrasonic wave is the new technology that had been used as a pre-treatment to POME to enhance the solubility of organic matter by breaking down the large molecule in order to ease the anaerobic digestion by bacteria to produce high biogas yield. During the sonication of POME, there was release of gas happen because of the cavitation that created gas and vapor bubbles. The type of gas produce was been identified in order to know the value of the gas in terms of biofuel potential gas from the sonication process. Four samples of POME were conducted in the experiment and categorize as treated and the untreated POME. The treated POME undergoes sonication while the untreated POME act as a reference sample. The gas release from sonication of POME was examine to identify any presence of useful biogas that can be used as biofuel such as methane gas without need to go through anaerobic digestion. Based on the result obtained, the gas yield mostly consist of bio-alcohol and some long chain alkanes based compound that were still acceptable to be used as biofuel. It was discovered that POME with sonication treatment produce higher amount of biofuel potential gas compared to the unsonicated POME.**

Keywords*— POME, Ultrasonic Sonic Wave, Anaerobic Treatment, Bacteria, Temperature, Gas Compound, Treated POME, Untreated POME

I. INTRODUCTION

Palm oil industry has become one of the significant agriculture-based industries in Malaysia. The palm oil mill industry in Malaysia has practiced continuous and progressive development in that made the country being the second largest palm oil supplier in the world after Indonesia [1]. The production of palm oil from fresh fruit bunch (FFB) will contribute to the generation of palm oil mill effuent (POME). Based on 2016 MPOB statistic on palm oil production stated that the crude palm oil total production in 2016 was 17,319,177 ton. For every ton processed of fresh fruit bunches (FFB) it produce approximately 0.65 ton of raw POME [2], [3]. The encouraging growth of palm oil mill leads to negative effect towards the environment because of the identification as the largest contribution for discharging the major waste pollution in the form of POME [1]. POME is a traceable point source of water pollutant that consists of high COD and suspended solids with high content of organic matter and pathogenic organisms [4].

The treatment of POME is an alternatives action to minimise the discharges of wastewater, recycle the POME, and can improve the methane so as to reduce the greenhouse gas releases problem. It was been discovered by many researchers that the pre-treatment of POME by using ultrasonic wave before undergoes anaerobic digestion gives a high yield of methane and other valuable biogas. Ultrasonic treatment is a renowned method for degrading the microbial cells to discharge the intracellular materials [5]. The ultrasound treatment can cause the organic compounds change from solids into aqueous phase that leads to the reduction of particle size that make the organic matter more soluble thus improve biodegradability by the bacteria and subsequently increase the methane yield. Acoustic cavitation is a growing of a nucleus in a liquid, and the following collapse will formed gas bubble [6], [7]. The collapse that occur in just microsecond is considered as adiabatic. The temperature and pressure were rise inside the bubbles due to the gas compression. The amount of energy reach is high during the collapse that cause of several thousand of Kelvin [8], [9]. The generation of pressure by the ultrasound wave will create a high amount of energy to produces gas and vapour bubbles, growing and collapsing aggressively at high velocity. During the collapse and after the bounces, the energy is distributed to the surrounding to allow the temperature of the gas in the hot spot rapidly return to the ambient value.

Luminescence of the bubbles is a usual phenomenon that may observed during the cavitation [10], [11], [12], [13], high heating and cooling rates [10], production of radical [14], [15], [16], high strain rates near the bubble wall [17], streaming of the liquid around the bubble [18] and the formation of liquid jet [19], [20]. Dissolved gas exist in a form of nuclei in the liquid. The dust particles will stabalize the nuclei, or by solid parts in the system, or by amphiphilic molecules or other contaminations [21]. The physics and chemistry of nonlinearly oscillating acoustic cavitation bubbles are intensely influenced by the dissolved gas in the surrounding liquid [22]. In this study, the generation of gas from POME by using sonic wave was been tested and analyzed in order to examine the presence of biofuel potential gas from sonication process without need to undegoes the anaerobic digestion.

II. METHODOLOGY

A. POME Sample

10 liters of POME was collected at the Sime Darby Plantation Carey Island Port Klang at the effluent of the palm oil mill production and the POME sample was been left for three month in a 10 liter plastics container with sealed cap before the experiment was been conducted. During the experiment, the sample was been grinded by using blender in order to ease the solubilisation and the sonication process since POME consists of water and mostly insoluble suspended solid. Fig 3.1 and 3.2 shows before and after grinded POME respectively. From the experiment conducted, POME sample was been divided into two category which are the untreated and the treated POME. Low intensity sonic wave was been used to treat the POME sample. The untreated POME act as a reference to compared the biogas production with the treated POME.

Fig. 1: Before grinded POME

Fig. 2: After grinded POME

Two sample of the untreated POME (both 1ml) were prepared and one of them was been heated up into 40ºC while the other one was heated up into 50ºC. Both sample were been heated up for 10 minutes. The gas produce from both of the sample will be collected and tested using gas chromatography-mass spectrometry (GC-MS). Fig 1 shows 1ml of POME sample been heated up to 40ºC for 10 minutes by using hot plate.

Fig. 3: Heated POME sample on hot plate

Meanwhile for the treated POME, were divided into two types of sample which were the filtered POME and the unfiltered POME. Filter paper was used to filter the POME sample to remove the suspended solid presence and to collect preceding solution produce from the POME. Fig 2 and 3 shows the filtered POME and the solution of POME after filtration respectively. Both the unfiltered POME and the subsequent solution produce from the filtered POME were sonicated and the gas collected will be tested by using GC-MS.


Fig. 4: Filter POME using filter paper.

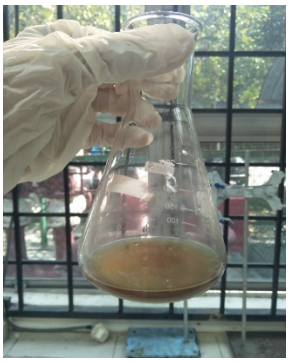


Fig. 5: POME solution after filtration.

B. Ultrasonic wave Treatment

The two sample of filtered and unfiltered POME (both 10ml) will be sonicated using 500W with 20kHz operating frequency ultrasonicator. Each of the sample was been place inside the sonicator and the sonication process was been left for 3 minutes. Fig. 6 shows the sonicator used in sonication of POME. The gas tube at the sonicator was connected with a peristaltic pump by using a transfer pipe and the upper part of the sonicator was been sealed by using rubber gloves and rubber band in order to maintain the amount of biogas produce inside the sonicator within 3 minutes period. Fig. 7 and 8 shows the transfer of gas produce from sonication by peristaltic pump into the gas bag. After 3 minutes the biogas produce inside the sonicator was been pump by peristaltic pump to transfer the gas into the gas bag. The gas collected was been tested by using GC-MS.


Fig. 6: Sonicator for sonication of POME


Fig. 7: Transfer of gas from sonicator into the gas bag by peristaltic pump


Fig. 8: Gas bag used to collect gas.

III. RESULTS AND DISCUSSION

Based on the experiment conducted, there were four types of sample that have been tested by using GC-MS in order to identify the type of gas produce from the different types of condition in the experiment. Based on the GC-MS result, it shows that the gas produced from both treated and the untreated POME consist of many amount of various long chain compound that mostly not suitable to be used as biofuel. The gas component discovered mostly consist of bio-alcohol and does not contain any pure biofuel component such as methane, ethane, propane or butane but it comprise of long chain compound with very little similarity with the pure biofuel component. The data extracted from the GC-MS was selected based on the simplest type of component presence that have potential to be flammable gas and have similarity with biofuel gas such as methane, ethane, propane and butane. Apart from that, long chain compound exists as easily volatile liquid and bio-alcohol that have potential to act as flammable gas was also been listed in the table below and can be considered as valuable gas compound that have potential to be biofuel.

Based on Table 1, the sonicated unfiltered POME produce highest amount of potential biofuel with various type of compound compared to the unsonicated POME. Propagation of the ultrasonic wave in aqueous solution (basically known as sonolysis) containing

a solute can cause in an oxidation process, which is called sonochemistry [23]. Most liquids including water and water-based liquids contain at least some dissolved gas [24]. Thousands of microscopic vacuum bubbles was form in the solution due to the cycles of pressure during the sonication process. The bubbles collapse into the solution in a process known as cavitation that is, the growth and formation of microscopic bubbles that collapse violently in a medium of liquid by ultrasonic wave radiation [25]. A barely adiabatic condition is created by the microbubbles fast collapse. This cause a powered microreactor exist inside each of the bubbles with temperature of several thousands of Kelvin and pressure of several hundreds of atmospheres that were reached [6]. This causes a release of a massive force of energy in the cavitation field, which interrupts molecular interactions such as interactions between molecules of water and separates clumps of particles [26]. As a result, the trapped molecules in the bubble (water vapor, gases and vaporized solutes) were brought to an exited state and dissociated. Thus for dissolved gases in POME, the gas bubbles combine together and collapse and easily leaves the solution as a gas that was been collected and tested. Based on the result obtained most of the gas consist of bio-alcohol and some alkanes based gases that has potential to be combustible gas or biofuel. The sonication process increase the production of potential biofuel gases in a short time (3 minutes) because of the particles in the solution are broken down by extreme hydro-mechanical forces in the solution [27]. According to [26], sonication breaks apart molecules and rupture the cells. Therefore, the gas formation during sonication can also come from the breaking apart molecules in POME that combine to become other molecule gases with biofuel potential.

Table 1: Unfiltered POME with Sonication Treatment

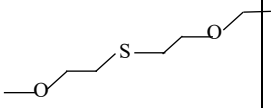
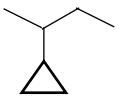
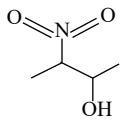
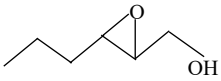
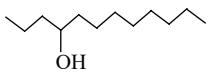
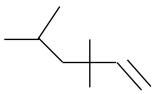
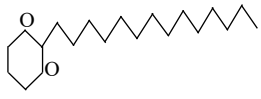
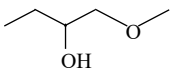
Unfiltered POME With Sonication Treatment					
No.	**Chem. Name**	**Chem. Formula**	**Chemical Structure**	**Comp. Amount (%)**	**Comp. Amount (ml/L)**
1	Ethane,1-methoxy-2-(2-methoxyethyl)-	$C_6H_{14}O_2S$		0.0872	872
2	Butane,2-cyclopropyl	C_7H_{14}		0.533	5330
3	3-Nitro-2-butanol	$C_4H_9NO_3$		0.0226	226
4	2,3-Epoxyhexanol	$C_6H_{12}O_2$		0.0220	220
5	4-Dodecanol	$C_{12}H_{26}O$		0.0210	210
6	1,3,3,5-Trimethyl-1-hexene	C_9H_{18}		0.00226	22.6
7	2-Pentadecyl-1,3-dioxane	$C_9H_{38}O_2$		0.0872	872
8	1-Methoxy-2-butanol	$C_5H_{12}O_2$		0.00872	87.2

Table 2: Filtered POME with Sonication Treatment

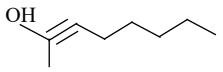
Filtered POME With Sonication Treatment					
No.	**Chem. Name**	**Chem. Formula**	**Chemical Structure**	**Comp. Amount (%)**	**Comp. Amount (ml/L)**
1	3-Decyn-2-ol	$C_{10}H_{18}O$		0.408	4080

Table 3: POME without Sonication Treatment (50°C)

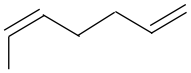
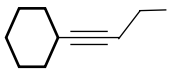
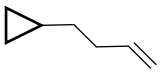
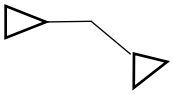
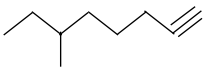
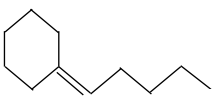
POME Without Sonication Treatment (50°C)					
No.	**Chem. Name**	**Chem. Formula**	**Chemical Structure**	**Comp. Amount (%)**	**Comp. Amount (ml/L)**
1	1,5-Heptadiene	C_7H_{12}		0.105	1050
2	1-Pentynylcyclohexane	$C_{11}H_{18}$		0.095	950
3	3-Butenylcyclopropane	C_7H_{12}		0.085	850
4	Methane, dicyclopropyl-	C_7H_{12}		0.075	750

Table 4: POME without Sonication Treatment (40°C)

POME Without Sonication Treatment (40°C)					
No.	**Chem. Name**	**Chem. Formula**	**Chemical Structure**	**Comp. Amount (%)**	**Comp. Amount (ml/L)**
1	7-Methyl-1-nonyne	$C_{10}H_{18}$		0.00116	11.6
2	4-Cyclohexyldene-1-butanol	$C_{10}H_{18}O$		0.00115	11.5
3	2,4-Nonadien-1-ol	$C_9H_{16}O$		0.00563	56.3

Based on Table 3 and 4, the heated POME at 50°C without sonication produced high amount of potential biofuel compound compared to POME that was been heated at 40°C without sonication treatment. This is because high temperature increase the kinetics energy for the dissolves gases to escape from the POME solution thus increase the gas formation. Apart from that, increase at certain temperature can facilitated the activities of bacteria to digest the organic compound and release the gas. While for the filtered POME with sonication treatment produce the lowest amount of potential biofuel compound compared to the other three sample. Based on the observation there were very few of biofuel potential compound exits from this sample. This result may cause by the insufficient of nutrients in the medium for the bacteria to grow and digest the waste as we remove all the suspended solid from the POME. Wastewater with high organic content can serve as raw material for biogas production.

However, due to low solubilisation of organic matter an enormous amount of valuable end product (biogas) is not recovered [28]. Nevertheless, the amount of potential biogas gas created without sonication was much lesser and need more time (10minutes) compared to the biogas produce from the sonicated POME.

IV. CONCLUSION

Based on the result observation most of the gas produce was from bio-alcohol and some alkanes based compound. The compound selected was based on high volatility and biofuel potential compound. During the sonication treatment, there were no any pure biogas compound such as methane, ethane or propane that is considered as valuable type of biogas exist. The presence of this compound from the experiment may cause by partially aerobic or anaerobic bacterial digestion that release some of the partially converted biogas. The partially converted may cause by the improper condition (less oxygen) with no mixing inside the container for the bacteria to digest the organic matter. This lead to the bio-alcohol production that dissolved in the POME solution. POME contain high organic matter due to the presence of different sugars such as glucose, xylose, manose, galactose and arabinose [29]. Since POME was kept in a container with limited oxygen and it contain various types of microorganism, the bacteria in POME can covert the sugar into alcohol such as ethanol or butanol under lack of oxygen content. *S. Cerevisiae* is a type of fungi that can lives in anaerobic and aerobic condition with ability to ferment a sugar and convert it into alcohol and carbon dioxide in poorly supplied oxygen condition [30]. This fungi can be found all around the world such as on the surface of fruits and plants, in the soil, the gastrointestinal tract of animals, and the skin surface of animals [31]. As POME consist of mostly water and bio-alcohol is less dense than water, thus the alcohol can exits as dissolved gas in POME. Some of the alcohol was created and mix with the POME solution during the three month POME was kept inside the plastic container. During the sonication process, the bio-alcohol was converted into gas due to the acoustic cavitation that cause generation of pressure by the ultrasound wave that created a high amount of energy that converted the dissolved gases into free vapor.

Apart from that, the result also shows the presence of alkane base compound that was considered to be similar with methane gas. This presence may cause by the anaerobic bacteria that digest the organic matter in POME and convert it into alkane base compound and it was kept in POME as dissolved gases. In anaerobic digestion, methane gas produce at the methanogenesis stage. Unsuitable condition of POME during three month period in the plastic container (no mixing with limited oxygen) cause the improper digestion of organic matter and lead to the limitation of pure methane production. However according to the result observation, by using low frequency ultrasonic wave, the release of potential biogas amount was high in just a few minutes (3 minutes) compared to the POME sample without sonication. Therefore sonication is an efficient alternatives to fasten the release of dissolved gases. However, high yield of biogas from POME cannot be done by just using the sonication but it has to undergo a proper anaerobic digestion. Instead, sonication is just a pre-treatment to enhance the solubility of the organic matter by breaking the large molecule in waste in order to facilitate the digestion of organic matter by the anaerobic bacteria to produce methane gas.

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