ANAERORBIC MONO AND CO- DIGESTION OF FOOD WASTE AND PALM OIL MILL EFFLUENT FOR PHOSPHORUS RECOVERY

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ABSTRACT

Anaerobic digestion (AD) is a process by which microorganisms break down biodegrable material in the absence of oxygen. The process involves hydrolysis, acedogenesis and methanogensis stages. This technology have gained interests as a technique to recover resources such as energy and nutrient. Additionally, it can help in reducing waste volume as well as greenhouse gases. To improve the production of anaerobic digestion products, co-digestion of different substrates is being introduced. The benefits of co-digestion are to increase the efficiency of digestion process as the co-substrates can supply the missing nutrient in the main substrates. So far, there are no studies have been carried out for applications of anaerobic co-digestion of food waste (FW) with palm oil mill effluent (POME) to recover phosphorus. FW is a type of municipal solid wastes which abundantly available. It has high organic content and can cause various environmental problems if disposed on landfill. While POME is a largest wastewater produced by palm oil mill industry that contain significant nutrient content. It has been reported that phosphorus is a limited and non-renewable mineral source that is essential in our daily life especially for agricultural industry as fertilizers. Therefore, this study aims to investigate phosphorus recovery from FW using anaerobic co-digestion with POME. The physicochemical properties of the samples were determined to study the suitability to be used in anaerobic digestion. The results showed that the total solids and volatile solid of FW and POME were 15%, 3% and 94% and 68%, respectively. pH were, 3 and 5, respectively. These results suggested that FW and POME were appropriate to undergo anaerobic co-digestion for phosphorus recovery. The anaerobic digestion was performed using batch anaerobic digester at mesophilic condition at 37^{O}C (± 1) and pH between 6.8-7.2. Mono-digestion of single FW and POME was carried out to investigate phosphorus recovery at different digestion period for 40 days. It was found the optimum days to recover phosphorus was within 30 days with 89% and 77%, phosphorus recovery from FW and POME, respectively. Therefore, the co-digestion was performed for 30 days at different ratios of FW to POME, namely 70:30% and 30:70%. The results showed co-digestion increased phosphorus recovery to 183-247%, compared to mono-digestion, with 70:30 (FW:POME) was the highest, followed by 30:70 (FW:POME), 100% FW and 100% POME with percentages 247%, 183%, 89% and 77%, respectively. When expressed in mg P/g, the values were, 6.70 mg P/g, 3.00 mg P/g, 4.90 mg P/g and 0.68 mg P/g, respectively. From the results, this study suggested that phosphorus recovery can be improved using co-digestion with FW as the main substrates and POME was a suitable co-substrate in anaerobic co-digestion. While the waste reduction was presented by total solid and volatile solid reduction with 41% and 45%, respectively from the result.

ABSTRAK

PENCERNAAN ANAEROBIK TUNGGAL DAN BERSAMA DI ANTARA SISA MAKANAN BERSAMA EFLUEN KILANG KELAPA SAWIT UNTUK PEMULIHAN FOSFORUS

Pencernaan anaerobik (PA) adalah suatu proses di mana mikroorganisma memecahkan bahan biodegrable dalam ketiadaan oksigen. Proses ini melibatkan peringkat hidrolisis, asidogenesis dan methanogensis. Kepentingan teknologi ini telah meningkat kerana ia merupakan teknik yang digunakan bagi mendapatkan sumber-sumber seperti tenaga dan nutrien. Selain itu , ia boleh membantu dalam mengurangkan jumlah sisa dan gas rumah hijau.Untuk meningkatkan pengeluaran produk pencernaan anaerobik, pencernaan bersama pelbagai substrat diperkenalkan. Manfaat proses ini adalah untuk meningkatkan kecekapan proses pencernaan di mana substrat bersama boleh membekalkan nutrien yang hilang dalam substrat utama. Setakat ini, tidak ada kajian telah dijalankan untuk aplikasi anaerobik bersama pencernaan bagi sisa makanan (SM) dengan efluen kilang minyak sawit (EKMS) untuk pemulihan fosforus. SM merupakan sisa pepejal perbandaran yang banyak dihasilkan. Ia mempunyai kandungan organik yang tinggi dan boleh menyebabkan pelbagai masalah alam sekitar sekiranya ia dilupuskan di tapak pelupusan. Manakala, EKMS merupakan sisa air terbesar yang dihasilkan oleh industri kilang minyak sawit dan ia juga disignifikasikan mengandungi nutrien. Fosforus telah dilaporkan sebagai sumber mineral terhad dan ia tidak boleh diperbaharui. Namun begitu, ia amat penting dalam kehidupan harian kita terutamanya bagi industri pertanian di mana ia igunakan sebagai baja. Dengan itu, tujuan kajian ini adalah untuk mengkaji pemulihan fosforus daripada SM menggunakan pencernaan anaerobik bersama dengan EKMS. Bagi menentukan kesesuaian sampel yang digunakan dalam proses pencernaan anaerobik, sifat-sifat fizikokimia telah di analisa. Hasil kajian menunjukkan bahawa jumlah pepejal dan pepejal meruap bagi SM dan EKMS adalah 15%, 3% dan 94% dan 68%. Manakala, niai pH masing-masing adalah 3 dan 5. Keputusan ini menunjukkan bahawa SM dan EKMS adalah sesuai untuk menjalani anaerobik bersama bagi pemulihan fosforus. Pencernaan anaerobik dijalankan dengan menggunakan kumpulan anaerobik pencernaan pada keadaan mesophilic 37^{0}C (± 1) dan pH antara 6.8-7.2. Pencernaan tunggal SM dan EKMS telah dijalanan pada tempoh penghadaman yang berbeza iaitu selama 40 hari untuk menyiasat pemulihan fosforus. Keputusan kajian menunjukkan hari ke-30 merupakan hari yang optimum untuk pemulihan fosforus. Dimana hasil kajian daripada SM dan EKMS masing-masing menunjukkan pemulihan fosforus adalah sebanyak 89% dan 77%. Oleh itu, penghadaman bersama dilakukan selama 30 hari pada nisbah yang berbeza di antara SM dan EKMS, iaitu, 70: 30% dan 30: 70%.

Hasil kajian menunjukkan penghadaman bersama meningkatkan pemulihan fosforus sebanyak 183-247%, berbanding dengan penghadaman tunggal, dengan 70:30 (SM: EKMS) adalah yang tertinggi, diikuti oleh 30:70 (SM: EKMS), 100% SM dan 100 % EKMS dengan peratusan masing-masing 247%, 183%, 89% dan 77%. Apabila dinyatakan dalam unit mg P/g, nilai masing-masing adalah 6.70 mg P/g, 3.00 mg P/g, 4.90 mg P/g dan 0.68 mg P/g. Keputusan kajian ini mencadangkan bahawa pemulihan fosforus boleh dipertingkatkan dengan menggunakan penghadaman bersama. Di mana SM sebagai substrat utama dan EKMS subagai substrat bersama dalam anaerobik penghadaman bersama. Daripada hasil kajian, pengurangan jumlah sisa pepejal and pepejal meruap juga dapat ditunjukkan di mana nilai masing-masing adalah 41% dan 45% .

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LIST OF ABBREVIATIONS

AAS	-	Atomic Absorption Spectrometer
AD	-	Anaerobic Digestion
AO	-	Anaerobic/Oxic process
A2O	-	Advanced Anaerobic/Oxic process
BVS	-	Biodegrable Volatile Solid
CH_4	-	Methane
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide Gas
CPO	-	Crude Palm Oil
CRFW	-	Carbohydrates Rich Food Waste
C:N	-	Carbon to Nitrogen
FWD_S	-	Food Waste Disposal Units
H_2	-	Hydrogen Gas
H_2O	-	Water
FFB	-	Fresh Fruit Bunch
FRFW	-	Fiber Rich Food Waste
FW	-	Food waste
HRT	-	Hydraulic Retention Time
K^+	-	Potassium ion
MHLG	-	Ministry Housing and Local Government
MAP	-	Magnesium: Ammonium: Phosphorus
MPOB	-	Malaysia Palm Oil Board

MSW	-	Municipal Solid Waste
Na^{+}	-	Sodium ion
O_2	-	Oxygen Gas
P	-	Phosphorus
PAO	-	Phosphorus Accumulating Organisms
POME	-	Palm Oil Mill Effulent
POMW	-	Palm Oil Mill Waste
PRFW	-	Protein Rich Food Waste
MD1	-	100% of FW
MD2	-	100% of POME
CD1	-	70:30% of FW:POME
CD2	-	30:70% of FW:POME
RVS	-	Refractory Volatile Solid
TKN	-	Total Kjedhal Nitrogen
TS	-	Total Solid
TVFAs	-	Total volatile fatty acids
SBR	-	Sequencing Batch Reactor
SCFA	-	Short Chain Fatty Acid
UCT	-	University Cape Town process
UV-Vis	-	Ultraviolet-visible
VS	-	Volatile Solid
Mg^{2+}	-	Magnesium ion
NH_4^{+}	-	Ammonium ion
PO_4^{3-}	-	Phosphate ion
VIP	-	Virginia Innovative Plant

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Anaerobic digestion (AD) is an attractive and appropriate treatment process for organic wastes such as food waste (FW) (Xian *et al.,* 2013) and palm oil mill effluent (POME) (Abdurahman *et al.,* 2013). It is classified as a biological process where the organic materials are decomposed by bacteria in oxygen free state (Iacovidov *et al.,* 2012). According to Kangle *et al.* (2012), the main principle of this method is degradation and destruction of the organic substances sequentially as a process of stabilizes which also resulting in the diminishing of odor and pathogens. This view is supported by Hariprasad *et al.* (2014) as AD treatment provides a better environmental advantages compared to other technologies, for instance: composting. It is also considered as a technology that can convert waste to energy that widely applied for treatment on organic wastes that are easily biodegrable in nature (Chen *et al.,* 2010; Baba & Nasir, 2012; Cunsheng *et al.,* 2013). Additionally, AD also can solubilize phosphorus (P) for recovery that is useful to community and economy of a country (Hood *et al.,* 2001; Batitistoni *et al.*, 2006; Martina *et al.,* 2013).

Recent developments in the field of AD have led to a renewed interest on anaerobic co-digestion (Co-AD) due to the positive synergisms effects establish in the medium which directly can improve the digestion and nutrient balance (Mata-Alvarez *et al.,* 2000; Angelidaki *et al.* 2003; Cunsheng *et al.* 2013). Co-AD described as a combination treatment of several wastes with complementary characteristics as being one of the main advantages of the anaerobic technology (Fernandez & Forster, 1993; Kangle *et al.*, 2012).

Nowadays, it becomes one of the most widely treatment used for treating wastes due to its advantages opposed to traditional AD. Gomez *et al.* (2006) stated that the intentions of this technology are to stabilize the AD process as well increases resources production such as methane gas and valuable nutrients (Batistoni *et al.*, 2006; Chen *et al.,* 2008; Coats *et al.,* 2011; Maranon *et al.,* 2012). Nevertheless, there are very limited research works that have been carried out to recover phosphorus (P) using co-AD technique. Therefore, one of the intentions of this study is to provide data and information on P recovery using AD techniques. For future work, AD can be applied in P recovery in the form of struvite, which can be used as slow - release fertilizer.

1.2 Problem Statement

Over the past decades, municipal solid waste (MSW) management has become a central issue in developing countries (Mohd Dinie and Mashitah, 2013). In Malaysia, MSW is the most challenging problems due to the rapid urbanization, industrialization and high demand in the quality of life. According to Kathiravale & Mohd Yunus (2008), Malaysian generates almost 17,000 tonnes of domestic waste daily, which one of the most significant current MSW is food waste (FW). This report is supported by Nurhidayati Abdul Aziz (2009) who stated that in the past decades FW has become the major components of MSW particularly in the rapid development countries. Recent years, Solid Waste and Public Cleansing Management Corporation (SWCorp, 2015) also have reported about 45% of waste in Malaysia was contribute by FW. FW generation rate in India also increased by 1.33 times per year due to the increasing of population (Ankur *et al.,* 2013). In addition, similar observations found in United States (US), where FW becomes the single largest component of waste produced in the country (Kubaska *et al.*, 2010). According to a report published by California Integrated Waste Management Board (Carr, 2004), the estimated amount of FW generated in 1999 was 5.6 million wet tons per year and this value increase gradually in a year (Liu *et al.,* 2009).