UNIVERSITI PUTRA MALAYSIA

SOLID STATE BIOCONVERSION OF OIL PALM EMPTY FRUIT BUNCHES INTO COMPOST BY SELECTED MICROBES

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Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

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قَالُوا۟ سُبْحَـٰنَكَ لَا عِلْمَ لَنَآ إِلَّا مَا عَلَّمْتَنَآ ۖ إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ ﴿٣٢﴾

Surat Al-Baqara.

Especially dedicated to my parents

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

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Chairman: **Associate Professor Azni Bin Hj Idris, Ph.D.**

Faculty: **Engineering**

The palm oil industry plays a major role in the economic development of several tropical countries. In processing oil palm fruit for oil extraction, palm oil mills produce a considerable amount of solid wastes in the form of fibres, nut shells and empty fruit bunches (EFB). For every 100 tonnes of fresh fruit bunches processed there will be approximately 20 tonnes of nutshells, 7 tonnes of fibres and 26 tonnes of empty bunches discharged from the mill. In order to prevent environmental pollution, disposal of the oil palm wastes needs prudent handling and consideration.

The composting process is currently viewed primarily as a waste management method to stabilise organic wastes. Composting is a management system that uses microbial activity to degrade raw organic material. The stabilised end product (compost) is widely used as a soil amendment to improve soil structure and to provide plant nutrients. These beneficial uses of compost can improve healthy plant production, reduce the use of chemical fertilisers and conserve natural resources.

The main objective of this study is to develop an alternative technology for the production of compost from oil palm empty fruit bunches (EFB), using a solid state biconversion technique (SSB), by selected microorganisms. SSB is a process whereby an insoluble substrate, with sufficient moisture, but not free water, can be converted to compost by different microorganisms. It is a simple and cost effective way of treating the organic waste, which requires no complex controls.

Three efficient cellulolytic cultures *Aspergillus niger, Trichoderma reesei* and *Phanerochaete chrysosporium* were used as inoculum in this study. The strains used did not produce any toxic by-products during the bioconversion processes and they were able to utilise lignin and grow on lignocellulosic materials. Shredded and partially dried EFB (280g) were allowed to compost for 8 weeks using ammonium sulfate as a source of nitrogen with the addition of single and mixed culture innoculum of *A.niger, T.resie* and *P.chrysosporium,* and compared to the natural process as control. The composting process was carried out in 1L flasks and the controlling parameters such as moisture content, temperature and aeration were optimised.

The investigation showed that due to inoculation, the period of composting was reduced to four weeks compared to normal composting time of 24 - 32 weeks. In addition to this, the quality of the compost was improved and there was greater production of nitrate and ammoniacal nitrogen due to the accelerated decomposition. During four week period, the total carbon degraded to 54% with mixed culture showing a maximum decomposition, followed by *P. chrysosporium* 53.4%, *A. niger* 41%, T. *reesie* 34.6% and control 22.7%.

A maximum increase of total nitrogen content of 92.1% was recorded with mixed culture followed by 77.4% with *P.chrysosporium,* 67.6% with *A.niger*, 64.7% with *T.reesie* and 39% with control. The C/N ratio of 47 in EFB compost improved to 11.34 with mixed culture, to between 12.32 - 18.67 with single cultures and to 26.14 with control. There was a 60% reduction in the C/N ratio over the control.

The addition of mixed culture is therefore shown to be more effective than single culture and natural composting (control). The SSB technique was found to be feasible technology with high potential for EFB conversion into compost. The compost prepared by such techniques was rich in nitrogen, phosphorus, potassium and humus content. The observations of this study will provide future guidelines for the production of non-hazardous environmental friendly organic fertilisers.

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

PENGHASILAN BAJA KOMPOS DARIPADA SERABUT KELAPA SAWIT MENGGUNAKAN KAEDAH BIODEGRADASI DALAM KEADAAN PEPEJAL DENGAN BANTUAN MIKROB TERPILIH

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Pengerusi: **Profesor Madya Azni Bin HJ. Idris, Ph.D.**

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Industri minyak kelapa sawit merupakan sumber utama kepada perkembangan ekonomi negara-negara tropika. Proses perkilangan minyak kelapa sawit banyak menghasilkan sisa pepejal dalam bentuk gentian, isirung dan serabut kelapa sawit (EFB). Bagi setiap 100 tan metrik buah kelapa sawit segar yang diproses, lebih kurang 20 tan isirung, 7 tan gentian dan 26 tan serabut kelapa sawit dihasilkan sebagai bahan buangan. Perhatian yang serius perlu diambil ke atas proses pelupusan bahan buangan ini bagi mengelakkan kesan pencemaran alam sekitar.

Proses pengkomposan kini mendapat perhatian serius dan merupakan cara atau teknologi terkini dalam menstabilkan bahan buangan organik ini. Teknologi ini menggunakan tindakbalas mikrob untuk proses biodegradasi bahan buangan ini. Proses biodegradasi ini menghasilkan baja kompos yang digunakan secara meluas sebagai agen pembaik struktur tanah, penghasilan zat-zat untuk pertumbuhan pokok dan agen penentang hakisan tanah. Kebaikan dan faedah baja kompos ini seterusnya boleh meningkatkan tahap pertumbuhan pokok,

mengurangkan kos penanaman dengan mengurangkan penggunaan baja kimia dan seterusnya melindungi sumber asli di Malaysia.

Objektif utama kajisan ini adalah untuk mancari satu alternatif bagi penghasilan kompos dari serabut kelapa sawit, iaitu menggunakan teknik biodegradasi dalam keadaan pepejal (SSB) dengan bantuan mikrob yang terpilih. Biodegradasi dalam keadaan pepejal (SSB) ialah satu proses di mana substrat tak larut dengan kelembapan yang sesuai ditukar menjadi kompos oleh pelbagai mikrob. Proses ini adalah mudah dan kos efektif sebagai cara melupuskan sisa organik tanpa memerlukan proses kawalan yang kompleks.

Tiga kultur selulolitik yang efisien (*Aspergillus niger , Trichoderma reesei and Phanerochaete chrysosporium)* telah digunakan sebagai inocula dalam kajian ini. Mikrob ini tidak menghasilkan produk sampingan yang toksik sepanjang proses biodegradasi, malahan ia dapat menggunakan lignin dan tumbuh di atas bahan lignoselulosik. Sebanyak 280g kepingan-kepingan kecil EFB separa kering dalam kultur tunggal dan kultur kelompok yang terdiri daripada *A. niger, T. reesei* dan *P. chrysosporium*, dibiarkan kompos selama lapan minggu dengan menggunakan ammonium sulfat sebagai sumber nitrogen. Proses semulajadi telah dijadikan kawalan sebagai perbandingan dengan kultur tunggal dan kelompok. Proses pengkomposan dijalankan dengan menggunakan kelalang 1L dan parameter kawalan yang dioptimumkan ialah seperti kandungan kelembapan, suhu dan proses pengudaraan.

Berdasarkan pemerhatian yang dibuat, tempoh pengkomposan telah berkurangan kepada empat minggu disebabkan penginokulan jika dibandingkan menggunakan cara normal iaitu 24 hingga 32 minggu. Kualiti kompos juga bertambah baik dan terdapat peningkatan penghasilan nitrate dan ammoniacal nitrogen disebabkan penguraian yang lebih cepat. Dalam tempoh empat minggu jumlah karbon telah didegradasi sebanyak 54% menggunakan kultur campuran diikuti P.chrysosporium 53.4%, A.niger 41%, T.reesie 34.6% and kawalan 22.7%.

Dengan menggunakan kultur campuran, peningkatan maksimum jumlah kandungan nitrogen sebanyak 92.1% telah direkodkan, 77.4% menggunakan P.chrysosporium, 67.6% menggunakan A.niger, 64.6% menggunakan T.reesie dan 39% menggunakan kawalan.nisbah C/N daripada 47 didalam kompos EFB meningkat 11.34 menggunakan kultur campuran, antara 12.32 hingga 18.67 menggunakan satu kultur dan 26.14 menggunakan kawalan. Ini menunjukkan pengurangan sebanyak 60% nisbah C/N berbanding kawalan.

Penggunaan kultur kelompok adalah lebih efektif daripada kultur tunggal dan pengkomposan semulajadi. Proses biodegradasi dalam keadaan pepejal (SSB) sangat berpotensi untuk menjadi teknologi terkini untuk penghasilan baja kompos dari serabut kepala sawit. Baja kompos yang dihasilkan melalui teknologi ini terbukti kaya dengan kandungan nitrogen, fosforus, potassium dan humus. Diharapkan agar hasil kajian ini akan menjadi panduan asas untuk penghasilan baja organik yang mesra alam.

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CHAPTER I

INTRODUCTION

General

The recycling of organic wastes as fertiliser for maintenance of soil quality and improved crop productivity is of economic importance. The burning of rural and urban refuse without energy recuperation or disposal in landfills are wasteful processes, which should be avoided.

The major advances in agriculture have taken place by the use of non-renewable petroleum and its products. The cost of non-renewable sources has, however, risen sharply during the last decade, increasing the prices of fertilizers and pesticides.

Composting is a microbiological, non-polluting and safe method for disposal and recycling of organic wastes by bioconversion to fertilisers. Bioconversion by this method eliminates environmental pollution. Moreover, sites for dumping refuse on the outskirts of cities are gradually shrinking due to progressive urban expansion. Traditional methods of composting are proving unsuitable for disposal of the huge quantities of city wastes generated. Besides compostable materials, these city wastes contain non-compostable components such as metals, stones, glass, etc. In this context, mechanisation of composting, particularly for large cities, has several advantages, such as: converting of large quantity of city refuse and thus increasing environmental sanitation; minimising

pollution; recovering discarded materials; and producing better quality compost in a shorter time.

Waste material generated by the society can be classified into three major categories: agricultural wastes, industrial wastes and domestic wastes. Industrial wastes are produced by various industries, and waste characteristics vary greatly from one industry to another. In Malaysia, the major agro-industrial wastes are produced by the oil palm industry. Currently more than one third of the total cultivated area in Malaysia is under oil palm cultivation, generating a huge quantity of organic wastes every day.

Recently there has been wide interest in the utilisation of agro-industrial wastes. This is evident in countries where agriculture is an important part of the economy. These organic wastes are also potential sources of pollution.

Initially empty fruit bunches from the mill were incinerated producing bunch ash, which causes air pollution. At present oil palm empty bunches are either distributed in the field as mulch or incinerated, and the ash produced used as potash fertiliser for the palms. With the present stringent DOE regulation on air pollution, most of EFB produced by oil palm mills are used for mulching and oil palm mills should get rid or treat all mill effluent, to a required minimum level.

With the above concerns in mind, this study proposes to evaluate the utilisation of agro-industrial by-products of the oil palm industry, with emphasis

on the use empty fruit bunches (EFB) as organic fertiliser by means of composting using the solid state bioconversion technique.

The recycling of renewable organic wastes to meet the challenges of the 21st century for fertiliser, food and feed is of the utmost importance. This research was undertaken to improve the traditional method of composting by hastening the process through inoculation of cellulolytic fungi, such as species of *Aspergillus niger, Trichoderma reesie* and *Phynarochaeta chrysosporium.*

Justification

Generally tropical soil is less fertile when compared to temperate soils. Soils in temperate zones possess an average organic matter content of 5 to 10 percent whereas tropical soils, especially those in the plains, have only 1 percent organic matter (Gaur, 1980). But nearly all of the nutrients are returned by the trees and this cycle goes on. Something should be done to the soil to improve its fertility and also to facilitate root penetration and the growth of the tree itself. Composts are known to last longer than chemical fertilisers in the soil, thus releasing nutrients in a sustained manner. The application of the compost is the right solution to land areas where the topsoil is degraded in terms of its chemical composition and fertility.

The oil palm empty fruit bunches contain a lot of nutrients useful to plants. Normally the length of time for composting process varies from 6 to 8 months. This time can be shortened to 1 month by inoculating the mixture with certain

microorganisms, and cutting the bunch into smaller fractions. The cutting of EFB into smaller fractions can produce a greater surface area for attacking and destroying the natural resistance of vegetation to microbial invasion.

Objective

The main objective of this study is to develop an alternative technology for production of compost from oil palm empty fruit bunches (EFB), using a solid state biconversion technique, by selected microorganisms.

CHAPTER II

LITERATURE REVIEW

Composting and Compost

Definition of Compsting

There is a need to separate the two terms (Stentiford , 1993):

Composting: referring to the biodegradative process;

Compost: The product of a composting process, which is suitable for use in agriculture or horticulture.

Composting is a bio-oxidative process leading to a highly stabilised organic product called compost, which may then contribute directly to soil conditioning and fertility (Bertoldi, 1985). According to Gaur (1982) composting may be defined as a biochemical process in which diverse and mixed groups of microorganisms break down organic materials to a humus like substance which is similar in properties to farm yard manure. Composting is the biological decomposition of the organic constituents of wastes under controlled conditions (Golueke, 1977).

Haug (1993) stated that composting is defined as the biological decomposition and stabilisation of organic substrates under conditions which allow development of thermophilic temperatures as a result of biologically produced heat, with a final product sufficiently stable for storage and application

to land without adverse environmental effects. He also added that composting is a form of waste stabilisation, but one that requires special conditions of moisture and aeration to produce thermophilic temperatures. Composting is usually applied to solid or semi solid materials, making composting somewhat unique among the biological stabilisation processes used in sanitary and biochemical engineering.

Gaur (1987) wrote that composting is the most environmentally successful process for waste recycling by:

a. Reducing moisture content and thereby reducing weight.

b. Making the material of consistent size to facilitate even application.

c. Inactivating weed seeds.

d. Avoiding odours usually associated with manures and sewage sludge.

Mitchell (1993) reported that composting is a process which can be carried out using low or high technology, but it is basically a socio-economic process since it removes or renders harmless a waste which might otherwise result in undesirable and offensive fermentation. In low technology applications the agricultural wastes are placed in piles and occasionally turned. A succession of microbes arises from the original microflora. Readily utilisable substrates are degraded mainly to carbon dioxide and water, leaving a product containing substrates that are more difficult for microbes to degrade (especially lignocellulose) and this product is then suitable for use as a soil conditioner. These biologically stable wastes represent much less of a pollutant to the environment than the original agricultural by-products.