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EFFECT OF STEAM PRE-TREATMENT ON CO-COMPOSTING OF OIL PALM EMPTY FRUIT BUNCH

NURUL HUSNA CHE HAMZAH

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EFFECT OF STEAM PRE-TREATMENT ON CO-COMPOSTING OF OIL PALM EMPTY FRUIT BUNCH

By

NURUL HUSNA CHE HAMZAH

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EFFECT OF STEAM PRE-TREATMENT ON CO-COMPOSTING OF OIL PALM EMPTY FRUIT BUNCH

NURUL HUSNA BINTI CHE HAMZAH

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Chairman: **Azmi Yahya, Ph.D., Ir.**
Faculty: **Faculty of Engineering**

Palm oil mill effluent (POME) which is abundant in most palm oil mills is harmful to the surrounding environment. Methane gas emission during POME open pond treatment contributes to the global warming effect. However, the nutrient in POME could be utilized by co-composting with oil palm empty fruit bunches (OPEFB). Conventional mulching of OPEFB takes about 6 to 12 months while current controlled composting takes 50–90 days to mature. This study aims to produce an accelerated composting treatment by treating shredded OPEFB with steam pre-treatment and raw POME as acid pre-treatment prior to composting. Two baseline composting studies were conducted in 80 days. The first baseline study examined the effect of steam pre-treatment, while the second baseline study examined the effect of raw POME as acid pre-treatment on OPEFB. The final composting treatments were selected from both baseline studies that have highly significant effects in temperature, C/N ratio, and tensile strength properties. The composting treatments were performed under a roofed area near the Machinery Design Laboratory in the Faculty of Engineering, Universiti Putra Malaysia. The compost was placed in plastic drums, which were regularly turned for aeration purpose. The compost mixtures were also monitored for temperature, moisture content, oxygen content, C/N ratio, and fibers tensile strength. Carbon to nitrogen (C/N) ratio is the main parameter measured in this study because it indicates the maturity of compost. The compost C/N ratio has reduced to below than 20 and accelerated to about 40 days of composting by pre-treatment with steam and raw POME. On the 40^{th} day, the C/N ratio of all composting treatments have achieved lower than 20 of C/N ratio where the C/N ratio of steam treated-soaked OPEFB, steam treated OPEFB co-composted with chicken manure, steam treated OPEFB co-composted with anaerobic POME, and non-steam treated OPEFB co-composted with anaerobic POME are 17.7, 10.1, 13.8, and 15.6, respectively. The treatment of steam treated OPEFB co-composted with chicken manure has the lowest final C/N ratio and mean tensile strength, which indicates fast maturity and physical degradation of fibers. The tensile strength of steam-treated OPEFB co-composted with chicken manure

(31.67 N/mm^2) and soaked OPEFB co-composted with chicken manure (33.86 N/mm^2) showed lower mean tensile strength compared to other compost treatments especially with non-steam-treated OPEFB co-composted with POME (37.68 N/mm^2). Scanning Electron Microscopy (SEM) observations showed the presence of crack around the silica bodies while some fibers showed a rupture on the fiber's surface. Fibers from treatment steam-treated OPEFB co-composted with chicken manure showed a removal of silica bodies and more remaining holes compared to other compost treatments.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

KESAN PRA-RAWATAN WAP KE ATAS PENGKOMPOSAN TANDAN BUAH KELAPA SAWIT KOSONG

Oleh

NURUL HUSNA BINTI CHE HAMZAH

April 2017

Pengerusi: **Azmi Yahya, PhD, Ir**
Fakulti: **Fakulti Kejuruteraan**

Kumbahan kilang minyak sawit (POME) yang banyak terhasil di kilang-kilang minyak sawit adalah berbahaya kepada alam sekitar. Pelepasan gas metana semasa rawatan POME secara kolam terbuka menyumbang kepada kesan pemanasan global. Walau bagaimanapun, nutrien dalam POME boleh digunakan untuk dikompos bersama dengan tandan buah kosong kelapa sawit (OPEFB). Sungkupan OPEFB yang dilakukan secara konvensional mengambil masa 6 hingga 12 bulan manakala pengkomposan terkawal terkini mengambil masa selama 50-90 hari untuk matang. Kajian ini bertujuan untuk menghasilkan rawatan kompos yang boleh dipercepatkan dengan merawat OPEFB yang dicincang dengan pra-rawatan wap dan POME mentah sebagai pra-rawatan asid sebelum pengkomposan. Dua kajian kompos asas telah dijalankan selama 80 hari. Kajian asas pertama mengkaji kesan pra-rawatan wap, manakala kajian asas kedua mengkaji kesan POME mentah sebagai pra-rawatan asid kepada OPEFB. Rawatan kompos akhir telah dipilih daripada kedua-dua kajian garis dasar yang mempunyai kesan yang sangat ketara dari segi suhu, nisbah karbon kepada nitrogen (C/N) dan kekuatan tegangan gentian OPEFB. Rawatan kompos telah dijalankan di bawah kawasan berbumbung berhampiran Makmal Rekabentuk Mesin di Fakulti Kejuruteraan, Universiti Putra Malaysia. Kompos itu diletakkan di dalam tong plastik, yang telah kerap dipusing-pusing untuk tujuan pengudaraan. Campuran kompos juga dipantau dari segi suhu, kandungan kelembapan, kandungan oksigen, nisbah C/N, dan kekuatan tegangan gentian. Nisbah C/N adalah parameter utama yang diukur dalam kajian ini kerana ia menunjukkan kematangan kompos. Nisbah C/N kompos telah berkurang kepada kurang daripada 20 manakala kompos pra-rawatan OPEFB dengan wap dan POME mentah telah mencapai nisbah C/N kurang 20 dalam masa 40 hari. Pada hari ke-40, nisbah C/N semua rawatan kompos telah mencapai kurang 20 di mana nisbah C/N OPEFB yang dirawat dengan wap dan direndam dalam POME mentah, OPEFB yang dirawat dengan wap dan dikompos dengan tahi ayam, OPEFB yang

dirawat dengan wap dan dikompos bersama dengan POME anaerobik, dan OPEFB tidak dirawat dengan wap dan dikompos dengan POME anaerobik masing-masing adalah 17.7, 10.1, 13.8 dan 15.6. OPEFB yang dirawat dengan wap dan dikompos dengan tahi ayam mempunyai nisbah akhir C/N yang paling rendah. Kekuatan tegangan OPEFB yang dirawat dengan wap dan dikompos dengan tahi ayam (31.67 N/mm^2) dan OPEFB yang direndam dan dikompos dengan tahi ayam (33.86 N/mm^2) adalah rendah kerana ia menunjukkan kekuatan tegangan yang rendah berbanding dengan rawatan kompos lain terutamanya dengan OPEFB yang tidak dirat dengan wap dan dikompos dengan POME (37.68 N/mm^2). Pemerhatian daripada Scanning Electron Microscopy (SEM) menunjukkan kehadiran retakan sekitar badan silika manakala beberapa gentian menunjukkan pecah di permukaan gentian ini. Gentian daripada OPEFB yang dirawat dengan wap dan dikompos dengan tahi ayam menunjukkan leih banyak penyingkiran badan silika dan baki lubang berbanding rawatan kompos lain.

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I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of Nurul Husna Binti Che Hamzah on her thesis entitled " Effect of Steam and Palm Oil Mill Effluent Pre-Treatment on Co-composting of Oil Palm Empty Fruit Bunch" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student is awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

SAMSUZANA ABD AZIZ
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

MOHD NORIZNAN MOKHTAR
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

NORAZWINA ZAINOL
Associate Professor
Faculty of Chemical and Natural Resources
Universiti Malaysia Pahang
(External Examiner)

ZULKARNAIN ZAINAL, Ph.D
Professor / Deputy Dean of
Graduate School
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Azmi Bin Dato Haji Yahya, Ph.D., Ir
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Azhari Bin Samsu Baharuddin, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Hasfalina Binti Che Man, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ROBIAH YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: _____
Name of Chairman of Supervisory Committee: Azmi Yahya, PhD

Signature: _____
Name of Supervisory Committee: Hasfalina Che Man, PhD

Signature: _____
Name of Member of Supervisory Committee: Azhari Samsu Baharuddin, PhD

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LIST OF ABBREVIATIONS

CM	Chicken manure
POME	Palm oil mill effluent
EM	Effective bacteria
OPEFB	Oil palm empty fruit bunch
FFB	Fresh fruit bunch
C/N	Carbon to nitrogen
CPO	Crude palm oil
ST	Steam-treated
SO	Soak

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Palm oil provides most of the oil for international trade and the demand keeps increasing as the human population rapidly increases. However, palm oil production significantly generates around 21.27 million metric tonnes of oil palm empty fruit bunch (OPEFB) and 49.85 million metric tonnes of palm oil mill effluent (POME) worldwide (Ng. et al., 2012).

OPEFB mulching has been conventionally practiced and highly recognized to be able to improve crop yield. The slow breakdown process of OPEFB leads to the slow release of nutrients to the soil. In addition, OPEFB mulching could also improve soil moisture, soil structure, organic matter content, and microbial activity. Besides, it also can reduce soil erosion, nutrient loss, and soil surface temperature. However, OPEFB mulching has various disadvantages and limitations such as high transportation cost and high labor requirement (KeTTHA, 2011).

Composting is allowing OPEFB to decompose under controllable conditions to produce a product that can be used as a fertilizer or soil conditioner. It can improve soil fertility by adding high nutritional qualities to the soil, thus, it can replace the use of chemical fertilizers. Insufficient amounts of nutrients in the soil for rapid growth and high yield production urge farmers to use chemical fertilizers. However, it would cause waterway and air pollution, mineral depletion, soil acidification, and chemical burn to the crops.
In addition, composting OPEFB could reduce approximately 50% of the volume to make application easier (Thambirajah et al., 1995), thus, can reduce the high transportation and distribution cost (Singh et al., 2010). An accelerated composting can be conducted by performing a pre-treatment and co-composting with suitable co-composting materials or co-substrates.

Most palm oil mills applied physical pre-treatment by mechanical shredding of OPEFB to increase the accessible and exposed surface area for enzymatic attacks. However, its disadvantages are high electrical energy consumption, time-consuming, and loss of important nutrients. Biological pre-treatment employs microorganisms such as fungi and white rot fungi to degrade hemicellulose and lignin in OPEFB. Chemical pre-treatment by the application of weak acid hydrolysis, strong acid hydrolysis, and alkaline hydrolysis could be combined with other types of treatment such as steam pre-treatment. It is one of the most applied pre-treatment processes because of low use of chemicals and limited energy consumption.

1.2 Problem Statement

POME contains a high level of nutrients that are greatly beneficial for composting. However, the POME open pond treatment leads to environmental pollution and methane gas emission. Therefore, composting using POME is significant to reduce the amount of POME in palm oil mills and to utilize its high nutrients for agricultural sectors, especially in the oil palm sector.

Table 1 shows the C/N ratio of compost obtained from earlier studies. C/N ratio plays an important role in determining the maturity of compost**.** Long degradation time is one of the problems in composting of OPEFB even though many works have been performed to enhance the biodegradation process. The composting time could be shortened by performing steam and acid pre-treatment on OPEFB prior to composting. Baharuddin (2009) reported that using partially treated POME will reduce the C/N ratio to 12.7 in 60 days; while Thambirajah J.J., (1995) claimed that composting with chicken manure will result in a lower C/N ratio, which is 12 in the same duration. The composting period of 60 days could be shortened by treating OPEFB with pre-treatments prior to composting.

Table 1. Composting comparison with earlier studies

No	Amendment (s) material	Composting days	C/N ratio	Reference
1	Partially treated POME	60	12.7	Baharuddin A.S., 2009
2	POME and wheat flour	60	20	Alam, Z., 2007
3	Without any amendment material	60	24	Thambirajah J.J.,1995
4	Goat dung	60	14	Thambirajah J.J.,1995
5	Cow dung	60	18	Thambirajah J.J.,1995
6	Chicken manure	60	12	Thambirajah J.J.,1995
7	Sewage sludge, oil palm trunk, oil palm frond	90	19	Kala D.R., 2009

Steam treatment has the potential to degrade the complex structure of OPEFB by degrading the silica bodies embedded in the fibers, break down the lignin structure, and disrupt the crystalline structure of cellulose so that the acids or enzymes can easily access and hydrolyze the cellulose to become more susceptible to cellulose-degrading enzymes (Shamsudin, et. al., 2012). Hence, the composting time will be shortened and immediately solve the problems of insufficient landfills and inefficient mulching. Acid pre-treatment by soaking OPEFB in raw POME can replace the current use of corrosive and harmful strong acid. Drawbacks of using concentrated acids are corrosive nature of the reaction and the need to recycle acids in order to lower cost (Harmsen, P., et. al.,

2010). The addition of chicken manure increases a higher amount of nitrogen, phosphorus, and potassium to the compost compared to other animal manures and POME.

1.3 Scope of Study

This study is a pilot-scaled composting in ten vertical open top HDPE plastic drums with a maximum capacity of 60-liters respectively. Each plastic drum referred to the different composting treatments which gather treated or non-treated OPEFB with different composting materials. The composting process was performed on a cement base under a shaded area. Two baseline composting studies were conducted and then followed by the final composting. The compost measurement on temperature, C/N ratio, and tensile strength of the composting material were collected while the moisture content, oxygen level, bulk density, and relative humidity were monitored closely for optimum compost condition.

1.4 Objectives

The general objective of this study is to produce an accelerated composting system by using steam and acid pre-treatments of shredded OPEFB. The specific objectives are:

1. To determine the effect of steam pre-treatment at 40 psi and 140°C for 90 minutes and raw POME pre-treatment to enhance the co-composting of OPEFB.

2. To determine the effect of co-composting OPEFB and different co-substrates such as chicken manure, anaerobic POME, and EM solution.

3. To determine the significance of tensile strength testing as an indication of the fibers' decomposition state.

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