USE OF BIOACTIVATOR MIXTURE FOR THE COMPOSTING PROCESS OF EMPTY FRUIT BUNCH

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ABSTRACT

The development of palm oil industry generates large numbers of empty fruit bunches (EFB) as a by-product. Commonly, palm oil industries discharge EFB to their plantation as mulching. However, this strategy requires a large space, a lot of labours, high costs for EFB distribution and it reduces soil fertility due to its oil content. An alternative method that can be applied for reducing EFB is by composting the EFB. However, the drawback of this approach is the long duration of this composting process. Hence the purpose of this study was to shorten the duration of the EFB composting by mixing EFB with some bioactivator consisting of agro-wastes such as palm oil mill effluent, *Eucalyptus* leaf litter and biosludge of pulp and paper (BPP). The composting of EFB used passive aeration method in the reactor bin with the composting duration for 90 days. During the composting process, physical changes such as colour, odour, texture and temperature were recorded every day. Chemical changes such as pH, moisture content, macronutrients, micronutrients, heavy metal contents and bacterial concentrations were analyzed for every ten days interval. Findings of this study showed that BPP was the best bioactivator in the composting of EFB. The optimization of EFB composting process was carried out by setting the EFB size and adjusting the initial moisture ratio. The best treatment combination was using SR_6 which was EFB size of 1.5 cm with a mixture ratio of 60 % of EFB and 40 % of BPP. Finally, the resulted compost from treatment of SR_6 was tested in the plantation study, and the best dose for enhancing the growth and yield of corn was using compost of 35 ton/ha. For future study, mechanical treatment and forced aeration method are suggested to be applied before starting the composting process. In addition, soil analysis and comparison between the application of organic and chemical fertilizers are suggested to be observed in order to know the effect of compost application.

ABSTRAK

Perkembangan industri kelapa sawit menjana peningkatan jumlah tandan buah kosong (EFB) sebagai sisa. Kebanyakan EFB dibuang oleh industri kelapa sawit ke kawasan ladang mereka sebagai sungkupan. Namun, strategi ini memerlukan kawasan yang luas, ramai pekerja dan biaya yang tinggi untuk penyebaran EFB, dan ia juga mengurangkan kesuburan tanah kerana kandungan minyaknya. Kaedah alternatif yang dapat dilakukan dalam mengurangkan EFB adalah melalui strategi pengkomposan. Namun kelemahan strategi ini adalah jangka masa pengkomposan yang lama. Oleh itu, tujuan kajian ini adalah untuk memendekkan jangka masa pengkomposan EFB dengan mencampurkan beberapa bio-pengaktif yang terdiri dari sisa agro-industri seperti efluen kilang kelapa sawit, daun *Eucalyptus* dan bioenapcemar pulpa dan kertas (BPP). Pengkomposan EFB ini menggunakan kaedah pengudaraan pasif dalam reaktor dengan waktu pengkomposan selama 90 hari. Sepanjang proses pengkomposan, perubahan fizikal seperti warna, bau, tekstur dan suhu direkod setiap hari. Perubahan kimia seperti pH, kandungan lembapan, nutrisi makro dan mikro, kandungan logam berat dan kandungan bakteria direkod setiap selang sepuluh hari. Hasil kajian ini menunjukkan bahawa BPP merupakan bio-pengaktif terbaik bagi proses pengkomposan EFB. Pengoptimumam proses pengkomposan EFB dilakukan dengan mengatur saiz EFB dan melaraskan nisbah awal lembapan. Kombinasi rawatan terbaik adalah rawatan menggunakan SR_6, iaitu saiz EFB 1.5 cm dengan nisbah campuran 60 % EFB dan 40 % BPP. Akhirnya, kompos yang dihasilkan melalui rawatan SR_6 diuji dalam kajian perladangan, dan dos kompos terbaik untuk meningkatkan pertumbuhan dan hasil jagung adalah 35 ton/ha. Untuk kajian masa hadapan, rawatan mekanikal dan kaedah pengudaraan paksa disarankan agar digunakan sebelum proses pengkomposan. Di samping itu, analisis tanah dan perbandingan antara penggunaan baja organik dan kimia dicadangkan untuk direkod agar mengetahui kesan aplikasi kompos.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variant
As	-	Arsenic
BOD	-	Biological Oxygen Demand
BPP	-	Biosludge Pulp and Paper
Ca	-	Calcium
Cd	-	Cadmium
Co	-	Cobalt
COD	-	Chemical Oxygen Demand
CPO	-	Crude Palm Oil
Cr	-	Chromium
CRD	-	Completely Randomized Design
Cu	-	Copper
C/N	-	Carbon to Nitrogen
DAP	-	Diammonium Phosphate
Df	-	Dilution Factor
DNMRT	-	Duncan Multiple Range Test
EC	-	Electrical Conductivity
ELL	-	*Eucalyptus* Leave Litter
EFB	-	Empty Fruit Bunch
Fe	-	Ferrum
FIA	-	Flow Injection Analyzer
FFB	-	Fresh Fruit Bunch
FTIR	-	Fourier Transform Infrared
GI	-	Germination Index
Hg	-	Mercury
ICP	-	Inductively Couple Plasma
ISPO	-	Indonesia Sustainable Palm Oil
K	-	Potassium
MC	-	Moisture Content

MCT	-	Microbes Concentration
MLVSS	-	Mix Liquor Volatile Suspended Solid
Mg	-	Magnesium
Mn	-	Manganese
MOP	-	Muriate of Potassium
N	-	Nitrogen
Na	-	Natrium
NA	-	Nutrient Agar
Ni	-	Nickel
NMR	-	Nuclear Magnetic Resonance
P	-	Phosphorus
Pb	-	Plumbum or Lead
POME	-	Palm Oil Mill Effluent
PTPN	-	PT. Perkebunan Nusantara
Rey	-	Rainfall Equivalent per Year
RSPO	-	Roundtable on Sustainable Palm Oil
SEM	-	Scanning Electron Microscope
TOC	-	Total Carbon Organic
TSS	-	Total Suspended Solid
VFA	-	Volatile Fatty Acid
WHO	-	Worth Health Organization
Zn	-	Zinc

LIST OF SYMBOLS

A	-	Probability value
μ	-	Mean value
C	-	ICP reading / FIA reading
CO_2	-	Carbon dioxide
εij	-	Experimental error on the treatment to-I and replication to-j
H	-	Hydrogen
HPO_4^{2-}	-	Secondary orthophosphate
H_2O	-	Water
$H_2PO_4^-$	-	Primary orthophosphate
N	-	Nitrogen
NH_3	-	Ammonia
NH_4^+	-	Ammonium
NO_2^-	-	Nitrogen dioxide
NO_3^+	-	Nitrate
O_2	-	Oxygen
R	-	Pearson correlation value
$SR_{1, 2, 3, \ldots 9}$	-	Treatment combination from size of EFB and ratio $_{1, 2, 3 \ldots 9}$
τi	-	Effect of treatment to-I
W	-	Weight
X	-	Concentration of elemet
Y_{ij}	-	Value of observation on treatment to-I and replication to-j

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CHAPTER 1

INTRODUCTION

1.1 Background of the Research

The palm oil industry sector in Indonesia has been growing rapidly for the past ten years. Palm oil production increases every year to satisfy domestic and export demand. Domestically, the palm oil industry is still processing palm oil into food product such as cooking oil, while the export demand is still supplied in the form of crude palm oil (CPO). The increasing of palm oil production is supported by the expansion of oil palm plantation area. The oil palm plantation area has been spread to all provinces in Indonesia. The oil palm has grown successfully in different soil conditions ranging from the fertile land to the marginal land and from a neutral pH to acidic pH. Directorate General of Estate Crops (2018) reported that the total area of oil palm plantation in 2007 was 6,766,836 ha; the total CPO production was 17,664,725 tons and the export volume was 5,701,286 tons with the value of $ 3,738,652. The oil palm plantation area and CPO production were increasing continuously to 2017; the total area of oil palm plantation achieved 14,048,722 ha, the total CPO production reached 37,965,224 tons and the export volume gained 7,076,061 tons with the value of $ 4,698,220.

In the same circumstances, the increasing of palm oil production also encourages the replenishment of palm oil industries in Indonesia. The palm oil industries in Indonesia consist of government and private companies. There were about 1,779 palm oil companies in Indonesia consisting of 164 government-owned companies and 1,615 private companies (Badan Pusat Statistik Indonesia, 2017). On the other side, the effect of the increase in palm oil production generates a lot of the solid wastes such as empty fruit bunch. Every 1 ton of CPO production will generate about 1,150 kg of empty fruit bunch (EFB) (Stichnothe & Schuchardt, 2010).

Obviously, the EFB can be utilized as organic fertilizer to improve the soil fertility because the EFB contains macro and micronutrients such as nitrogen, phosphorus, potassium, magnesium, calcium, ferum, sulphur, manganese, zinc, cuprum, natrium and boron (Stichnothe & Schuchardt, 2010; Vakili et al., 2012). Most of the palm oil industries dispose the EFB to their plantations as mulch. This method does not only add plant nutrient but also maintains moisture around the plantation area (Oviasogie, Aisueni, & Brown, 2010). However, this method requires high transportation cost and many labourers to spread the EFB (Singh et al., 2010). In addition, the EFB contains millions of stiff and rough fibers. Therefore, the decomposition process of EFB in the mulching method takes a long time (Yahya et al., 2010). The other effect is the appearance of rodents and pests that can interfere the growth of oil palm (Law, Daud, & Ghazali, 2007).

The appropriate alternative in managing EFB is through the composting method. This method has the added value on the resulted compost and is an eco-friendly method (Huang et al., 2004; Embrandiri et al., 2012; Vakili et al., 2012; Norhasmillah et al., 2013). Stichnothe and Schuchardt (2010) and Yahya *et al*. (2010) clarify that the compost that has been produced can support the sustainability program of the oil palm plantation. The composting is a method to convert organic material into a stable matter form that involves microorganism in the degradation and transformation processes (Baharuddin et al., 2011). Conventionally, the composting of EFB requires time about 6 months to 1 year for the complete degradation. Kananam, Suksaroj, & Suksaroj (2011) state that the degradation of EFB has a low decomposition rate because it has a hard biodegradable matter. Thereby, many studies had been developed to enhance the efficiency of EFB composting. Several additional substrates in composting EFB included the addition of various nitrogen sources from goat dung, cow dung and chicken manure (Thambirajah, Zulkali, & Hashim, 1995), the blending of EFB with palm oil mill effluent (POME) and decanter cake slurry (Yahya et al., 2010), the mixing of EFB with chicken manure and decanter sludge (Kananam, Suksaroj, & Suksaroj, 2011), addition of microbial inoculums and POME (Yeoh et al., 2011), blending of EFB and poultry litter (Vakili et al., 2012), insertion of fungal inoculums and POME (Mohammad, Alam, & Kabashi, 2013).

Based on the information**,** the current study aimed to contribute in developing the EFB composting efficiency with addition of bioactivator. The bioactivator consisted of POME, *Eucalyptus* leaf litter (ELL) and biosludge of pulp and paper (BPP). This bioactivator did not only contain the nutrients but also had microorganisms that could degrade organic matter. POME is the wastewater that is generated from the process of palm oil mill. Commonly, the palm oil industries handle POME using the ponding system. The anaerobic and aerobic ponds contain various species of microorganisms that have capability in degrading organic matter. Yahya et al., (2010) reported that the addition of POME in composting EFB could speed up the compost formation rate.

Similar to ELL, it is a part of *Eucalyptus* tree that is left on the soil surface in the industrial forest. The stem of *Eucalyptus* is used as raw material in manufacturing pulp and paper, while *Eucalyptus* leaves will undergo the change of colour and dry out, then become a litter on the ground. Hence the *Eucalyptus* leaves can become organic and nutrient sources for the soil when it has been composted. The *Eucalyptus* leaves are green plant material and contribute as a nitrogen source for the composting process. In composting, nitrogen is required for the microbial growth. Nitrogen limitation will cause small microbial population. In effect, the process of carbon decomposition takes a long time. However, excessive nitrogen content from the microbial growth requirement will cause loss of nitrogen in the form of ammonia.

On the other hand, BPP is an effluent that is generated from pulp and paper industry. BPP originates from the biological treatment on the wastewater treatment plant. The wastewater treatment plant uses the activated sludge process that utilizes aerobic microorganism to degrade organic matter. The microorganisms that are involved in the wastewater treatment plant consist of bacteria, protozoa, alga, fungi and rotifer (Asia Pacific Resources International, 2012). The mixture of BPP with EFB could improve the efficiency of EFB composting.

Several requirements on the compost material should be considered before starting the composting process such as carbon to nitrogen ratio, particle size, moisture content, heap size and decomposer microorganism (De Bertoldi, Vallini, & Pera, 1983; Leton & Stentiford, 1990; Tanpanich, Chindachia, & Duriyaprapan, 2009a). This study has optimized the EFB composting by modifying the EFB size and adjusting the initial moisture content ratio.

The small size of material creates a large surface area **(**De Bertoldi, Vallini, & Pera, 1983; Schaub & Leonard, 1996). Material that has a large surface area increases the contact between microorganism and material (Epstein, 2011). The effect of this condition will raise the microorganism activity in degrading organic matter. Microorganism will break down complex cellulolytic compounds with long carbon chains into simple cellulolytic compounds or shorter carbon chains. In addition, microorganisms can also remove hard silica body in EFB around 11.1% or 12.9% using mechanical treatments such as hammering (Law, Daud, & Ghazali, 2007). Eventually, the decomposition process can occur quickly. Mtui (2009) declares that the reduction of the composting material size is a mechanical pretreatment technology to facilitate further treatment. Nonetheless, the size of compost material that is too small can cause compaction in the compost pile (Bernal, Alburquerque, & Moral, 2009). The effect will lead to deficiency of oxygen in the compost pile and induce anaerobic condition. Finally, the degradation rate undergoes slow process. Conversely, the size compost material that is too large leads to a narrow surface area for microorganism activities, and the degradation process also becomes slow (Bernal, Alburquerque, & Moral, 2009).

The same thing with moisture content, the water supply that is too much or too little into compost material can inhibit microorganisms to thrive (Ryckeboer et al., 2003). The effect of this condition also slows down the degradation process. Luo *et al*. (2008) asserts that the moisture content is a critical factor in optimizing compost-engineering system because the presence of water determines decomposition of organic matter. Meanwhile, Kalamdhad *et al*. (2009) suggests that the moisture content in the compost material should have a certain level in order for the organisms to thrive.

In this study, the EFB composting used the passive aeration method as aerobic composting. In the passive aeration, a pipe perforated was installed to promote convective airflow throughout the pile, provide oxygen, control the temperature of composting and regulate the moisture content in the pores of organic material, so that microorganisms can operate optimally when breaking down organic matter. Barrington *et al*. (2003) states that passive aeration is efficient aeration, higher composting rate, cheaper and lower N losses nitrogen. However, the success of composting by passive aeration depends on the proper design, wherein the air ventilations ducts should provide sufficient oxygen during the composting process. The increased microbial activity in the composting pile will increase oxygen consumption. Therefore, an adequate supply of oxygen will not divert it to anaerobic decomposition.

As a result, the compost that is applied to the soil affects the biological, physical and chemical properties of soil. Stichnothe & Schuchardt (2010) explain that application of compost to plantation increases fauna micro-activity and organic matter content of soil, improves aeration and infiltration of soil, supports root density and growth of plant, and enhances the cation exchange capacity of soil. Oviasogie, Aisueni, & Brown (2010) assert that the compost improves the capacity of water-holding and nutrient-holding on soil. For plants, the application of compost can increase its growth and yield (Liang, Das, & McClendon, 2003; Huang et al., 2004).

Besides that, the compost material that derives from the milling activity has the potential to contain heavy metal such as zinc (Zn), copper (Cu), cadmium (Cd) and Lead (Pb). Heavy metals that are contained in the compost become toxic to the soil and plants when it is applied. Oviasogie, Aisueni, & Brown (2010) explain that the toxicities symptoms will be exhibited by plants before the accumulation of heavy metals in plant tissue to be high. Therefore, the plantation study was conducted to observe the quality of resulted compost in stimulating plant growth, and examine the toxicity of resulted compost on the plants. The corn is chosen as a model crop because it is a tolerant plant on heavy metal. The corn has a high ability to accumulate metals in the above ground parts with a reasonable bioaccumulation factor. Dheeba, Sampathkumar, & Kannan (2015) state that corn has capable of constant phytoextarction of metal from impure soil and transfer them from root to shoot. Hassen *et al*. (2001) states that the pollution of heavy metal in the agricultural soil affects crop quality and human health. The toxicity level of heavy metals to human depends on their daily intake. Excessive uptake of dietary heavy metals will cause a number of serious health problems.

1.2 Problem Statement

The development of the palm oil industry generates large amounts of EFB and POME. Based on the palm oil production in 2017, the estimation of total EFB which could be generated was about 43,660,008 tons. Meanwhile, POME will generate around 127,354 ton/hour when the production capacity in the palm oil mill is 30 tons/day. On the other hand, the pulp and paper industry will generate *Eucalyptus* leaves from industrial plantation activities and BPP from mill activities. In processing pulp and paper, *Eucalyptus* plant is only utilized from plant stem, while the leaves will be left behind on the soil surface. Furthermore, the leaves will dry up and become a potential source of forest fires. At the same time, wastewater will be generated from pulp and paper processing. Typically, the pulp and paper industry handles their wastewater by wastewater treatment plant and generates biosludge as a by-product.

These industrial wastes require safe handling solution and do not pollute the environment. The composting is an appropriate alternative method in overcoming these industrial wastes. As a result, compost can be used as organic fertilizer for agricultural crops. In addition, the effect of compost application on the soil can enhance soil fertility and productivity. This study has contributed in improving the efficiency of EFB composting by mixing EFB with POME, ELL and BPP as bioactivator. The nutrient contents and microbial inoculums in POME and BPP were utilized to enhance the efficiency of the EFB composting process, while ELL was used to utilize the nitrogen content in the leaves.

Optimization of EFB composting is required to achieve maximum composting efficiency. The optimization could be done by adjusting the EFB size and the initial moisture ratio. The small size of EFB will increase the degradation process, because microbe can break down faster in large surface areas. However, too small particle size will cause compaction of compost pile, so that oxygen diffusion will reduce. Likewise with moisture content, the moisture content that is too high or too low will inhibit the growth of microbes. The composting materials that have excessive moisture cause the pore space in the material to be filled with water.

In addition, the proper composting design also determines the success of the aerobic composting process. The composter should provide sufficient air circulation for microbial growth. The use of passive aeration with perforated pipe is one of the efficient aeration methods, high composting rate and low nitrogen loss. In addition, the passive aeration with a pipe perforated can flow oxygen from the ambient to the compost pile, and release heat from the compost pile to the ambient.

Consequently, the resulted compost from industrial wastes had the potential to contain heavy metals. The application of industrial wastes compost can cause accumulation in the soil, contamination on crop, low quality agricultural yield and risk to human health. Therefore, the measurement of the heavy metal concentration in crop and the daily intake rate of metal is important to know the heavy metal contamination level on food. As a model crop, corn is an appropriate plant for industrial waste compost application, because it is a tolerant crop that can accumulate heavy metals in its plant parts such as root, leave, shoot and fruit.

1.3 Objectives of the Study

The objectives of this research are as follows:

(a) To study the suitable biocomposter design for aerobic EFB composting.

(b) To study the most suitable bioactivator formulations that consisted of POME, ELL and BPP for improving the EFB composting efficiency.

(c) To optimize the EFB composting by modification of EFB size and initial moisture ratio.

(d) To evaluate the effectiveness and safety (minimum heavy metal content) on the resulted compost in the growth of corn crop.

(e) To determine the daily intake rate of metal in corn fruit.

1.4 Research Scopes

The scopes of the study consist of:

(a) Utilization of biocomposter design with the perforated pipe as passive aeration in aerobic composting.

(b) Physical and chemical characterizations on the compost material comprised of the EFB, POME, ELL and BPP.

(c) Physical, chemical and biological observations during the composting process either in the preliminary composting or the optimization of composting.

(d) Investigation and selection of the best bioactivator in the preliminary composting based on the result of physical, chemical and biological observations. The selection result of the bioactivator was used for the optimization of EFB composting.

(e) Optimization of EFB composting by adjusting the EFB size and the initial moisture content ratio.

(f) Investigation of the effectiveness and safety (minimum heavy metal content) on the resulted compost by application on corn crop as a model crop.

(g) Determination of the daily intake rate of metal in corn fruit.

1.5 Significant of Study

The significant findings of this study consist of:

(a) The biocomposter design with the perforated pipe had contributed in the aerobic EFB composting.

(b) The composting that was conducted in this study had contributed in handling the industrial wastes such as EFB, POME, ELL and BPP.

(c) The BPP could be used as a bioactivator in composting EFB.

(d) Adjustment of EFB size and mixture ratio between EFB and BPP as factors that influenced the composting process could enhance the efficiency of EFB composting.

(e) The application of resulted compost on corn crop determined the effectiveness and toxicity on corn growth.

(f) Investigation of the daily intake rate of metal had contributed in providing information that corn fruit was safe to be consumed.

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