OIL PALM FROND: VALUE-ADDING THROUGH PRODUCTION OF BIOCOMPOST WITH FUNGAL INOCULATION

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FACULTY OF SUSTAINABLE AGRICULTURE
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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

6 August 2014

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I felt immense pleasure to present my thesis with the title “Oil palm biomass: value-adding through production of biocompost with fungal inoculation” after three years working on it.

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ABSTRACT

This investigation highlights the chemical, physical and biological properties of oil palm frond (OPF) observed during 14 weeks of composting period. Composting is a controlled biological decomposition process, which converts organic wastes into humus-like materials. Two white rot fungi species, *Trametes versicolor* and *Schizophyllum commune* were introduced as inoculants for composting process. The oil palm fronds (OPF) were composted for 14 weeks, with four treatments, i) control (untreated OPF), ii) OPF treated with *T. versicolor*, iii) OPF treated with *S. commune*, iv) OPF treated with both *T. versicolor* and *S. commune*, with four replications. During composting period, eight genera of fungi, namely *Aspergillus*, *Trichoderma*, *Absidia*, *Geotrichum*, *Trametes, Schizophyllum*, *Syncephalastrum* and *Beauveria* species were isolated and identified from composted OPF. Resulted compost was brown in colour with homogeneous appearance, and no unpleasant odour was detected. Maturity of composted OPF was evaluated from the germination index (GI) of mung bean (*Vigna radiata*) and mustard (*Brassica chinensis*) seeds, and the measurement of phenolic contents. For germination test in extract of compost, the highest GI was observed in co-inoculation of *T. versicolor* and *S. commune* with value of 114, and in single inoculation of *T. versicolor* with GI of 124, for mung bean and mustard seeds, respectively. In germination test with added soil, the highest percentage of seed germination was recorded in OPF inoculated with *T. versicolor* for mung bean (97.8%), and OPF inoculated with *S. commune* for mustard (98.9%), respectively. At the end of composting, the maximum reduction in phenolic content was recorded in OPF co-inoculated with *T. versicolor* and *S. commune* with 76.5%. In this study, C/N ratio and percentage volume reduction became the most important parameters to be monitored. Inoculation with *S. commune* achieved the acceptable C/N ratio of 63.2 at the end of composting period. Compared to other treatments, single inoculation of *S. commune* indicated higher percentage of volume reduction with a value of 62.8%. Single inoculation of *S. commune*, therefore, provides a suitable medium for composting of OPF.

Keywords: composting, oil palm frond, white-rot fungi, inoculant, germination index

ABSTRAK

PELEPAH SAWIT: PENAMBAHAN-NILAI MELALUI PENGHASILAN BIO-KOMPOS DENGAN INOKULASI KULAT

Kajian ini menumpukan kepada sifat kimia, fizikal dan biologi pelepah sawit sepanjang 14 minggu tempoh pengomposan. Pengomposan merupakan proses penguraian biologi terkawal, yang menukarkan sisa organik kepada bahan seperti humus. Dua spesies kulat pereput putih iaitu Trametes versicolor dan Schizophyllum commune telah diperkenalkan sebagai inokula dalam pengomposan pelepah sawit. Pelepah sawit dikomposkan selama 14 minggu, dengan empat rawatan yang digunakan iaitu, i) kawalan (pelepah tidak dirawat), ii) pelepah dirawat dengan T. versicolor, iii) pelepah dirawat dengan S. commune, iv) pelepah dirawat dengan T. versicolor dan S. commune, dengan empat replikasi. Sepanjang tempoh pengomposan, lapan genus kulat, iaitu Aspergillus, Trichoderma, Absidia, Geotrichum, Trametes, Schizophyllum, Syncephalastrum dan Beauveria telah diasingkan dan dikenalpasti dalam kompos pelepah sawit. Kompos yang terhasil kelihatan coklat dalam keadaan homogenus dan tiada bau dikesan. Kematangan kompos pelepah sawit dinilai berdasarkan indeks percambahan biji benih kacang hijau (Vigna radiata) dan sawi (Brassica chinensis), serta kandungan fenolik. Bagi ujian percambahan menggunakan ekstrak kompos, indeks percambahan paling tinggi dikesan dalam ko-inokulasi T. versicolor dan S. commune dengan nilai 114, dan dalam inokulasi tunggal T. versicolor dengan indeks percambahan 124, masing-masing untuk biji benih kacang hijau dan sawi. Manakala bagi ujian percambahan dengan campuran tanah, peratus percambahan biji benih tertinggi direkodkan dalam pelepah sawit diinokulasi dengan T. versicolor untuk biji benih kacang hijau (97.8%), dan pelepah sawit diinokulasi dengan S. commune untuk biji benih sawi (98.9%). Pada akhir tempoh pengomposan, penurunan maksimum kandungan fenolik dicatatkan dalam pelepah yang diko-inokulasikan dengan T. versicolor dan S. commune iaitu 76.5%. Dalam kajian ini, parameter paling penting untuk diperhatikan adalah nisbah C/N dan peratus penurunan isipadu pelepah sawit. Inokulasi dengan S. commune mencapai nisbah C/N yang boleh diterimapakai iaitu 63.2 di akhir tempoh pengomposan. Berbanding dengan rawatan lain, inokulasi tunggal S. commune menunjukkan peratus penurunan isipadu tertinggi dengan nilai 62.8%. Oleh itu, inokulasi tunggal S. commune sesuai dijadikan medium bagi pengomposan pelepah sawit.

Kata kunci: pengomposan, pelepah sawit, kulat pereput putih, inokulan, indeks percambahan

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3.1 Percentage of moisture content = $\frac{(b-c)}{(b-a)}$ x 100 42

Moisture content = _______%
a = wt. of empty container in gram
b = wt. of air-dried sample + container in gram
c = wt. of oven-dried sample + container in gram

3.2 Loss on ignition (%) = $\frac{(b-c)}{(b-a)}$ x 100 43

a = wt. of empty crucible in gram
b = wt. of crucible + sample in gram
c = wt. of crucible + sample after ignition in gram

3.3 %N = [(V-B) x M x R x 14.01/Wt. x 1000] x 100 44

V = volume of 0.01 M H_2SO_4 titrated for the sample (ml)
B = digested blank titration volume (ml)
M = molarity of HCI or M H_2SO_4 solution
14.01 = atomic weight of N
R = ratio between total volume of the digest & the digest volume used for distillation
Wt. = weight of air-dry compost (g)

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a = volume of the composting material at the beginning
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y=mx + c
y: sample absorbance value
m: graph's slope
x: gallic acid concentration in the sample
c: value on y-axis

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$$GI = \frac{SG\ (\%) \times RE\ (\%)}{100}$$

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LIST OF ABBREVIATIONS

Al	Aluminium
ANOVA	Analysis of variance
ATP	Adenosine triphosphate
B	Boron
C	Carbon
C/N ratio	Carbon nitrogen ratio
Ca	Calcium
CCQC	California Compost Quality Council
Cd	Cadmium
CMC	Controlled microbial composting
CO_2	Carbon dioxide
CPO	Crude palm oil
Cu	Copper
DMRT	Duncan's Multiple Range Test
EFB	Empty fruit bunch
Fe	Iron
FELDA	Federal Land and Development Authority
GAE	Gallic acid equivalent
GI	Germination index
GLOX	Glyoxal oxidase

GNI	Gross National Income
H_2O	Water
H_2SO_4	Sulphuric acid
H_3BO_3	Boric acid
HCl	Hydrochloric acid
HKORC	Hong Kong Organic Resources Centre
HNO_3	Nitric acid
ICP-OES	Inductively coupled plasma-optical emission spectroscopy
K	Potassium
LiP	Lignin peroxidase
Mg	Magnesium
Mn	Manganese
MnP	Manganese peroxidase
MnT	Million tonnes
MPOB	Malaysian Palm Oil Board
MPOC	Malaysia Palm Oil Council
N	Nitrogen
Na_2CO_3	Sodium carbonate
NaOH	Sodium hydroxide
NH_3	Ammonia
Ni	Nickel
NKEA	National Key Economic Areas
O_2	Oxygen

OPF	Oil palm frond
P	Phosphorus
Pb	Lead
PDA	Potato dextrose agar
PEMANDU	Performance Management and Delivery Unit
POME	Palm oil mill effluent
RE	Relative root elongation
S	Sulphur
SD	Standard deviation
SEM	Scanning electron microscope
SG	Seed germination
Si	Silicon
TAS	Thai Agricultural Standard
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
VA	Veratryl alcohol
Zn	Zinc

LIST OF SYMBOLS

%	Percent
<	Less than
>	More than
±	Plus minus
°C	Degree celcius
cm	Centimeter
g	Gram
g.mg^{-1}	Gram per milligram
M	Molarity
mg.kg^{-1}	Milligram per kilogram
min	Minute
ml	Millimeter
nm	Nanometer (= 10^{-9} m)
rpm	Revolutions per minute
w/v	Weight per volume
µg	Micro gram
µm	Micro meter

CHAPTER 1

INTRODUCTION

1.1 Agricultural sustainability

World agricultural systems now stand at the crossroads. Sixty years ago, the introduction of synthetics inputs, like chemical fertilizers and a wide array of pesticides changed the face of traditional integrated agricultural systems. This new generation of synthetic inputs, no doubt, boosted agricultural production quite dramatically over the past fifty years, leading to Green Revolution of the 70's, which managed to feed millions of people and diverted hunger in the post World War II era. The conventional agricultural system which heavily relied upon synthetic chemical inputs to boost agricultural productivity, clearly at the same time, have resulted in environmental catastrophe. Severe damages done to natural resource base are now well documented and recognised. As a result, special emphasis is now being placed towards returning to nature and an adoption of a system of sustainable agriculture.

Recycling of the nutrients on farm, green manuring in soil, and composting of organic wastes are now seen as some of the options to restore the soil health and build the soil environment complex, and achieve sustainability in agriculture production. Composting is an alternative way to deal with the agriculture and industrial waste produced worldwide. Transformation of agricultural wastes into compost is one of the validated recycling methods, on top of its ability to transform various organic wastes into product that can be used as bio-fertilizers and soil conditioner. The stable composted product helps in replenishment of plant nutrients, maintenance of soil organic matter and improving the soil physical and microbial properties.

1.2 Composting of agricultural biomass

Composting is a biological decomposition of organic matters into simple nutrients. In composting, aerobic environment is preferable considering the ability to produce stable and high quality compost at short period of time. During this bio-oxidative process, the presence of bacteria, fungi and other microorganisms accelerate the breakdown of organic matters into partial humic substances. These microorganisms will metabolise the simple organic compounds to produce CO_2, NH_3, H_2O, organic acids and heats. The final product of compost must be usable, free of toxic substances, pathogens and plant seeds. Different stages of compost maturity have their own functions; high quality compost used in landscaping, turf and nurseries while low quality compost used in site remediation and landfill covers. Compost helps to increase soil organic matter, improve water holding capacity and reduce the amount of synthetic fertilizer used in crop production.

In Malaysia, oil palm tree offers as unique sources of biomass that can be converted into a range of value-added products such as bio-compost and bio-organic blends. Oil palm, *Elaeis guineensis* was introduced to Malaya in early 1870's by the British (MPOB, 2001). Oil palm plantation estates developed well and currently about 60% of agricultural land is dominated by oil palms, providing employment nationwide and boost our economy revenues (PEMANDU, 2010). Oil palm is a multifunctional crop which has led to the development of a variety of food products, industrial cleaning agents, candles, cosmetics, toiletries and also as material rich sources of agricultural biomass. Biomass can be defined as organic matter available on a renewable basis, includes forest and mill residues, wood wastes, agricultural waste, animal waste and municipal waste. These organic materials are valuable by-products that are produced throughout the years. In oil palm plantation, only 10% of oils could be derived from total biomass production (Salathong, 2007). Other than that, the remaining consist of huge amount of oil palm wastes such as oil palm shells, mesocarp fibers, empty fruit bunches (EFB), oil palm fronds and oil palm trunks (during replanting). In Malaysia, oil palm biomass are plentiful since Malaysia produces about 47% of the world's supply of palm oil that were shipped to China, Pakistan, India, United State and European Union (Sumathi *et al.*, 2008).

Oil palm fronds (OPF) are normally left to rot in between oil palm trees in plantation site or as mulching component. Fronds can be recycled as mulch, paper pulp and animal feed (Chan, 1999). Oil palm fronds cut during pruning and harvesting can be processed into green feed or silage, and the fibrous characteristic is similar to rice straw (Abu Hassan and Yeong, 1999). The possible uses of OPF in Malaysia still lack attention, however, several studies have been carried out regarding fronds as ruminant feeds (Abu Hassan *et al.*, 1996), herbivore feedstock (Dahlan, 2000), pulp production (Wan Rosli *et al.,* 2007), fuel pellet (Trangkaprasith and Chavalparit, 2010) and pressed juice (Zahari *et al.*, 2012). The physico-chemical structural of OPF itself is unique, such as the presence of silica bodies that need to be alter or remove through pre-treatment approaches especially in wood industry. There were many approaches in pre-treatment technologies, namely; physical (mechanical), chemical (acid, alkali or oxidizing agent), physico-chemical (hydrothermal or chemical) and biological (fungi). However, the biological treatment is preferable considering the cost and safety concern.

In composting, the adoption of multicellular fungi will induce the production of various hydrolytic enzymes that acts in synergistic ways to decompose lignocellulosic substrate. The decaying process of agriculture residues contribute significantly by lignocellulolytic enzymes secreted by fungi. Multicellular fungi have unique mechanism of degradation classified as white rot, brown rot and soft rot that preferentially degrade one or more wood components. White rot fungi acts either through simultaneous (nonselective) delignification or selective delignification (sequential decay) (Kubicek, 2012). This type of fungi will completely degrade the wood structure, displaying the uniform white appearance, or showed pockets of white rot due to selective decay of wood. Generally brown rot fungi will attack cellulose and hemicellulose, and not lignin or only a very small part of lignin. This condition caused the accumulation of lignin in degraded wood, displayed by crumbly, brittle and dark brown appearance of decayed wood. Both white and brown rot involved Basidiomycetes fungi, however soft rot developed from Ascomycetes and Basidiomycetes fungi (Kubicek, 2012). Soft rot fungi favourably attacked wood with low lignin constituent and requires higher moisture content. Soft rot fungi will decompose cellulose efficiently but acts slowly on lignin.

From ecological point of view, soil fertility is a key to healthy crop production. In managing soils, the fertilizer application, tillage and crop rotation are the efforts to preserve soil structure and nutrients within them. In agricultural fields, soil productivity depends on mineral composition and structure of soil, depth of irrigation and drainage, organic matter, intensity of earthworm, microbial activities and selection of crops varieties. Besides that, application of compost and organic fertilizers will help in restoring the soil properties. Compost or degraded product has enormous potential in recycling nutrient and maintaining soil fertility. For centuries, agriculture is the main important component in human community, which is a prime food source for entire living populations. The increasing world population significantly led to higher food consumptions, wider agricultural areas and food production increases in order to meet population demands. As the agriculture sectors developed rapidly, so as the agricultural waste generated becoming the main environmental issues since their bulky structures are difficult to dispose and require high management cost. Hence, the idea of composting is adopted to overcome this barrier. Thus, this project will highlight the importance of oil palm frond (OPF) wastes as medium for decomposition process by selective microorganisms. The OPF will be used as raw materials to generate high quality compost employing suitable fungi treatments.