UNIVERSITI PUTRA MALAYSIA

CO-COMPOSTING OF BIODEGRADABLE MUNICIPAL WASTE AND FRUIT AND VEGETABLE WASTES WITH INDIGENOUS MICROORGANISM FOR QUALITY COMPOST PRODUCTION

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By

MUSA AISHATU MALA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

November 2020

DEDICATION

I dedicate this work to two great men I am blessed with in my life; my father late Alhaji Mala Musa and my dear husband Alhaji Dr Abubakar Mohammed Sambo who both believe in the education of the girl child for a better and secured society.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy.

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Chairman : Professor Che Fauziah binti Ishak, PhD
Faculty : Agriculture

Large quantity of organic waste generation from agricultural sectors and their disposal become a safety and health issues around the world. However, this material can be turn into useful products by composting process. Therefore. the objectives of the study were to produce a high-quality compost, measure its carbon and nitrogen mineralization, and evaluate the release of nutrient contents using maize as the test crop. The compost was prepared using horticultural- and biodegradable municipal-wastes with and without indigenous microorganisms (IMO). The nitrogen (N) contents of the composts ranged from 1.52 to 2.76% (equivalent to 76 to 138 kg N ha^{-1} at the rate of 5 Mg ha^{-1}), while the other nutrients showed a significant variation due to the types of materials used. The initial C/N ratio declined in the range of 13.3 for 3:1+IMO compost to 26.0 for 1:2+IMO compost at the end of the 30 day of composting. Since initial separation was performed, the heavy metals were below permissible level by Malaysia standard MS1517 2012. Composts prepared at the ratio of 3:1 and 1:2 with and without IMO were superior in terms of plant nutrients content. In the soil incubation study, selected composts applied at the rate of 10 Mg ha^{-1} soil released the total-N (NH_4^+-N and + NO_3^--N) (in % over control) about 78.0 (3:1+IMO), 64.1 (1:2-IMO) and 64.4 % (1:2+IMO). At this rate, increased soil respiration rate was obtained for 3:1+IMO compost due to increased labile organic matter and higher amount of fruit and vegetable waste (FVW), which attract more soil microorganisms and/or the increased evolution of CO_2 from compost-amended soils in the process of decomposition of the added composts. The DHA activity increased with composts application rates; and significantly highest for 3:1+IMO compost added at 10 Mg ha^{-1} soil at 1.38 triphenylformazan (TPF)/g dry soil/24 hours. A broad band between 3,200-3,600 cm-1 wavelength in the Fourier transform infrared (FTIR) spectroscopy indicates the presence of carboxylic and hydroxyl functional groups as a result of carbon transformation in the compost. The quality of compost was evaluated by growing of maize in the glasshouse using Munchong, Typic Paleudox soil series amended with composts 3:1-IMO, 3:1+IMO, 1:2 +IMO at 0, 5 and 10 Mg ha-1 application rates in polybags showed significant differences ($P \leq 0.05$) in plant biomass, plant aerial weight and nutrients uptake at 45 day after sowing (DAS) for N, P, K, Ca, and Mg. Total plant biomass measured ranged from 26.74 to 8.05 g plant-1 while the aerial portion ranged from 9.66 to 18.07 g plant-1. The means foliar nutrient concentrations at the application rate of 10 Mg ha-1 for compost 3:1 + IMO were 2.5 % N, 0.1 % P, 2.2 % K, 0.1 % Ca and 0.1% Mg. Composts using a 3:1 ratio with and without IMO at 10 Mg ha-1 application rate gave higher nutrient content and subsequently released more nutrients for plant uptake. Hence, both these composts are recommended to be used as soil amendments and organic fertilizers for plants.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGKOMPOSAN BERSAMA SISA PERBANDARAN BIODEGRADASI DAN SISA BUAH-BUAHAN DAN SAYUR-SAYURAN DENGAN MIKOORGANISMA UNTUK PENGHASILAH KOMPOS BERKUALITI

Oleh

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Sebilangan besar penghasilan sisa organik dari sektor pertanian dan pembuangannya menjadi masalah keselamatan dan kesihatan di seluruh dunia. Walau bagaimanapun, bahan ini boleh berubah menjadi produk yang berguna dengan proses pengkomposan. Oleh itu. objektif kajian adalah untuk menghasilkan kompos berkualiti tinggi, mengukur mineralisasi karbon dan nitrogennya, dan menentukan pembebasan kandungan nutrien menggunakan jagung sebagai tanaman ujian. Kompos dihasilkan dengan menggunakan sisa perbandaran hortikultur dan juga sisa perbandaran biodegradasi dengan dan tanpa mikroorganisma asli (IMO). Kandungan nitrogen (N) kompos berjulat antara 1.52 hingga 2.76% (bersamaan 76 hingga 138 kg N ha^{-1} pada kadar 5 Mg ha^{-1}), sementara nutrien lain menunjukkan variasi yang ketara kerana jenis bahan yang digunakan. Nisbah asal C/N menurun dalam julat 13.3 untuk kompos 3: 1 + IMO kepada 26.0 untuk kompos 1: 2 + IMO pada akhir 30 hari pengkomposan. Oleh kerana pemisahan awal dilakukan, logam berat berada di bawah tahap yang dibenarkan oleh standard Malaysia MS1517 2012. Kompos yang disediakan pada nisbah 3: 1 dan 1: 2 dengan dan tanpa IMO lebih baik dari segi kandungan nutrien tumbuhan. Dalam kajian inkubasi tanah, kompos terpilih yang diaplikasikan pada kadar 10 Mg ha^{-1} tanah membebaskan jumlah-N (NH_4^+ -N + NO_3^- - N) (dalam % berbanding kawalan) sekitar 78.0 (3: 1 + IMO) , 64.1 (1: 2 - IMO) dan 64.4 (1: 2 + IMO). Pada kadar ini, peningkatan kadar respirasi tanah diperolehi untuk kompos IMO 3: 1 + kerana kandungan bahan organik labil dan jumlah sisa sayuran segar (FVW) yang lebih tinggi, yang menarik lebih banyak mikroorganisma tanah dan / atau peningkatan evolusi CO_2 dari kompos- tanah yang dipinda semasa proses penguraian kompos yang ditambah. Aktiviti DHA meningkat dengan kadar aplikasi kompos; dan tertinggi ketara untuk kompos IMO 3: 1 + yang ditambahkan pada kadar 10 Mg ha^{-1} pada 1.38 triphenylformazan (TPF) / g tanah kering / 24 jam. Jalur lebar antara 3.200-3.600 cm^{-1} jarak gelombang dalam spektroskopi inframerah transformasi Fourier (FTIR)

menunjukkan adanya kumpulan berfungsi karboksilik dan hidroksil hasil dari transformasi karbon (C) dalam kompos. Kualiti kompos dinilai dengan menanam jagung di rumah kaca menggunakan Munchong, siri tanah *Typic Paleudox* dipinda dengan kompos 3: 1 - IMO, 3: 1 + IMO, 1: 2 + IMO pada kadar 0, 5 dan 10 Mg ha^{-1} menunjukkan perbezaan yang signifikan ($P \leq 0.05$) pada biojisim tumbuhan, berat atas tumbuhan dan pengambilan nutrien pada 45 hari selepas penyemaian (DAS) untuk N, P, K, Ca, dan Mg. Jumlah biojisim tumbuhan yang ditentukan berjulat antara 26.74 hingga 8.05 g $pokok^{-1}$, sementara bahagian atas berjulat antara 9.66 hingga 18.07 g $pokok^{-1}$. Purata kepekatan nutrien foliar pada kadar aplikasi 10 Mg ha^{-1} untuk kompos 3: 1 + IMO adalah 2.5% N, 0.1% P, 2.2% K, 0.1% Ca dan 0.1% Mg. Kompos menggunakan nisbah 3: 1 dengan dan tanpa IMO pada kadar aplikasi 10 Mg ha^{-1} mengandungi kandungan nutrien yang lebih tinggi dan seterusnya membebaskan lebih banyak nutrien untuk pengambilan tumbuhan. Oleh itu, kedua-dua kompos ini adalah disarankan untuk penggunaan sebagai peminda tanah dan baja organik untuk tanaman.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
FVW	fruit and vegetable wastes
BMW	Biodegradable municipal waste
CRD	Complete randomized design
CMR	Chlorophyll meter readings
DAS	Days after sowing
EC	electrical conductivity
G	Gram
g kg^{-1}	gram per kilogram
LAI	Leaf area index
Mg	Milligram
mL	Milliliter
Mm	Millimeter
NH_4^+ N	ammonium nitrogen
NO_3^- N	nitrate nitrogen
ºC	Degree centigrade
Ppm	Part per million
RCBD	Randomized Complete Block Design
Rpm	Revolutions per minute
SAS	Statistical Analysis Software
Mg	Microgram

CHAPTER 1

INTRODUCTION

1.1 Background and problem statement

Solid waste generation is a global issue with its generation in the world predicted to increase by two times from 3.5 million tons waste generation in a day (2010) to about 6 million tons a day by 2025 (World Bank, 2013). Malaysia faced similar increment in solid waste generation contributed by industrialization and urbanization (Manaf et al., 2009). Foregoing projections predicted a rise up to 15.6 million tons in 2020 (Agamuthu and Dennis, 2011). Urbanization and rise in the human population globally contributed to increased waste generation (Awasthi et al., 2014; Sukholthaman and Sharp, 2016).

Among the solid wastes is the horticultural crop wastes coming from majority fruit and vegetable wastes (FVW). In 2014, Food and Agricultural Organization (FAO) has estimated an average loss of approximately 1.3 billion metric tons of all produced food globally with horticultural crops (fruits and vegetables) being the highest at 60% loss or wasted (Gustavsson et al., 2011). In Malaysia, 20-50% of all produced fruits and vegetables are left to waste according to research conducted by the Malaysian Agricultural Research and Development Institute (MARDI) and about 28.5% of all rice produced also goes to wastes (The Star May 24, 2016). An unprecedented increase in losses and wastes associated with using fruits and vegetables poses an economical, nutritional, and environmental problem (Sagar et al., 2018).

Municipal solid waste (MSW) generation comprising food remnants, packaging, kitchen wastes and/or grass cuttings is another contributor to solid waste disposition, estimated to be approximately 1.3 billion tons per year, and expected to rise to almost 2.2 billion tons per year (Leal Filho et al., 2016). In most developing countries, landfilling and open dumping of MSW are the main methods of waste disposal, resulting negative consequences with high pollution risks for human, soil, water, and environment. Therefore, recycling and turning such putrescible organic including horticultural wastes and MSW into a value-added product like composts that can be used safely on soils and improve soil fertility are seen as viable alternatives. While dumping solid wastes at landfills negatively impact the quality of groundwater, recycling wastes and returning the product to the soil as a nutrient sink is encouraged (Jodar et al., 2017; Kuo et.al., 2006).

Composting reduces landfills filling capacity by waste disposal as well as reducing formation of leachates and gases while ensuring the end product that increase plant nutrient in soil and improve water conservation (Jara-Samaniego et al., 2017a). Composting is a biological process that involves organic matter degradation by microorganisms through their metabolic activity and the decomposition process is usually carried out by different numbers and types of microorganisms including fungi, bacteria, and actinomycetes. (López-González et al., 2015). Traditionally, composting will take an average of 6 months before materials become matured (Song and Song, 2019) and safe for its application to soil. Using effective microorganisms including indigenous microorganism (IMO) and effective microorganism (EM) (lactic acid bacteria, yeast, and phototrophic bacteria) during composting ensures a good composting process (Namasivayam, 2010). Increased microbial population and activities during composting especially the primary decomposers are beneficial in any composting practice.

The factors for successful composting include right mixing ratio of primary materials (ratio of materials for composting) during the composting process (Zhang et al., 2016a), particle sizes and most importantly C to N ratio of the materials (Kazemi et al., 2016). Co-composting using vegetable wastes (VW) and paper (P) or carton (C) in the ratio 18kg : 2kg VW:P (C/N 22.9) yielded a better quality compost in comparison to using ratio 16.5kg :4.5 kg (C/N 31.8) VW:C (Rawoteea et al., 2017) because the composts produced was phytotoxic-free and had good water holding capacity. Composting of FVW with yard wastes in the ratio 2.5:1 produced a good quality compost with final C/N of 17.16, pH of 8.02, N, P, K contents of 0.84, 0.59 and 0.55% (Katre et al., 2012) respectively, which can have good fertilizer values. Co-composting of tree pruning and market wastes can produce a better quality compost with improved environmental conditions (Jara-Samaniego et al., 2017a). They used different combining ratios of 50:33:17 and 60:30:10, in composting market wastes: tree prunings : ornamental palms respectively, and 75:25% market waste : ornamental palms. Their results showed that composting these wastes in different ratios yielded composts with different nutrients (N, P, and K) and agronomic efficiency and heavy metals were less than critical values set for the state of Ecuador, C/N of 11.9-17.5 was recorded at the end of the composting. They concluded that the composts produced were phytotoxic-free and can be used as organic fertilizers. Composts made using MSW and a combination of source-seperated market waste and urban pruning wastes that lasted 97 days produced composts that had adequate physico-chemical properties in terms of compost quality. The total N, P_2O_5, and K_2O contents of the 6 composts they produced ranged from 1.60-2.58%, 0.76-1.04% and 1.04-3.47%, respectively, with a pH that ranged from 7.82-8.73. The 6 composts were made from unsorted municipal solid waste (MSW), organic fraction of municipal solid waste (OFMSW), source-separated OFMSW, fruit and vegetable wastes (FVW), with the proportion/ratio of FVW (1) + prunnings (4), and Lantana camara L(1): prunnings (2) (Jara-Samaniego et al., 2017b).

1.2 Objectives of the Study

The study aimed to compare compost quality produced from BMW (biodegradable municipal wastes) and FVW (fruits and vegetables wastes) mixtures with IMO (indigenous microorganisms) addition and assess the quality of the produced composts as soil amendments in nitrogen mineralization, carbon dynamics and their effects to soils (nutrient release to soils) and uptake by corn (*Zea mays* L.).

The specific objectives of the study were: -

1. To determine the right mixture ratio of FVW and BMW to produce good quality compost with and without IMO.
2. To study the quality of the compost in terms of nitrogen release, soil carbon dynamics and organic matter fractionation and
3. To determine the effect of composts application on growth performance of corn as well as its effect on soil physical and chemical properties.

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