Methane Production from Poultry Waste; Effect of Different Types of Pre-treatment

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***Abstract*—Anaerobic digestion (AD) of biomass is a well-established process to produce renewable energy, where organic matter is converted to biogas by microorganism. High solid content and complex structure of sludge-derived organic matter, methane production during digestion is limited at the hydrolysis step. Therefore pre-treatment of substrate is a way to accelerate the hydrolysis step. This study aimed to identify the optimum pre-treatment method to increase the methane production from poultry waste prior anaerobic digestion. The poultry waste was mixed with water, pre-treated, seeded with inoculums. Chemical and thermochemical pre-treatment were performed with NaOH and $Ca(OH)_2$. The AD was conducted in bioreactors and incubated in water bath at 37 °C for 15 days. Results obtained show that the highest methane yield was at the thermochemical pre-treatment with $Ca(OH)_2$ with cumulative amount of methane at 1665.17 ppm followed by chemical pre-treatment with $Ca(OH)_2$, thermochemical pre-treatment with NaOH and chemical pre-treatment with NaOH with cumulative amount of methane at 1381.76 ppm, 884.07 ppm and 607.98 ppm respectively. Based on the comparison of the results, the thermochemical pre-treatment with $Ca(OH)_2$ is the best pre-treatment as it produced the highest methane yield.**

***Index Terms*— Anaerobic digestion, poultry waste, pre-treatment.**

I. Introduction

Worldwide countries are facing two major problems; environmental deterioration caused by increment of solid waste and inadequate amount of energy supply [1].

Most of the countries in Asia are experiencing issues on the disposal of poultry waste especially from the slaughter houses. Malaysia Poultry and Product Annual Report (2014) stated that the consumption of poultry meat in Malaysia has been forecasted to be among the highest consumption in the world at over 40 kg per year, per capita consumption. Poultry meat is the most popular source of meat protein as it can be consumed by all religion unlike pork and beef. Most of the food service outlet also offering poultry meat in their services as the price is cheaper than pork and beef which explained the high demand of poultry meat [2].

When the poultry production keep increasing, the solid by-products and waste such as poultry manure, poultry litter (bedding materials), offal (feathers, entrails, organs of slaughtered birds, wastewater and bio solids are also increased [3]. Poorly managed of these organic by-products and waste could leads to environmental problems such as nutrient leaching, eutrophication and emission of greenhouse gases such as carbon dioxide and methane [4].Anaerobic digestion is a biological process by microorganisms that breakdown biodegradable materials in the absence of oxygen. Anaerobic digestion is one of the biotechnologies for organic treatment which is efficient in reducing waste and pathogens while producing renewable energy [5]. So, anaerobic digestion could solve both of the problems. Anaerobic digestion process consist of four steps; hydrolysis, acidogenesis, acetogenesis and methanogenesis [6].

Through hydrolysis step, insoluble and complex organic compounds such as lipids, large polymers, namely proteins, fats and carbohydrates were broken down into smaller molecules such as amino acid, fatty acids and simple sugar. In acidogenesis step, microorganisms will further break down the product of hydrolysis into acetic acid, hydrogen, carbon dioxide, some volatile fatty acids (VFA) and alcohols. Next step is acetogenesis where the acetogens catabolize the long chain fatty acids and volatile fatty acids into acetate, hydrogens and carbon dioxide. In the final step of anaerobic digestion, methanogens converted acetic acid, hydrogen and carbon dioxide into methane and carbon dioxide [7].

In anaerobic digestion, complexity of organic material could be one of the limiting steps. In order to break down the complex organic material, pre-treatment can be done. Pre-treatment of biomass will increase the particle size reduction, increase solubilisation, and make it more susceptible for microbial degradation [8]. Two examples of pre-treatment are chemical and thermochemical pre-treatment with alkali. For the chemical pre-treatment with alkali, addition of alkali will cause the lignocellulose to swell and the lignin partially solubilize [9] while for the thermochemical pre-treatment, it is the combination of chemical and heat to pre-treat the sample. When chemical is combined with thermal treatment, the solubilisation of the organic molecules is higher [10].

Renewable energy produced from anaerobic digestion process can be integrated with smart grid technology. Smart grid is a technology of delivering the electricity by incorporation of communication technology, computer processing and renewable energy with controlled automation system [11]. Smart grid allows communication among power generators with electricity consumers and makes the electricity distribution more efficient, quicker restoration of electricity after power disturbance, reduce the electricity rates and improve security [12].

II. MATERIALS AND METHODS

A. Sample collection

Poultry waste used in this experiment consists of chicken fats and chicken intestines collected from a chicken slaughtering house in Meru, Klang, Selangor. It was then blended with water at ratio of 2: 1 (water to poultry waste) by using Waring Commercial blender until it became slurry. This sample was

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kept below 4 ^{o}C until further experiment.

B. Sample preparation

For the preparation of chemical pre-treated sample, the blended sample (slurry) was pre-treated with two different alkali, NaOH and $Ca(OH)_2$ separately. This pre-treatment was performed by adding 0.2 g alkali/ g poultry waste, mixed them thoroughly and left to react for 120 minutes [13].

Thermochemical pre-treatment was done by repeating the chemical pre-treatment mentioned above. This batch of pre-treated samples was then heated at the temperature of 90 ºC for 120 minutes [13].

In order to improve the anaerobic digestion process, inoculum was added to the sample [14]. Inoculum used in this experiment was palm oil mill effluent (POME) that was collected from Tuan Mee Palm Oil Mill at Sungai Buloh, Kuala Selangor, Selangor. These inoculum were added to all three batches of the pre-treated samples; NaOH, $Ca(OH)_2$ and untreated samples at the ratio of 2:1 (inoculum: slurry). After that, the samples were poured into the bioreactors and maintained in water bath at 37 °C (Webb & Hawkest, 1985). The retention time was 15 days and methane production was measured daily by GC-FID (Perkin- Elmer Clarus 600) [16].

III. RESULTS AND DISCUSSION

A. Chemical pre-treatment

Figure 1 shows methane production of poultry waste which untreated, chemically pre-treated with NaOH and chemically pre-treated with $Ca(OH)_2$ within 15 days. The untreated sample was prepared to compare the results with the treated samples. Methane production of poultry waste that was chemically pre-treated with NaOH and $Ca(OH)_2$ was between range 0.14 ppm- 131.14 ppm and 6.59 ppm- 184.32 ppm respectively.

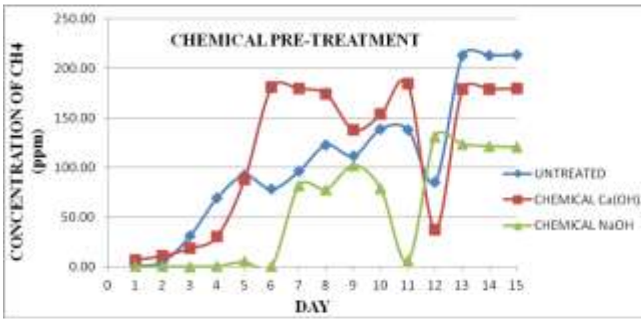

Fig. 1. Methane production from anaerobic digestion of untreated poultry waste, chemically pre-treated poultry waste with NaOH and chemically pre-treated of poultry waste with $Ca(OH)_2$

All of the pre-treated and untreated poultry waste show increment in methane production from day 1 until day 5. The increment of methane production was because of the presence of many essential microorganisms and enough food sources for them. The microorganisms will consume the substrate as their food source and enhance their activity to degrade the poultry waste and produce methane [17]. In previous study done by Saidu et al, it was proved that biodegradation occurred successfully when there were enough food sources for microbes [5]. On day 6, poultry waste that was chemically pre-treated with $Ca(OH)_2$ continue to increase while the untreated poultry waste and poultry waste that was pre-treated with NaOH started to decrease. On day 7 until day 15, methane production was slowly fluctuated in all three pre-treated poultry waste. This fluctuation may due to the inhibition of ammonia. In biodegradation of protein, ammonia will be produced. There are two forms of inorganic ammonia; free ammonia (NH_3) and ammonium ion (NH_4^+). Free ammonia is the main cause of ammonia inhibition since it is freely membrane-permeable. The anaerobic microorganisms especially methanogens are so sensitive and have the least tolerant to ammonia. As the ammonia concentrations increased, the growth of methanogens will eventually ceased and the methane production fluctuated [18].

The highest methane production was observed on the poultry waste which had chemically pre-treated with $Ca(OH)_2$ with cumulative amount of methane production at 1381.76 ppm followed by untreated poultry waste with cumulative methane production at 1181.51 ppm and poultry waste pre-treated with NaOH with cumulative methane production at 607.98 ppm. Methane production of poultry waste pre-treated with $Ca(OH)_2$ was the highest because in the presence of $Ca(OH)_2$, it neutralize free acids that produced during anaerobic digestion process. Besides that, $Ca(OH)_2$ also reduced the concentration of ammonia and provide good environment for methanogenic microorganism's activity in order to produce methane [19].

B. Thermochemical pre-treatment

Figure 2 shows the methane production of poultry waste which had thermo-chemically pre-treated with NaOH and $Ca(OH)_2$ separately. Methane production of poultry waste that was thermo-chemically pre-treated with $Ca(OH)_2$ shows higher concentration of methane production with the range between 13.43 ppm- 194.99 ppm whereas the methane production by poultry waste which had thermo-chemically pre-treated with NaOH was between range 0.22 ppm- 209.68 ppm.

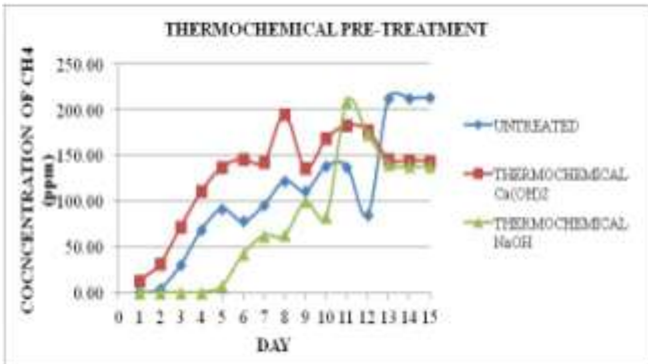

Fig. 2. Comparison of methane production between untreated poultry waste, thermo-chemically pre-treatedpoultry waste with NaOH and thermo-chemically pre-treated poultry waste with $Ca(OH)_2$

The trend of daily methane production in both thermo-chemically pre-treated poultry waste was observed after the graph was plotted. The methane production for both thermo-chemically pre-treated poultry waste started from day one with concentration of methane 13.43 ppm and 0.25 ppm respectively. This could cause by the degradation of substrate started immediately after the loading.

On day 2 until day 6, methane production continues to increase for both thermo-chemically pre-treated poultry waste. The increment of methane production may due to the high biodegradation of substrate by microorganisms during microbial activity [5]. On day 7, methane production of poultry waste which had thermo-chemically pre-treatment with NaOH increase while poultry waste which had thermo-chemically pre-treatment with $Ca(OH)_2$ decreased. Methane production in both thermo-chemically pre-treated poultry waste decrement may due to the production of carbon dioxide during the anaerobic digestion process which caused from the formation of ammonia during the biodegradation of protein in the substrate [20]. On day 9 until day 11, the methane yield in both thermo-chemically pre-treated poultry waste rose, which could due to the adaptation of the anaerobic microorganisms upon its surrounding condition [21]. On day 12 until day 15, the methane production decreased. This is because this experiment did not perform daily feeding and it lead to reduction of food source available for the microorganisms. Besides that, accumulation of long chain fatty acid (LCFA) may also cause the decreasing of methane production. The accumulation of LCFA will inhibit the anaerobic process as it is toxic to anaerobic microorganisms [18].

C. Methane production of poultry waste at different pre-treatment

From figure 1 and figure 2, it can be observed that poultry waste that was chemically and thermo-chemically pre-treated with $Ca(OH)_2$ generated high concentration of methane . Figure 3 shows the comparison between methane production of untreated poultry waste and poultry waste that was chemically and thermo-chemically pre-treated with $Ca(OH)_2$

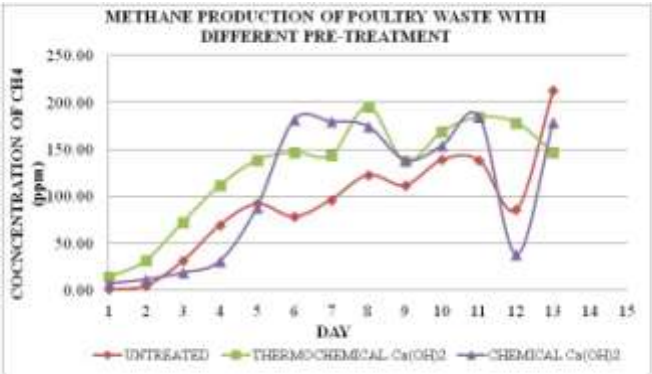

Fig. 3. Methane Production of Poultry Waste with Different Pre-treatment

Sample that thermo-chemically pre-treated with $Ca(OH)_2$ produced the highest methane concentration with cumulative amount of methane at 1665.17 ppm followed by chemical pre-treatment with $Ca(OH)_2$ with cumulative amount of methane at 1381.76 ppm. Poultry waste which had thermo-chemically pre-treated with $Ca(OH)_2$ turns out to be the best pre-treatment method because thermo-chemical pre-treatment solubilize complex organic matter in poultry waste before it was subjected to anaerobic digestion [22]. Addition of chemical promotes hydrolysis process and break down the complex polymers into simpler molecules. The process of splitting the complex polymers will be faster with the supply of heat. In previous study done by Talib, addition of alkaline will increase the solubility of various substance such as lignocellulose materials and speed up the biodegradability process of the substrate while producing methane gas [23].

IV. Conclusion

Regardless on the effect of different types of pre-treatment in this study, thermochemical pre-treatment of poultry waste with $Ca(OH)_2$ was the most suitable pre-treatment as it yields the highest methane production with cumulative amount of CH_4 at 1665.17 ppm followed by chemical pre-treatment of poultry waste with $Ca(OH)_2$ with cumulative amount of CH_4 at 1381.76 ppm.

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