Volatile Fatty Acids Production from Different Composition of Food Waste and Its Effect on Phosphorus Recovery

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Food waste is reported to be high in phosphorus content that can be solubilised during anaerobic digestion, hence enhancing phosphate release in the digested liquor. One of the important intermediate products during anaerobic digestion is volatile fatty acid that may influence the phosphorus release. There are limited studies were found in investigating the effect of volatile fatty acids on phosphorus recovery. Therefore, this study aims to study the effect of volatile fatty acids, specifically acetic acids on phosphorus recovery from different composition of food waste. In this study, food waste which segregated into three different composition, namely, protein-rich food waste, fibre-rich food waste and carbohydrate-rich food waste were used as substrates in anaerobic digestion to allow phosphorus to be solubilised for 15 days, in controlled temperature (37^{o}C) and pH (6.8-7.2). The volatile fatty acids, pH and total phosphorus concentration of each composition were analysed once in every three days. The results show that phosphorus recovery was significantly affected by the volatile fatty acids concentration. The highest phosphorus recovery was achieved from protein-rich food waste, followed by fibre-rich food waste and carbohydrate-rich food waste, with phosphorus concentrations of 614 mg/L, 466 mg/L and 478 mg/L, when the volatile fatty acids were 21090 mg/L, 8550 mg/L and 9690 mg/L, respectively. It was also found the optimum time to recover phosphorus was differ for each food waste composition. For high solid content of carbohydrate rich food waste, the time needed to digest was longer compared to protein rich and fibre rich-food waste.

Keywords: Anaerobic digestion, Volatile fatty acids, Phosphorus recovery, Food waste

I. INTRODUCTION

Volatile fatty acids (VFAs) are valuable substrates for many important applications such as production of biofuels (Chang *et al.*, 2010), biodegradable plastics (Cai *et al.*, 2009) and biological removal of nutrients (phosphorus and nitrogen) from wastewater (Zheng *et al.*, 2009). VFAs can be produced chemically using petrochemicals as the non-renewable raw materials or alternatively can be produced through anaerobic digestion of organic wastes. Anaerobic digestion (AD) which involves biochemical reactions is considered to be one of the sustainable pre-treatment method for solid waste as it not only reduces waste volume but

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also can recovers nutrients such as phosphorus. Acidogenic fermentation is one of the important step during AD which solubilises dissolved organic compounds of waste into organic acids of VFAs such as acetic acids, propionic acids, butyric acids and lactic acids, and then finally turned to methane and carbon dioxide as the main AD products. VFAs function as a carbon source in a process to release phosphate during AD. In this study food waste (FW) was chosen as AD substrate because it is produced in a daily basis makes it one of the most abundant wastes disposed on landfill. Due to its high organic content, FW can petrify rapidly which leads to environmental issues including greenhouse gases release and odour problem. It is also reported that food waste contains significant amount of phosphorus content, makes it an ideal substrate for phosphorus recovery (Wid *et al.*, 2017). The recovered phosphorus can be further precipitated and used as plant fertiliser in a form of struvite (magnesium ammonium phosphate hexahydrate). Research on AD has been extensively studied particularly for biogas recovery. However, study on the effect of VFAs for phosphorus recovery are very rare. Therefore, this study aims to determine the volatile fatty acids concentration of different composition of food waste and its effect on phosphorus recovery. Since the focus of this study was to use VFAs in releasing P from FW, AD was performed in 15 days, shorter than normal AD process, to allow the organic acids to be used for P release.

II. MATERIALS AND METHODS

The food waste sample was collected from a restaurant after lunch hour when needed. The sample was segregated into carbohydrate-rich food waste (CRFW), protein-rich food waste (PRFW) and fibre-rich food waste (FRFW), ground into small pieces and kept frozen prior to use. Primary sludge was collected from a sewage treatment plant and used as inoculum for anaerobic digestion. Three anaerobic reactors with mixture of 1.5:1, food waste to primary sludge, were prepared using Duran bottles with working volume of 200 mL. Each reactors representing different composition of food waste, i.e.CRFW, PRFW and FRFW and were put in a shaker incubator for 15 days at mesophilic temperature (~37^{o}C). The pH was controlled between pH6.8 to 7.2 using 1.0M HCl and 1.0M NaOH (Owen *et al.*, 1979; Wid *et al.*, 2017). Throughout the AD, about 5mL of the liquid part of the mixture was taken out on the initial day, and every interval of three (3) days which on day 3rd, 6th, 9th, 12th and 15th. The sample was taken to analyse the VFAs and P content. VFAs which represented by acetic acid was determined according to the method outlined by Siedlecka *et al.* (2008) by using distillation and titration methods (Buchi KjelFlex K-360), while P as described in APHA (2005) using UV-visible Spectrophotometer (Agilent Cary 60).

III. RESULTS AND DISCUSSIONS

As shown in Figure 1, VFAs was

proportionally affecting P recovery for all composition of FW, i.e. CRFW, PRFW and FRFW throughout the 15 days, significantly at the early stage of anaerobic digestion (AD). This suggests that AD of food waste accumulates organic acids, i.e. VFAs, in the digested liquor just after the digestion started and affect P release. According to Oehman *et al*. (2007), during AD, the microbes or biologically called phosphate accumulating organisms (PAOs) using VFAs as their carbon source which is stored as polyhydroxylbutyrats (PHBs). Everytime PAOs produce PHBs it will release polyphosphate (Poly-P) as its energy for the PHB production (Spring *et al*., 2005). The breakdown of Poly-P causes the releases of ortho-P in the digested liquor hence increasing P concentrations. Therefore, the P recovery increased with an increase of VFAs, which in this study represented by acetic acids (HAc). This study also suggests the P release was highly dependent on the type of FW. For CRFW, the VFAs production gradually increased from 6270 to 8550 mgHAc/L, together with P from 368 to 466 mg/L, throughout the AD process. This may due to the high solid content that needs longer time for the microorganisms to degrade the organic particulates. If the AD was to perform more than 15 days, optimum recovery may be achieved. CRFW represented by typical rice and noodle leftover, a solid form of food waste. As for PRFW, the VFAs increased significantly about 85% just in three days from day 3 to day 6 and then decreased afterwards. The highest P recovery was achieved at day 6 with 614 mg/L, when the VFAs was 21090 mgHAc/L. After day 6 the P recovery and VFAs decreased until day final to 470 mg/L and 10830 mgHAc/L, respectively. Therefore, the digestion of PRFW which represented by fish and chicken leftover, suggests that day 6 was the optimum time to produce the highest VFAs and P recovery. The decreasing of P after day 6 indicates the conversion of VFAs into methane was occurred, consequently suppressed the concentration of phosphate. However, for FRFW, the production of VFAs decreased steadily from initial to final day 15 because of rapid acidogenesis together with acetogenesis during AD, which mostly were green leafy of food leftover. Acidogenesis responsibles to ferment dissolved organic compounds into VFAs which causes the decrease in pH, while acetogenesis converts VFAs into acetate, hydrogen and carbon dioxide, consequently allows the formation of methane. Once methane was produced, this may jeopardize the condition of anaerobic digestion hence deteriorate P recovery, because the anaerobic bacteria consumes from the same source of carbon, i.e. VFAs. Therefore, the highest VFAs and P recovery from FRFW were at the initial day with 478 mg/L and 9690 mgHAc/L, respectively. Afterwards, these decreased to 436 mg/L and 5700 mgHAc/L, respectively.

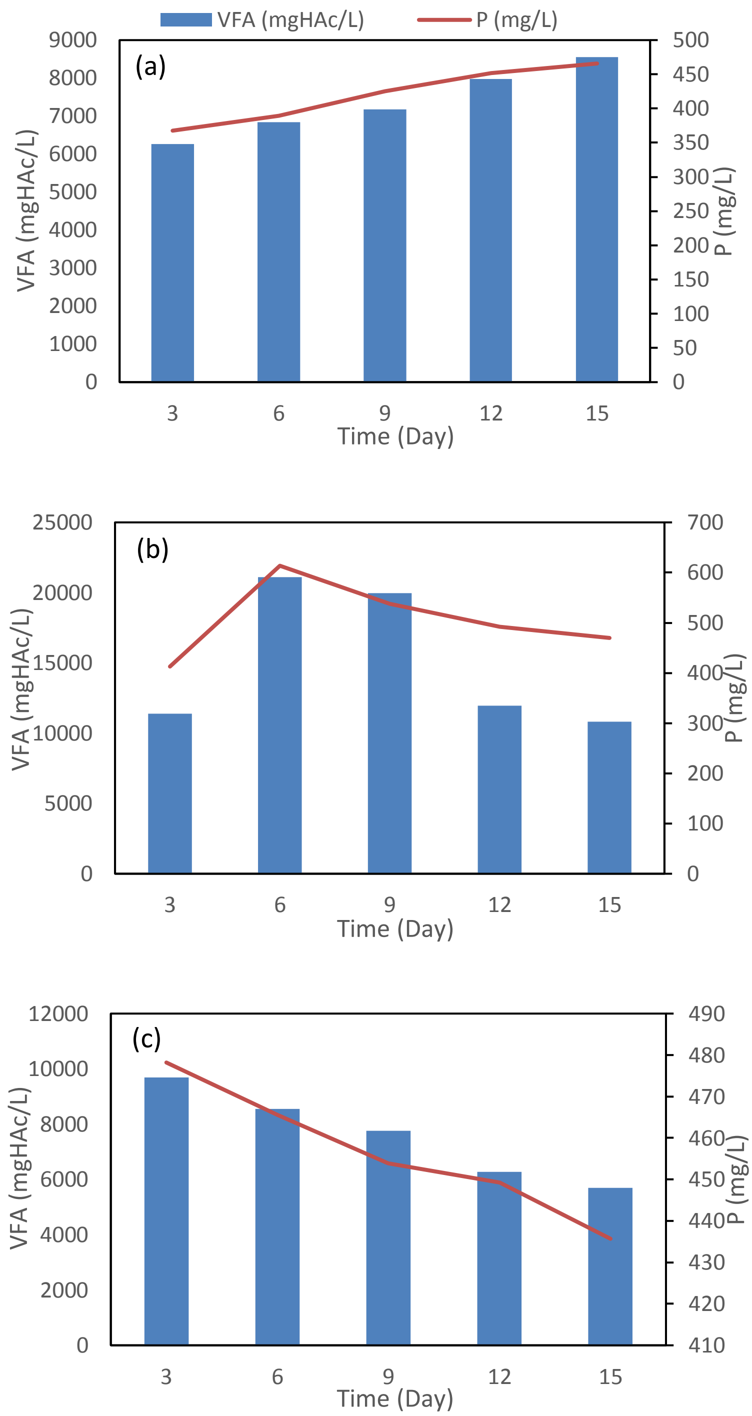

Figure 1: VFAs highly affect the P recovery from different composition of food waste (a) CRFW, (b) PRFW, and (c) FRFW

IV. SUMMARY

Anaerobic digestion is not only considered as a sustainable treatment method in stabilizing a range of organic wastes, but also as a technique to recover resources including biogas and phosphorus. While research on biogas recovery has been extensively reported, there are limited studies have been carried out to investigate the relationship between VFAs and P recovery. This study shows that anaerobic digestion of food waste produced high VFAs which the highest was observed from protein-rich food waste at day 6 with 21090 mgHAc/L and recovered the highest P with 614 mg/L. This may due to the conversion of carbon source in the organic acids of VFAs, as acetic acids, into soluble P, consequently enhance P recovery. As this study revealed that VFAs was significantly affect P recovery, it is important to find out which composition of food waste can be a viable substrate for AD. Through this study, it is suggested protein-rich food waste was the most suitable substrate to be used in anaerobic digestion for 6 days as the optimum time, to allow the optimum recovery of phosphorus (614 mg/L). While, carbohydrate-rich food waste needed longer time than 15 days to achieve optimum P recovery. As for fiber-rich food waste, the digestion was very rapid, hence the VFAs were easily converted to methane. composed of alternating carbazole donor unit and acceptor unit were successfully prepared. The polymer was synthesized by Suzuki's cross coupling reaction, in order to investigate its suitability for application in photovoltaic cell.

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