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

DESRIHASTUTI

A thesis submitted in fulfilment of the

requirements for the award of the degree of

Doctor of Philosophy

School of Chemical and Energy Engineering

Faculty of Engineering

Universiti Teknologi Malaysia

NOVEMBER 2019

ACKNOWLEDGEMENT

Alhamdulillahirabbil‘alamin, thank you ALLAH for all the blessings and strengths which you have always given me in completing this study.

I would like to express my sincere gratitude to my supervisor Prof. Dr. Ida Idayu Muhamad and Prof. Madya Dr. Roshanida Binti A. Rahman who have given constant support, guidance and motivation during this study.

I am also grateful to Bupati Pelalawan H. M. Harris and Amanah Pelalawan Foundation for providing PhD Scholarship. I am thankful to Prof. Dr. -Ing. Eko supriyanto, DR. Tengku Edi Sabli, Bapak Azwirman, Novriadi who have facilitated all the scholarship process. I am incredibly grateful to PT. RAPP and all employees who have supported, simplified and expedited all the research processes.

I deeply thank to my parents H. Ridwan and Hj. Yarma, my parents-in-law Alm. Bono Winarto and Zulikha for their unfailing emotional support. I also thank for heart-warming kindness of my sisters Dorisma Oktavia, S.E and dr. Khairullaini, my younger brother Khairul Rizky, my brother-in-law Novi Aris, S.T and dr. Miko Akmaroza.

I owe thanks to a very special person, my husband, Gading Sahyoga for his continued and unfailing love, support and understanding. I appreciate my daughters Allya Raj Permata Gading and Anindya Maheswari Niti Gading who have given all the purity of your love.

I am also thankful to my colleagues Cici, Hilda, Ravika, Nining, Netya, Sofi and Persatuan Pelajar Indonesia (PPI) - UTM for their prayers and supports.

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.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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

LIST OF APPENDICES

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.

REFERENCES

Ahmad, A. L., Ismail, S., & Bhatia, S. (2003). Water Recycling from Palm Oil Mill Effluent (POME) using Membrane Technology. *Desalination*, *157*, 87-95.

Ahmad, M. N., Mokhtar, M. N., Baharuddin, A. S., Hock, L. S., Ali, S. R. A., Abd-Aziz, S., Rahman, N. A. A., & Hassan, M. A. (2011). Changes in Physicochemical and Microbial Community during Co-Composting of Oil Palm Frond with Palm Oil Effluent Anaerobic Sludge. *Bioresources*, *6*(4), 4762-4780.

Asia Pacific Resources International. (2012). Riau Fiber and Mill Overview. APRIL Press. Indonesia.

Badan Pusat Statistik. (2017). Direktori Perusahaan Perkebunan Sawit 2017. Badan Pusat Statistik Publisher. Indonesia.

Baharuddin, A. S., Wakisaka, M., Shirai, Y., Abd-Aziz, S., Abd-Rahman, N. A., & Hassan, M. A. (2009). Co-Composting of Empty Fruit Bunches and Partially Treated Palm Oil Mill Effluent in Pilot Scale. *International Journal of Agricultural Research*, *4*(2), 69-78.

Baharuddin, A. S., Hock, L. S., Md-Yusof, M. Z., Abd-Rahman, N. A., Md-Shah, U. K., Hassan, M. A., Wakisaka, M., Sakai, K., & Shirai, Y. (2010). Effects of Palm Oil mill Effluent (POME) Anaerobic Sludge from 500 m^3 of Closed Anaerobic Methane Digested Tank on Pressed-Shredded Empty Fruit Bunch (EFB) Composting Process. *African Journal of Biotechnology*, *9*(16), 2427-2436. doi: 10.5897/AJB10.1418.

Baharuddin, A. S., Abd-Rahman, N. A., Md-Shah, U. K., Hassan, M. A., Wakisaka, M., & Shirai, Y. (2011). Evaluation Of Pressed Shredded Empty Fruit Bunch (EFB)-Palm Oil Mill Effluent (POME) Anaerobic Sludge Based Compost Using Fourier Transform Infrared (FTIR) And Nuclear Magnetic Resources (NMR) Analysis. *African Journal of Biotechnology*, *10*(41), 8082-8089.

Bakar, R. A., Darus, S. Z., Kulaseharan, S., & Jamaluddin, N. (2011). Effect of Ten Year Application of Empty Fruit Bunches in an Oil Palm Plantation on Soil Chemical Properties. *Nutr Cycl Agroecosyst*, *89*, 341-349. doi: 10.1007/s10705-010-9398-9.

Barrington, S., Choiniere, D., Trigui, M., & Knight, W. (2003). Compost Convective Airflow under Passive Aeration. *Bioresource Technology*, *86*, 259-266.

Bazrafshan, E., Zazouli, M. A., Bazrafshan, J., & Bandpei, A. M. (2006). Co-Composting of Dewatered Sewage Sludge with Sawdust. *Pakistan Journal of Biological Science, 9*(8), 1580-1583.

Bhamidimarri, S. M. R., & Pandey, S. P. (1996). Aerobic Thermophilic Composting of Piggery Solid Wastes. *Water Science and Technology, 33*(8), 89-94. doi: 10.2166/wst.1996.0156.

Bernal, M. P., Alburquerque, J. A., & Moral, R. (2009). Composting of Animal Manures and Chemical Criteria for Compost Maturity Assessment. A Review. *Bioresource Technology*, *100*, 5444-5453. doi: 10.1016/j/biortech.2008.11.027.

Bolzonella, D., Cavinato, C., Fatone, F., Pavan, P., & Cecchi, F. (2012). High Rate Mesophilic, Thermophilic, and Temperature Phased Anaerobic Digestion of Waste Activated Sludge: A Pilot Scale Study. *Waste Management*, *32*, 1196-1201. doi: 10.1016/j.wasman.2012.01.006.

Bom, F. V., Magid, J., & Jensen, L. S. (2017). Long-term P and K Fertilization Strategies and Balanced Affect Soil Availability Indices, Crop Yield Depression Risk and N Use. *European Journal of Agronomy*, *86*, 12-23.

Briones, M. J. I., & Ineson, P. (1996). Decomposition of Eucalyptus Leaves in Litter Mixture. *Soil Biological Biochemical*, *28*(11), 1381-1388.

Caceres, R., Flotats, X., & Marfa, O. (2006). Changes in the Chemical and Physicochemical Properties of the Solid Fraction of Cattle Slurry during Composting Using Different Aeration Strategies. *Waste Management*, *26*, 1081-1091. doi: 10.1016/j.wasman.2005.06.013.

Cekmecelioglu, D., Demirci, A., Graves, R. E., & Davitt, N. H. (2005). Applicability of Optimised In-Vessel Food Waste Composting for Windrow Systems. *Biosystems Engineering*, *91*(4), 479-486. doi: 10.1016/j.biosystemseng.2005.04.013.

Chartzoulakis, K., Psarras, G., Vemmos, S., Loupassaki, M., & Bertaki, M. (2006). Response of Two Olive Cultivars to Salt Stress and Potassium Supplement. *J. Plant Nutr, 29*, 2063–2078. doi: 10.1080/01904160600932682.

Cook, K. L., Ritchey, E. L., Loughrin, J. H., Haley, M., Sistani, K. R., & Bolster, C. H. (2015). Effect of Turning Frequency and Season on Composting Materials from Swine High-Rise Facilities. *Waste Management*, *39*, 86-95. doi: 10.1016/j.wasman.2015.02.019.

Courtney, R. G., & Mullen, G. J. (2008). Soil Quality and Barley Growth as Influenced by the Land Application of Two Compost Types. *Bioresource Technology*, *99*, 2913-2918. doi: 10.1016/j.biortech.2007.06.034.

Cunha-Queda, A. C., Ribeiro, H. M., Ramos, A., & Cabral, F. (2007). Study of Biochemical and Microbiological Parameters during Composting of Pine and Eucalyptus Bark. *Bioresource Technology*, *98*, 3213-3220. doi: 10.1016/j.biortech.2006.07.006.

De Bertoldi, M., Vallini, G., & Pera, A. (1983). The Biology of Composting: A Review. *Waste Management and Research*, *1*, 157-176.

De Bertoldi, M., Civilini, M., & Comi, G. (1990). MSW Compost Standards in the European Community. *BioCycle*, 60-62.

Dekker, M. (1999) *Hand Book of Agriculture*. New York: Rol-Press.

Dezsi, S., Badarau, A. S., Bischin, C., Vodnar, D. C., Silaghi-Dumitrescu, R., Gheldiu, A. M., Mocan, A., & Vlase, L. (2015). Antimicrobial and Antioxidant Activities and Phenolic Profile of *Eucalyptus globulus* Labill. And *Corymbia ficifolia* (F. Muell.) K.D. Hill and L.A.S Johnson Leaves. *Molecules, 20*, 4720-4734. doi: 10.3390/molecules20034720.

Dheeba, B., Sampathkumar, P., Kannan, K. (2015). Fertilizer and Mixed Crop Cultivation of Chromium Tolerant and Sensitive Plant under Chromium Toxicity. *Jurnal of Toxicology*, 1-9. doi: 10.1155/2015/367217.

Directorate General of Estate Crops. (2018). Tree Crop Estate Statistics of Indonesia 2017-2019. Directorate General of Estate Crops publisher, Jakarta.

Dirjen POM. 1989. Batasan Maksimum Cemaran Logam Dalam Makanan No 03725/B/SK/VII/89. Direktor Jenderal Pengawas Obat dan Makanan. Indonesia.

Dutt, D., & Tyagi, C. H. (2011). Comparison of Various Eucalyptus Species for their Morphological, Chemical, Pulp and Paper Making Characteristics. *Indian Journal of Chemical Technology*, *18*, 145-151.

Elvira, C., Sampedro, L., Dominguez, J., & Mato, S. (1996). Vermicomposting of Wastewater Sludge from Paper-Pulp Industry with Nitrogen Rich Materials. *Soil Biological Biochemical*, *29*(3), 759-762.

Elvira, C., Sampedro, L., Benitez, E., & Nogales, R. (1997). Vermicomposting of Sludge from Paper Mill and Dairy Industries with *Eisenia Andrei*: A Pilot-Scale Study. *Bioresource Technology*, *63*, 205-211.

Embrandiri, A., Singh, R. P., Ibrahim, H. M., & Ramli, A. A. (2012). Land Application Of Biomass Residue Generated From Palm Oil Processing: Its Potential Benefits And Threats. *Environmentalist*, *32*, 111-117. doi: 10.1007/s10669-011-9367-0.

Epstein, E. (2011). Industrial Composting: Environmental Engineering and Facilities Management. CRC Press. New York

Evanylo, G. K., & Daniels, W. L. (1999). Paper Mill Sludge Composting and Compost Utilization. *Compost Science and Utilization*, *7*(2), 30-39. doi: 10.1080/1065657X.1999.10701961.

Fontenelle, L. T., Corgie, S. C., & Walker, L. P. (2011). Abiotic and Biotic Dynamics during the Initial Stages of High Solids Switchgrass Degradation. *Environmental Technology*, *32*(10), 1107-1120. doi: 10.1080/09593330.2010.528042.

Forth, H.D. (1998) *Dasar-Dasar Ilmu Tanah.* Yogyakarta: Gadjah Mana University Press.

Fourti, O., Jedidi, N., & Hassen, A. (2008). Behaviour of Main Microbiological Parameter and of Enteric Microorganisms during the Composting of Municipal Soild Wastes and Sewage Sludge in a Semi-Industrial Composting Plant. *American Journal of Environmental Science*, *4*(2), 103-110.

Gajalakshmi, S., & Abbasi, S. A. (2008). Solid Waste Management by Composting: State of the Art. *Critical Reviews in Environmental Science and Technology*, *38*, 311-400. doi: 10.1080/10643380701413633.

Gao, M., Li, B., Yu, A., Liang, F., Yang, L., & Sun, Y. (2010). The Effect of Aeration Rate on Forced-Aeration Composting of Chicken Manure and

Sawdust. *Bioresource Technology*, *101*, 1899-1903. doi: 10.1016/j.biortech.2009.10.027.

Giller, K. E., Witter, E., & Mcgrath, S. P. (1998). Toxicity of Heavy Metals to Microorganisms and Microbial Processes in Agricultural Soils: A Review. *Soil Biology Biochemical*, *30*(10), 1389-1414.

Goyal, S., Dhull, S. K., & Kapoor, K. K. (2005). Chemical and Biological Changes during Composting of Different Organic Wastes and Assessment of Compost Maturity. *Bioresource Technology*, *96*, 1584-1591. doi: 10.1016/j.biortech.2004.12.012.

Goya, J. F., Frangi, J. L., Perez, C., & Tea, F. D. (2008). Decomposition and Nutrient Release from Leaf Litter in *Eucalyptus grandis* Plantations on Three Different Soils in Entre Rios, Argentina. *Bosque*, *29*(3), 217-226.

Guedes de Carvalho, R. A., Gonzales Beca, C. G., Neves, O. R., & Sol Pereira, M. C. (1991). Composting of Pine and Eucalyptus Bark. *Bioresource Technology*, *38*, 51-63.

Hakim, N., Nyakpa, M.Y., Lubis, A.M., Nugroho, S.G., DiHa, M.A., Hong, G.B. and Bailey, H.H. (1986) *Dasar-Dasar Ilmu Tanah.* Indonesia: Universitas Lampung Press.

Hanafiah, K. A. (2014). Rancangan Percobaan Teori & Aplikasi. RajaGrafindo Persada. Jakarta.

Hanc, A., Tlustos, P., Szakova, J., & Balik, J. (2008). The Influence of Organic Fertilizers Application on Phosphorus and Potassium Bioavailability. *Plant Soil Environment*, *54*(6), 247-254.

Hassen, A., Belquith, K., Jedidi, N., Cherif, A., Cherif, M., & Boudabous, A. (2001). Microbial Characterization during Composting of Municipal Solid Waste. *Bioresource Technology, 80*, 217-225.

Hayashi, K. (2007). Environmental Impact of Palm Oil Industry In Indonesia. *Proceedings of International Symposium on Eco Topia Science (ISETS07)*. Nagoya, Japan, 646-651.

Hayawin, Z. N., Astimar, A. A., Ibrahim, M. H., Wan-Hasamudin, W. H., & Khalil, H. P. S. A. (2011). Vermicomposting of Different Types of Oil Palm Fibre Waste Using *Eudrilus eugeniae*: A Comparative Study. *Journal of Oil Palm Research*, *23*, 979-989.

Hayawin, Z. N., Astimar, A. A., Anis, M., Ibrahim, M. H., Khalil, H. P. S. A., & Ibrahim, Z. (2012). Vermicomposting of Empty Fruit bunch with Addition of Palm Oil Mill Effluent Solid. *Journal of Oil Palm Research*, *24*, 1542-1549.

He, X. T., Logan, T. J., & Traina, S. J. (1995). Physical and Chemical Characteristics of Selected U.S. Municipal Solid Waste Compost. *Journal of Environmental Quality*, *24*(3), 543-552. doi: 10.2134/jeq1995.00472425002400030022x.

Hendana, G. (2005) *Laporan Hasil Kajian Pemanfaatan Limbah Cair Industri Kelapa Sawit pada Tanah Perkebunan Kelapa Sawit* (*Land Application System*). Indonesia: PT. Gandaerah Hendana Press.

Hernandez, T., Chocano, C., Moreno, J-L., & Garcia, C. (2016). Use of Compost as an Alternative to Conventional Inorganic Fertilizers in Intensive Lettuce (*Lactuca sativa* L.) Crops-Effects on Soil and Plant. *Soil and Tillage Research, 160*, 14-22. doi: 10.1016/j.still.2016.02.005.

Hikam, S., & Timotiwu, P. B. (2016). Roles of Calcium and Magnesium as Selection Factors in Sweet Corn Quality Improvement on Acidic Red-Yellow Podsolic Soil. *Agrivita Journal of Agricultural Science, 38*(2), 163-173. doi: 10.17503/agrivita.v38i2.552.

Hong, N., Chen, J., Zhang, X-H., & Chen, T-B. (2013). Effect of Turning on Moisture Content in Sewage Sludge Composting. *Advanced Materials Research*, *777*, 457-460. doi: 10.4028/www.scientific.net/AMR.777.457.

Huang, G. F., Wong, J. W. C., Wu, Q. T., & Nagar, B. B. (2004). Effect of C/N on Composting of Pig Manure with Sawdust. *Waste Management*, *24*, 805-813. doi: 10.1016/j/wasman.2004.03.011.

Hubbe, M. A., Nazhad, M., & Sanchez, C. (2010). Composting as a Way to Convert Cellulosic Biomass and Organic Waste into High-Value Soil Amendments; A Review. *Bioresource*, *5*(4), 2808-2854.

Indonesia (1995) *Baku Mutu Limbah Cair bagi Kegiatan Industri*. KEP-51/MENLH/10/1995/Lampiran B.IV.

Indonesia (1999) *Pengelolaan Limbah Bahan Berbahaya dan Beracun*. KEPRES/85. Lampiran II.

Indonesia (2003) *Pedoman dan Tata Cara Perizinan Pemanfaatan Air Limbah Industri Minyak Sawit pada Tanah di Perkebunan Kelapa Sawit.* MNLH/29.2003.

Indonesia (2009) *Deskripsi Jagung Manis Varietas Bonanza*. 2071/Kpts/SR.120/5/2009.

Indonesia (2014) *Baku Mutu Air Limbah*. KMLH/5. Lampiran III dan XXXV.

Indonesia (2015) D*irektorat Jenderal Industri Agro*. Jakarta: Kementrian Perindustrian Press.

Iyengar, S. R., & Bhave, P. P. (2006). In-Vessel Composting of Household Wastes. *Waste Management*, *26*, 1070-1080. doi: 10.1016/j.wasman.2005.06.011.

Jimenez, E. I., & Garcia, V. P. (1989). Evaluation of City Refuse Compost Maturity: A Review. *Biological Waste*, *27*, 115-142.

Kalamdhad, A. S., Singh, Y. K., Ali, M., Khwairakpam, M., & Kazmi, A. A. (2009). Rotary Drum Composting of Vegetable Waste and Tree Leaves. *Bioresource Technology*, *100*, 6442-6450. doi: 10.1016/j/biortech.2009.07.030.

Kananam, W., Suksaroj, T. T., & Suksaroj, C. (2011). Biochemical Changes during Oil Palm (*Elaeis Guineensis*) Empty Fruit Bunches Composting with Decanter Sludge and Chicken Manure. *ScienceAsia*, *37*, 17-23. doi: 10.2306/scienceasia1513-1874.2011.37.017.

Kavut, Y. T., Geren, H., Avcioglu, R., & Soya, H. (2015). Effects of Previous Legume Crop Levels of Nitrogen and Sowing Date on Yield Components and some Morphological Characteristics of Corn. *Legume Research*, *38*(3), 341-347. doi: 10.5958/0976-0571.2015.00074.0.

Khalil, A. I., Beheary, M. S., & Salem, E. M. (2001). Monitoring of Microbial Populations and Their Cellulolytic Activities during the Composting of Municipal Solid Waste. *World Journal of Microbiology and Biotechnology*, *17*, 155-161.

Khalil, A. I., Hassouna, M. S., El-Ashqar, H. M. A., & Fawzi, M. (2011). Changes in Physical, Chemical and Microbial Parameters during the Composting of Municipal Sewage Sludge. *World Journal of Microbiological Biotechnology*, *27*, 2359-2369. doi: 10.1007/s11274-011-0704-8.

Kim, J. D., Park, J. S., In, B. H., Kim, D., & Namkoong, W. (2008). Evaluation of Pilot-Scale In-Vessel Composting for Food Waste Treatment. *Journal of Hazardous Materials*, *154*, 272-277. doi: 10.1016/j.jhazmat.2007.10.023.

Kothari, C. R. (2004). Research Methodology Methods & Techniques. New Age International Publisher. New Delhi.

Law, K. N., Daud, W. R. W., & Ghazali, A. (2007). Morphological and Chemical Nature of Fiber Strands of Oil Palm Empty-Fruit-Bunch (OPEFB). *Bioresources, 2*(3), 351-362.

Leiwakabessy, F. M., Wahyudin, U. M., & Suwarno. (2003). *Kesuburan Tanah*. Bogor: Departement Ilmu Tanah dan Sumberdaya Lahan. Fakultas Institut Pertanian Bogor.

Leton, T. G., & Stentiford, E. I. (1990). Control of Aeration in Static Pile Composting. *Waste Management and Research*, *8*, 299-306. doi: 0734-242X/90/040299.

Li, X., Zhang, R., & Pang, Y. (2008). Characteristics of Dairy Manure Composting with Rice Straw. *Bioresource Technology*, *99*, 359-367. doi: 10.1016/j.biortech.2006.12.009.

Liang, C., Das, K. C., & McClendon, R. W. (2003). The Influence of Temperature and Moisture Contents Regimes on the Aerobic Microbial Activity of a Biosolids Composting Blend. *Bioresource Technology*, *86*, 131-137.

Lim, P. N., Wu, T. Y., Clarke, C., & Nik-Daud, N. N. (2015). A Potential Bioconversion of Empty Fruit Bunches into Organic Fertilizer using *Eudrilus eugeniae*. *International Journal Science Technology*, *12*, 2533-2544. doi: 10.1007/s13762-014-0648-2.

Liu, H., & Li, J. (2010). The Study of the Ecological Problems of *Eucalyptus* Plantation and Sustainable Development in Maoming Xiaoliang. *Journal of Sustainable Development*, *3*(1), 197-201.

Liu, D., Zhang, R., Wu, H., Xu, D., Tang, Z., Yu, G., & Xu, Z. (2011). Changes in Biochemical and Microbiological Parameters during the Period of rapid Composting of Dairy Manure with Rice Chaff. *Bioresource Technology*, *102*, 9040-9049. doi: 10.1016/j.biortech.2011.07.052.

Luo, W., Chen, T. B., Zheng, G. D., Gao, D., Zhang, Y. A., & Gao, W. (2008). Effect of Moisture Adjustments on Vertical Temperature Distribution during Forced-Aeration Static-Pile Composting of Sewage Sludge. *Resources, Conservation and Recycling*, *52*, 635-642. doi: 10.1016/j.resconrec.2007.08.004.

Madan, S., Bhatia, A., Rajpal, A., & Kazmi, A. A. (2012). Maturity Assessment of Rotary Drum and Windrow Composts in Terms of Germination Index and

Enzymatic Activities. *International Journal of Applied Science and Engineering Research*, *1*(3), 415-426. doi: 10.6088/ijaser.0020101042.

Mahajan, A., & Gupta, R. D. Integrated Nutrient Management (INM) in a Sustainable Rice-Wheat Cropping System. Springer. India.

Majid, M. A., Islam, M. S., Sabagh, A. EL., Hasan, M. K., Saddam, M. O., Barutcular, C., Ratnasekera, D., Abdelaal, Kh. A. A., & Islam, M. S. (2017). Influence of Varying Nitrogen Levels on Growth, Yield and Nitrogen Use Efficiency of Hybrid Maize (*Zea Mays*). *Journal of Experimental Biology and Agricultural Science*, *5*(2), 134-142. doi: 10.18006/2017.5(2).134.142.

Masmoudi, S., Jarboui, R., Feki, H. E., Gea, T., Medhioub, K., & Ammar, E. (2013). Characterization of Olive Mill Wastes Composts and Their Humic Acids: Stability Assessment within Different Particle Size Fractions. *Environmental Technology*, *34*(6), 787-797. doi: 10.1080/09593330.2012.715761.

Mehta, C. M., Palni, U., Franke-Whittle, I. H., & Sharma, A. K. (2014). Review, Compost: Its Role, Mechanism and Impact on Reducing Soil-Borne Plant Diseases. *Waste Management*, *34*, 607-622. doi: 10.1016/j.wasman.2013.11.012.

Mkhabela, M. S., & Warman, P. R. (2005). The Influence of Municipal Solid Waste Compost on Yield, Soil Phosphorus Availability and Uptake by Two Vegetable crops grown in a Pugwash Sandy Loam Soil in Nova Scotia. *Agriculture*, *Ecosystems and Environment*, *106*, 57-67. doi: 10.1016/j.agee.2004.07.014.

Mohammad, N., Alam, Md. Z., Kabashi, N. A., & Ahsan, A. (2012). Effective Composting of Oil Palm Industrial Waste by Filamentous Fungi: A Review. *Resources, Conservation and Recycling*, *58*, 69-78. doi: 10.1016/j.resconrec.2011.10.009.

Mohammad, N., Alam, Md. Z., & Kabashi, N. A. (2013). Development of Composting Process of Oil Palm Industrial Wastes by Multi-Enzymatic Fungal System. *Journal Mater Cycles Waste Management, 15,* 348-356. doi: 10.1007/s10163-013-0125-x.

Mohee, R., & Mudhoo, A. (2005). Analysis of the Physical Properties of an In-Vessel Composting Matrix. *Powder Technology*, *155*, 92-99. doi: 10.1016/j.powtec.2005.05.051.

Mokhtari, M., Nikaeen, M., Amin, M. M., Bina, B., & Hasanzadeh, A. (2011). Evaluation of Stability Parameters in In-Vessel Composting of Municipal Solid Waste. *Iran Journal Environment Health Science Engineering*, *8*(4), 325-332.

Molla, A. H., Fakhru'l-Razi, A., Hanafi, M. M., & Alam, Md. Z. (2005). Compost Produced by Solid State Bioconversion of Biosolids: A Potential Resource for Plant Growth and Environmental Friendly Disposal. *Communications in Soil Science and Plant Analysis*, *36*, 1435-1447. doi: 10.1081/CSS-200058487.

Monte, M. C., Fuente, E., Blanco, A., & Negro, C. (2009). Waste Management from Pulp and Paper Production in the European Union. *Waste Management, 29,* 293-308. doi: 10.1016/j.wasman.2008.02.002.

Mtui, G. Y. S. (2009). Recent Advances in Pretreatment of Lignocellulosic Wastes and Production of Value Added Products. *African Journal of Biotechnology*, *8*(8), 1398-1415.

Nakasaki, K., Ohtaki, A., & Takano, H. (2001). Effect of Bulking Agent on the Reduction of NH_3 Emissions during Thermophilic Composting of Night-Soil Sludge. *Waste Management and Research*, *19*(4), 301-307. doi: 10.1177/0734242X0101900406.

Nieder, R., & Benbi, D. K. (2008). Carbon and Nitrogen the Terrestrial Environment. Springer. Germany.

Neiva, D. M., Fernandes, L., Araujo, S., Lourenco, A., Gominho, J., Simoes, R., & Pereira, H. (2015). Pulping Potential of Young Eucalyptus: a Comparative Study of Wood and Pulp Properties of 12 Eucalypt Species. *7th International Colloquium on Eucalyptus Pulp*. 26-29 May. Vitoria, Espirito Santo, Brazil.

Neuman, W. L. (2014). Pearson New International Edition - Social Research Methods: Qualitative and Quantitative Approaches. Pearson Education. United States of America.

Nordin, A. B. A., Simeh, M. A., Amiruddin, M. N., Weng, C. K., & Abd-Salam, B. (2004). Economic Feasibility of Organic Palm Oil Production in Malaysia. *Oil Palm Industry Economic Journal*, *4*(2), 29- 38.

Norhasmillah, A. H., Puah, C. W., Ibrahim, N. A., Baharuddin, A. S., & Choo, Y. M. (2013). Life Cycle Inventory of the Commercial Production of Compost from

Oil Palm Biomass: A Case Study. *Environ Dev Sustain, 15*(6), 1663-1670. doi: 10.1007/s10668-013-9457-x.

Ogunwande, G. A., Osunade, J. A., Adekalu, K. O., & Ogunjimi, L. A. O. (2008). Nitrogen Loss in Chicken Litter Compost as Affected by Carbon to Nitrogen Ratio and Turning Frequency. *Bioresource Technology*, *99*, 7495-7503. doi: 10.1016/j,biortech.2008.02.020.

Okwute, Ojonoma, L., & Nnennaya, I. (2007). The Environmental Impact of Palm Oil Mill Effluent (POME) on Some Physico-Chemical Parameters and Total Aerobic Bioload of Soil At A Dump Site In Anyigba, Kogi State, Nigeria. *African Journal of Agricutural Research*, *2*(12), 656-662.

Ordonez, C., Tejada, M., Benitez, C., & Gonzales, J. L. (2006). Characterization of a Phosphorus-Potassium Solution Obtained during a Protein Concentrate Process from Sunflower Flour. Application on Rye-Grass. *Bioresource Technology*, *97*, 522-528. doi: 10.1016/j.biortech.2005.02.047.

Oviasogie, P. O., Aisueni, N. O., & Brown, G. E. (2010). Oil Palm Composted Biomass: A Review of the Preparation, Utilization, Handling and Storage. *African Journal of Agricultural Research*, *5*(13), 1553-1571. doi: 10.5897/AJAR09.016.

Page, K., Harbottle, M. J., Cleall, P. J., & Hutchings, T. R. (2014). Heavy Metal Leaching and Environment Risk from the Use of Compost-Like Output as an Energy Crop Growth Substrate. *Science of the Total Environment*, *487*, 260-271. doi: 10.1016/j.scitotenv.2014.04.021.

Pandey, S. P (2001) *Aerobic Thermophilic Composting of Piggery Solid Wastes*. PhD Thesis, Massey University, New Zealand.

Raclavska, H., Juchelkova, D., Skrobankova, H., Wiltowski, T., & Campen, A. (2011). Conditions for Energy Generation as an Alternative Approach to Compost Utilization. *Environmental Technology*, *32*(4), 407-417. doi: 10.1080/09593330.2010.501089.

Raj, D., & Antil, R. S. (2012). Evaluation of Maturity and Stability Parameters of Composts Prepared from Farm Wastes. *Archives of Agronomy and Soil Science*, *58*(8), 817-832. doi: 10.1080/03650340.2010.547191.

Rasapoor, M., Nasrabadi, T., Kamali, M., & Hoveidi, H. (2009). The Effects of Aeration Rate on Generated Compost Quality, Using Aerated Static Pile

Method. *Waste Management*, *29*, 570-573. doi: 10.1016/j.wasman.2008.04.012.

Rashad, F. M., Saleh, W. D., & Moselhy, M. A. (2010). Bioconversion of Rise Straw and Certain Agro-Industrial Wastes to Amendments for Organic Farming System: 1 Composting, Quality, Stability and Maturity Indices. *Bioresource Technology*, *101*(15), 5952-5960.

Rasyad, A., Samiaji, J., & Efendi, E. (2008). Kandungan Logam Berat pada Jagung yang Dipupuk dengan Kompos IPAL Pabrik Pulp dan Kertas serta Kelayakannya untuk Konsumsi. *Journal Ilmu Lingkungan*, *2*(1), 1-8.

Razali, W. A. W., Baharuddin, A. S., Talib, A. T., Sulaiman, A., Naim, M. N., Hassan, M. A., & Shirai, Y. (2012). Degradation of Oil Palm Empty Fruit Bunches (OPEFB) Fiber during Composting Process Using In-Vessel Composter. *Bioresources*, *7*(4), 4786-4805.

Ribeiro, H. M., Romero, A. M., Pereira, H., Borges, P., Cabral, F., & Vasconcelos, E. (2007). Evaluation of a Compost Obtained from Forestry Wastes and Solid Phase of Pig Slurry as a Substrate for Seedlings Production. *Bioresource Technology*, *98*, 3294-3297. doi: 10.1016/j.biortech.2006.07.002.

Rihani, M., Malamis, D., Bihaoui, B., Etahiri, S., Loizidou, M., & Assobhei, O. (2010). In-Vessel Treatment of Urban Primary Sludge by Aerobic Composting. *Bioresource Technology*, *101*, 5988-5995. doi: 10.1016/j.biortech.2010.03.007.

Ryckeboer, J., Mergaert, J., Vaes, K., Klammer, S., De Clercq, D., Coosemans, J., Insam, H., & Swings, J. (2003). A Survey of Bacteria and Fungi Occurring during Composting and Self-Heating Processes. *Annals of Microbiology*, *53*(4), 349-410.

Sanchez-Arias, V., Fernandez, F. J., Villasenor, J., & Rodriguez, L. (2008). Enhancing the Co-Composting of Olive Mill Wastes and Sewage Sludge by the Addition of an Industrial Waste. *Bioresource Technology*, *99*, 6346-6353. doi: 10.1016/j.biortech.2007.12.013.

FSANZ. (2002) *Food Standards Australia New Zealand*. The Copyright Act 1968. Canberra BC.

Schaub, S. M., & Leonard, J. J. (1996). Composting: An Alternative Waste Management Option for Food Processing Industries. *Trends in Food Science and Technology*, *7*, 263-268.

Sesay, A. A., Lasaridi, K., Stentiford, E., & Budd, T. (1997). Controlled Composting of Paper Pulp Sludge Using the Aerated Static Pile Method. *Compost Science and Utilization, 5*(1), 82-96. doi: 10.1080/1065657X.1997.10701866.

Shackford, L. D. (2003) A Comparison of Pulping and Bleaching of Kraft Softwood and Eucalyptus Pulps. *36^th^ International Pulp and Paper Congress and Exhibition.* 13-16 October. Sao Paulo, Brazil.

Shihe, C. (1994). Survey on Municipal Domestic Waste Composting Technology in Mainland China. *Chinese Journal of Environmental Science*, *15*(1), 53-56.

Singh, Y. K. (2006). Fundamental of Research Methodology and Statistics New Age International Publisher. New Delhi.

Singh, R. P., & Agrawal, M. (2008). Potential Benefits and Risks of Land Application of Sewage Sludge. *Waste Management*, *28,* 347-358. doi: 10.1016/j.wasman.2006.12.010.

Singh, Y. K., Kalamdhad, A. S., Ali, M., & Kazmi, A. A. (2009). Maturation of Primary Stabilized Compost from Rotary Drum Composter. *Resources, Conservation and Recycling*, *53,* 386-392. doi: 10.1016/j.resconrec.2009.02.004.

Singh, R. P., Ibrahim, M. H., Esa, N., & Iliyana, M. S. (2010). Composting of Waste from Palm Oil Mill: A Sustainable Waste Management Practice. *Rev Environ Sci Biotechnol, 9*, 331-344. doi: 10.1007/s11157-010-9199-2.

Singh, S., Young, L-S., Shen, F-T., & Young, C-C. (2014). Impacts of Industrial Waste Resources on Maize (*Zea mays* L.) Growth, Yield, Nutrients Uptake and Soil Properties. *Waste Management*. *34,* 1877-1883. doi: 10.1016/j.wasman.2014.01.007.

Siregar, S. (2013) *Metode Penelitian Kuantitatif Dilengkapi Perbandingan Perhitungan Manual dan SPSS.* Indonesia: Prenadamedia Group.

Solano, M. L., Iriarte, F., Ciria, P., & Negro, M. J. (2001). Performance Characteristic of Three Aeration Systems in the Composting of Sheep Manure and Straw. *Journal Agriculture Engineering Resource*, *79*(3), 317-329. doi:10.1006/jaer.2001.0703.

Sommer, S. G. (2001). Effect of Composting on Nutrient Loss and Nitrogen Availability of Cattle Deep Litter. *European Journal of Agronomy*, *14*, 123-133.

Soro, D., Ayolie, K., Zro, F. G. B., Yeboua, F. Y., Kouadio, H. K. K., Bakayoko, S., Angui, P. T., & Kouadio, J. Y. (2015). Impact of Organic Fertilization on Maize (*Zea mays* L.) Production in a Ferralitic Soil of Centre-West Cote D'ivoire. *Journal of Experimental Biology and Agricultural Science*, *3*(6), 556-565. doi: 10.18006/2015.3(6).556.565.

Stichnothe, H., & Schuchardt, F. (2010). Comparison of Different Treatment Options for Palm Oil Production Waste on A Life Cycle Basis. *International Journal Life Cycle Assessment*, 15, 907-915. doi: 10.1007/s11367-010-0223-0.

Sundberg, C., & Jonsson, H. (2008). Higher pH and Faster Decomposition in Biowaste Composting by Increased Aeration. *Waste Management*, *28*, 518-526. doi: 10.1016/j.wasman.2007.01.011.

Sutoro, Y., Soelaeman., & Iskandar. (1988) *Budidaya Tanaman Jagung*. Bogor: Balitbang Pertanian. Puslitbang Tanaman Pangan.

Swarnalatha, B., & Reddy, M. V. (2011). Leaf Litter Breakdown and Nutrient Release in Three Tree Plantations Compared with a Natural Degraded Forest on the Coromandel Coast (Puducherry, India). *Ecotropica*, *17*, 39-51.

Tanjung, A. (2009) *Rancangan Percobaan.* Indonesia: Tantaramesta Asosiasi Direktori Indonesia.

Tanpanich, S., Chindachia, R., & Duriyaprapan, S. (2009a). Rate of Composting and Quality of Compost under Different Passively Aerated composting. *Supplement*, *37*, 153-161.

Tanpanich, S., Chindachia, R., Niwasprakit, C., & Keawdoung, M. (2009b). Performance of Low Input Active Aeration Pile, Turning Pile and Static Pile for Composting Organic Fertilizer. *Asian Journal of Food and Agro-Industry*, 211-215.

Tejada, M., Gonzalez, J. L., Garcia-Martinez, A. M., & Parrado, J. (2008). Effects of different Green Manures on Soil Biological Properties and Maize Yield. *Bioresource Technology*, *99*, 1758-1767. doi: 10.1016/j.biortech.2007.03.052.

Thambirajah, J. J., Zulkali, M. D., & Hashim, M. A. (1995). Microbiological and Biochemical Changes during the Composting of Oil Palm Empty-Fruit-Bunches. Effect of Nitrogen Supplementation on the Substrate. *Bioresource Technology*, *52*, 133-144.

Tits, M., Elsen, A., Bries, J., & Vandendriessche, H. (2014). Short-Term and Long-Term Effects of Vegetable, Fruit and Garden Waste Compost Applications in an Arable Crop Rotation in Flanders. *Plant and Soil*, *376*, 43-59.

Tiquia, S. M., Tam, N. F. Y., & Hodgkiss, I. J. (1996). Microbial activities during Composting of Spent Pig-manure Sawdust Litter at Different Moisture Content. *Bioresource Technology*, *55*, 201-206.

Tiquia, S. M., & Tam, N. F. Y. (2000). Co-composting of Spent Pig Litter and Sludge with Forced-Aeration. *Bioresource Technology*, *72*, 1-7.

Tiquia, S. M., & Tam, N. F. Y. (2002). Characterization and Composting of Poultry Litter in Forced-Aeration Piles. *Process Biochemistry*, *37*, 869-880.

Tognetti, C., Mazzarino, M. J., & Laos, F. (2007). Improving the Quality of Municipal Organic Waste Compost. *Bioresource Technology, 98*, 1067-1076. doi: 10.1016/j.biortech.2006.04.025.

Tubail, K., Chen, L., Michael Jr, F. C., Keener, H. M., Rigot, J. F., Klingman, M., Kost, D., & Dick, W. A. (2008). Gypsum Additions Reduce Ammonia Nitrogen Losses during Composting of Dairy Manure and Biosolids. *Compost Science and Utilization*, *16*(4), 285-293. doi: 10.1080/1065657X.2008.10702390.

Tsai, W.T. (2012). An Analysis of the Use of Biosludge as an Energy Source and Its Environmental Benefits in Taiwan. *Energies*, *5*, 3064-3073.

United State Department of Agriculture. (2017). “Oilseeds: World Market and Trade”. http://apps.fas.usda.gov/psdonline/circulars/oilseeds.pdf. Accessed 11 February, 2017.

Vakili, M., Haque, A. A. M., Hosseini, S. M., & Salamatinia, B. (2012). Evaluation of Maturation and Stability Some Indexes of Mixed Palm Oil Biowaste Composting Process and Poultry Litter. *World Applied Sciences Journal*, *19*(2), 234-240. doi: 10.5829/idosi.wasj.2012.19.02.1404.

Vuorinen, A. H., & Saharinen, M. H. (1997). Evaluation of Microbiological and Chemical Parameters during Manure and Straw Co-Composting in a Drum Composting System. *Agriculture, Ecosystems and Environment*, *66*, 19-29.

Wang, M. J. (1997). Land Application of Sewage Sludge in China. *The Science of the Total Environment*, *197*, 149-160.

Watson, S. A., & Ramstad, P. E. (1994). *Corn Chemistry and Technology*. USA: American Association of Cereal Chemists.

Wei, Y. S., Fan, Y. B., Wang, M. J., & Wang, J. S. (2000). Composting and Compost Application in China. *Resources, Conservation and Recycling, 30*, 277-300.

Wei, Y., & Liu, Y. (2005). Effects of Sewage Sludge Compost Application on Crops and Cropland in a 3-Year Field Study. *Chemosphere, 59,* 1257-1265. doi: 10.1016/j.chemosphere.2004.11.052.

Wong, J. W. C., Mak, K. F., Chan, N. W., Lam, A., Fang, M., Zhou, L. X., Wu, Q. T., & Liao, X. D. (2001). Co-composting of Soybean Residues and Leaves in Hong Kong. *Bioresource Technology*, *76*, 99-106.

Xu, Y. W., Zou, Y. T., Husaini, A. M., Zeng, J. W., Guan, L. L., Liu, Q., & Wu, W. (2011). Optimization of Potassium for Proper Growth and Physiological response *of Houttuynia cordata* Thunb. *Environmental and Experimental Botany, 71*, 292-297. doi: 10.1016/j.envexpbot.2010.12.015.

Yahya, A., Sye, C. P., Ishola, T. A., & Suryanto, H. (2010). Effect of Adding Palm Oil Mill Decanter Cake Slurry with Regular Turning Operation on the Composting Process and Quality of Compost from Oil Palm Empty Fruit Bunches. *Bioresource Technology*, 101, 8736-8741. doi: 10.1016/j.biortech.2010.05.073.

Yang, X., Li, Q., Tang, Z., Zhang, W., Yu, G., Shen, Q., & Zhao, F. (2017). Heavy Metal Concentrations and Arsenic Speciation in Animal Manure Composts in China. *Waste Management*, *64*, 333-339. doi: 10.1016/j.wasman.2017.03.015.

Yeoh, C. Y., Chin, N. L., Tan, C. S., & Ooi, H. S. (2011). Acceleration Effects of Microbial Inoculums on Palm Oil Mill Organic Waste Composting. *Compost Science and Utilization*, *19*(2), 135-142.

Yeoh, C. Y., Chin, N. L., Tan, C. S., & Ooi, H. S. (2012). Industrial Scale Co-composting of Palm Oil Mill Waste with Starter Cultures. *Journal of Food, Agriculture and Environment*, *10*(2), 771-775.

Yin, X., McClure, M. A., Jaja, N., Tyler, D. D., & Hayes, R. M. (2011). In-Season Prediction of Corn Yield using Plant Height under Major Production System. *Agronomy Journal*, *103*(3), 923-929. doi: 10.2134/agronj2010.0450.

Yin, X., Hayes, R. M., McClure, M. A., & Savoy, H. J. (2012). Assessment of Plant Biomass and Nitrogen Nutrition with Plant Height in Early- to Mid-Season Corn. *Journal Science Food Agriculture*, *92*, 2611-2617. doi: 10.1002/jsfa.5700.

Yunqin, L., Dehan, W., & Lishang, W. (2010). Biological Pretreatment Enhances Biogas Production in the Anaerobic Digestion of Pulp and Paper Sludge. *Waste Management and Research, 28,* 800-810. doi: 10.1177/0734242X09358734.

Yuzelma., Ahmad, A., & Nofrizal. (2013). Kajian Toksisitas Limbah Biosludge yang berasal dari IPAL Industri Pulp dan Kertas dengan Metode Toxicity Characteristik Leaching Procedure. *Jurnal Lingkungan, 1*, 60-67.

Zang, B., Li, S., Michel, F., Li, G., Luo, Y., Zhang, D., & Li, Y. (2016). Effects of Mix Ratio, Moisture Content and Aeration Rate on Sulfur Odor Emissions during Pig Manure Composting. *Waste Management*, *56*, 498-505. doi: 10.1016/j.wasman.2016.06.026.

Zhang, W. (2012). Did Eucalyptus Contribute to Environment Degradation? Implications from a Dispute on Causes of Severe Drought in Yunnan and Guizhou, China. *Environmental Skeptics and Critics*, *1*(2), 34-38.

Zhao, S., Liu, X., & Duo, L. (2012). Physical and Chemical Characterization of Municipal Solid Waste Compost in Different Particle Size Fractions. *Journal Environment Study*, *21*(2), 509-515.

Zimmer, M., Oliveira, R., Rodrigues, E., & Graca, M. A. S. (2005). Degradation of Leaf Litter Phenolics by Aquatic and Terrestrial Isopods. *Journal of Chemical Ecology*, *31*(8), 1933-1952. doi: 10.1007/s10886-005-5935-4.