UNIVERSITI PUTRA MALAYSIA

EVALUATION OF COMPOST PRODUCED COMMERCIALLY FROM OIL PALM BIOMASS

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

EVALUATION OF COMPOST PRODUCED COMMERCIALLY FROM OIL PALM BIOMASS

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July 2014

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Processing of fresh fruit bunches (FFB) to extract its oil at the same time produced biomass namely mesocarp fibre, shell, empty fruit bunches (EFB) and palm oil mill effluent (POME). EFB and POME were the most abundance among the oil palm biomass. Composting was proposed as one of the potential alternatives to the management of EFB and POME. However, production of compost from oil palm biomass may adversely affect the environmental quality. To date, there is no detail study conducted to evaluate the production of compost from oil palm biomass. The main objective of this study is to evaluate the compost produced commercially from oil palm biomass namely EFB and POME. Further objectives are to identify environmental impacts related to composting of oil palm biomass and to determine chemical characteristics of compost produced from oil palm biomass. In this study, life cycle assessment (LCA) was the chosen tool to identify the potential environmental impacts related to composting of oil palm biomass while the chemical characteristics of compost produced from oil palm biomass were determined using Fourier transform infrared (FT-IR) spectroscopy and thermogravimetry analysis (TGA). Life cycle inventory (LCI) was obtained from three commercial oil palm biomass composting projects in Malaysia. The LCI was calculated based on the functional unit of one tonne of compost produced. Composting 2.0 - 2.5 t of EFB and 5.0 – 7.5 t of POME required diesel from 218.7 – 270.2 MJ and electricity from 0 – 6.8 MJ. Life cycle impact assessment was carried out using the SimaPro software version 7.2 and the Eco-indicator 99 methodology. The results showed that the environmental impact from the production of compost is related to the use of diesel which contributes to the impact categories of fossil fuel, respiratory inorganics, acidification or eutrophication and climate change. It is estimated that the composting emitted from 0.01 - 0.02 tCO_{2eq} / $t_{compost}$ mainly from diesel used to operate machineries. Based on the FT-IR spectra and TGA thermogram, the composting of oil palm biomass is affected by factors including pretreatment of raw material and the use of microbes. The most efficient process consisted of the use of shredded EFB for composting. FT-IR spectra and TGA showed that composting resulted in the loss of aliphatic structures by enrichment of amide and aromatic structures and subsequently

increasing the stability of the compost. The production of compost of the three plants showed very minimal impact to environment and chemical characteristics as a potential soil conditioner.

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

PENILAIAN TERHADAP KOMPOS YANG DIHASILKAN SECARA KOMERSIL DARI BIOJISIM SAWIT

Oleh

NORHASMILLAH ABU HASSAN

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Pemprosesan buah tandan segar (FFB) untuk mengestrak minyaknya dalam masa yang sama menghasilkan biojisim iaitu sabut mesokarpa, tempurung sawit, buah tandan kosong (EFB) dan efluen kilang sawit (POME). EFB dan POME adalah yang paling banyak antara biojisim. Pengkomposan telah dicadangkan sebagai salah satu alternatif dalam pengurusan EFB dan POME. Walau bagaimanapun, penghasilan kompos dari biojisim sawit mungkin menjejaskan kualiti alam sekitar. Setakat ini, tiada kajian khusus dijalankan untuk menilai penghasilan kompos dari biojisim sawit. Objektif utama kajian ini adalah untuk menilai kompos yang dihasilkan secara komersil dari biojisim sawit iaitu EFB dan POME. Objektif selanjutnya adalah untuk mengenalpasti kesan alam sekitar berkaitan pengkomposan biojisim sawit dan menentukan sifat kimia kompos yang dihasilkan dari biojisim sawit. Dalam kajian ini, penilaian kitaran hidup (LCA) merupakan kaedah yang dipilih untuk mengenalpasti kesan alam sekitar berkaitan pengkomposan biojisim sawit manakala sifat kimia kompos yang dihasilkan dari biojisim sawit ditentukan menggunakan spektroskopi infra merah penjelmaan Fourier (FT-IR) dan analisis termogravimetri (TGA). Inventori kitaran hidup diperoleh dari tiga projek komersil kompos biojisim sawit di Malaysia. Inventori tersebut dikira berdasarkan unit berfungsi satu tan kompos yang dihasilkan. Kompos 2.0 – 2.5 t EFB dan 5.0 – 7.5 t POME memerlukan diesel dari 218.7 – 270.2 MJ dan elektrik dari 0 – 6.8 MJ. Penilaian kesan kitaran hidup telah dijalankan menggunakan perisian SimaPro versi 7.2 dan kaedah Ecoindicator 99. Keputusan menunjukan kesan alam sekitar daripada penghasilan kompos adalah berkaitan penggunaan diesel yang menyumbang kepada kategori kesan bahan api fosil, respirasi tak organik, pengasidan atau eutrofikasi dan perubahan iklim. Dianggarkan bahawa kompos mengeluarkan dari 0.01 – 0.02 tCO_{eq}/t_{kompos} terutamanya dari diesel yang digunakan untuk mesin beroperasi. Berdasarkan spektrum FT-IR dan TGA, didapati bahawa penghasilan kompos dari biojisim sawit dipengaruhi oleh faktor termasuklah rawatan awal bahan mentah dan penggunaan mikrob. Proses yang paling efisyen adalah penggunaan EFB yang telah disiat untuk penghasilan kompos. Spektrum FT-IR dan TGA menunjukkan kehilangan struktur alifatik melalui peningkatan terhadap struktur amida dan aromatik seterusnya

meningkatkan kestabilan kompos. Penghasilan kompos di ketiga-tiga kilang menunjukkan kesan alam sekitar yang sangat minima dan sifat kimia yang berpotensi sebagai perapi tanah.

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I certify that an Examination Committee has met on 11th July 2014 to conduct the final examination of Norhasmillah Abu Hassan on her thesis entitled "Evaluation of Compost Produced Commercially from Oil Palm Biomass" 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 be awarded the Master of Science (Environmental Chemistry).

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LIST OF ABBREVIATIONS

BOD	Biochemical oxygen demand
C/N	Carbon to Nitrogen
CDM	Clean development mechanism
CER	Certified emission reduction
CH_4	Methane
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CPO	Crude palm oil
EFB	Empty fruit bunches
FAO	Food and Agriculture Organisation of The United Nations
FFB	Fresh fruit bunches
FT-IR	Fourier transform-infrared
GHG	Greenhouse gas
IPCC	Intergovernmental Panel of Climate Change
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
MPOB	Malaysian Palm Oil Board
NO_2	Nitrous oxide
POME	Palm oil mill effluent
TGA	Thermogravimetry analysis
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency

CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

Processing of fresh fruit bunches (FFB) to extract its oil at the same time produced biomass namely mesocarp fibre, shell, empty fruit bunches (EFB) and palm oil mill effluent (POME) (Figure 1.1). Mesocarp fibre are the fibre left after separating the nuts from presscake while shell are the outer layer of the nuts and obtained after the nut cracking process. POME is effluent water discharged from the milling process, which contains many soluble chemical materials (Mohammad *et al*., 2012). EFB on the other hand is the fibrous material left after the fruits are stripped for palm oil production (Liew *et al*., 2009; Shinoj *et al*., 2011).

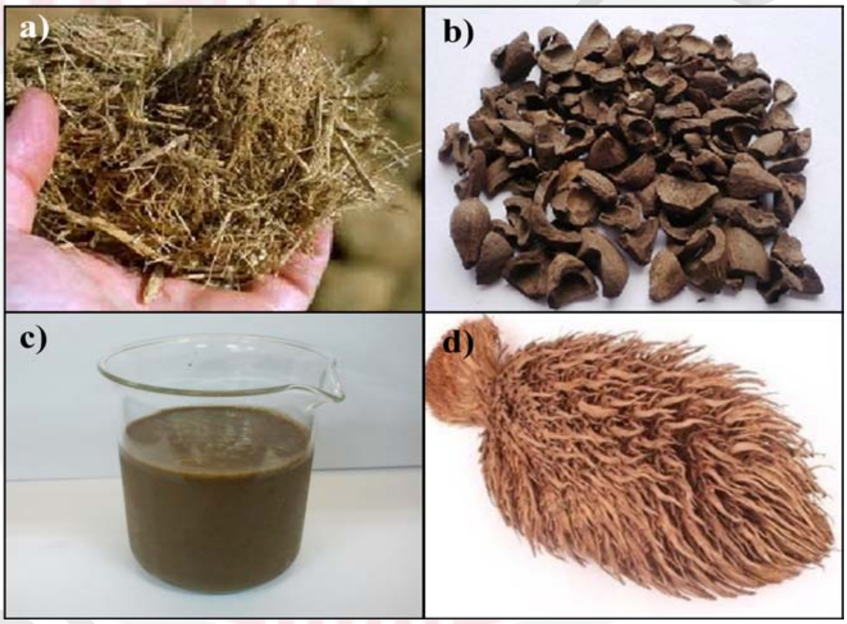

Figure 1.1. Oil palm biomass (a) mesocarp fibre, (b) shell, (c) palm oil mill effluent, (d) empty fruit bunch

The Malaysian oil palm industry sought for solutions to manage the large amount of biomass generated. Utilisation of the oil palm biomass into energy, biocomposites, construction and building industries became current most favourable solution in managing the biomass towards a sustainable system. After the launched of clean development mechanism (CDM), more investors interested to invest on the projects as it provide incentives. However, the incentives were given after successful implementation of the projects and those projects required high investment cost for development which was unaffordable by some of the millers. It is reported that only 55 or 12.9% of the palm oil mills in Malaysia have implemented a system for the capture of biogas from POME and as of August 2012, only eight oil palm biomass energy projects and 12 oil palm biogas projects have obtained total certified emissions reduction (CER) (The Star, 2012). Hence, composting was proposed as one of the potential alternatives to the management of oil palm biomass. Converting the biomass into compost offers a simple method and economical advantage (Baharuddin *et al.*, 2009). Composting project also has the potential to be incorporated with CDM to further enhanced the economic returns through the carbon credits earned.

As the Malaysian oil palm industry is serious in implementing a sustainable management of oil palm biomass, there is a need to study the impact of the production of compost to the environment. In this case, the Life Cycle Assessment (LCA) is one of the appropriate tools to evaluate the performance of the system. There were various reports on life cycle study of the production and application of compost from domestic and municipal solid waste (Gilbert *et al*., 2011; Hermann *et al*., 2011; Jimenez and Garcia, 1989); comparative life cycle study on other industrial byproduct (Cabaraban *et al*., 2008; Contreras *et al*., 2009); and a comparative study on the utilisation of oil palm biomass into composting (Stichnothe and Schuchardt, 2010). The LCA study conducted for the oil palm system in Malaysia was summarised in Table 1.1. It considered the plantation, milling, refinery and different option for waste treatment system. However, a detail study on LCA emphasising on the commercial production of compost from oil palm biomass has yet to be conducted. Such studies are useful for millers and compost plant owners to identify opportunities to reduce their respective environmental impacts, for example through process optimisation or new technology innovation.

1.2 Problem Statement

In extracting crude palm oil (CPO), POME and EFB were the most abundance among the oil palm biomass produced. Actions have been taken by the Malaysian oil palm industry to effectively utilise the biomass. There were a few and composting is one of it. A list of advantages from composting has been discussed, for example composting as an economical and environmental friendly option in managing abundance of biomass. However, production of compost from oil palm biomass may adversely affect the environmental quality. These effects are potentially occurring at any stages of the life cycle of production of compost, starting from raw material extraction, manufacturing process, packaging, consumption until final disposal. Todate, there is no detail study conducted to evaluate the production of compost from oil palm biomass. As public concern on environmental health has increased, it is important to identify the potential environmental effects as well as the evaluation on the compost characteristics associated with the production of compost from oil palm biomass.

1.3 Objectives

The main objective of this study is to evaluate the compost produced commercially from oil palm biomass namely POME and EFB.
Further objectives of this study are:

i. to identify environmental impacts related to composting of oil palm biomass
ii. to determine chemical characteristics of compost produced from oil palm biomass

1.4 Scope of the Study

Scope of this study covers the evaluation of compost produced from oil palm biomass, using LCA as the tool encompassing receiving of raw material, processing and final compost ready for sale as well as the identification of chemical characteristics of compost. This study focuses on potential emissions associated with the production of compost which lead to environmental impact plus the determination of chemical characteristics of compost produced.

1.5 Significance of the Study

An LCA will help decision makers to identify and select the product or process that has the minimum impact to the environment. LCA data identifies the transformation of environmental impacts from one life cycle stage to another. In this study, LCA will be able to identify the potential environmental impacts associated with the production of compost from oil palm biomass. It will help the compost plants owner to control their process and production effectively. Hence, LCA is significant in improving process and minimization of the environmental risks.

Determination of compost characteristics identifies the elements content and confirms maturity of compost produced from oil palm biomass. It provides information on the optimum condition for compost plant owner to select the system that meets their end product requirement.

Table 1.1. Summary of life cycle assessment (LCA) conducted in oil palm industry in Malaysia

Boundary	Functional unit	Reference
Plantation		
Study considered from oil palm seedling to plantation.	Single oil palm seedling	Halimah *et al*., 2010
From transplanting of seedling to fresh fruit bunches (FFB) delivered to palm oil mill.	1 t of FFB produced	Zulkifli *et al*., 2010
Milling		
Boundary started from FFB received until production of crude palm oil (CPO) in storage tanks.	1 t of CPO produced (with weight allocation)	Vijaya *et al*., 2010a
Study considered from plantation process, transportation of FFB into mill and milling.	Production of 1 t CPO (output from 5 t of FFB)	Yusoff and Hansen, 2007
Kernel collected and transported to kernel crushing plant.	1 t of crude palm kernel oil (CPKO) produced at kernel crushing plant	Vijaya *et al*., 2010b
Refinery		
Study begins with the transportation of CPO to the refinery gate and ends with the bulk of storage of refined palm oil (RPO), refined palm olein (RPOo) and refined palm stearin (RPOs).	1 t of RPO, RPOo and RPOs	Tan *et al*., 2010
Palm biodiesel		
The system boundary includes the production of biodiesel and use of palm biodiesel.	The production and use of 1 MJ palm biodiesel in diesel engine vehicles	Puah *et al*., 2010
Byproducts		
Evaluation of environmental impacts of empty fruit bunches (EFB) and palm oil mill effluent (POME) treatment by comparing four different treatment options.	1 t of FFB processed	Stichnothe and Schuchardt, 2010

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