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CO-COMPOSTING OF KITCHEN WASTE AND SAWDUST WITH ADDITION OF BIOCHAR

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By

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Chair : Professor Dr. Mohd Ali Hassan, PhD
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Composting is a feasible way to convert kitchen waste into valuable products, as a better method in kitchen waste management. Kitchen waste contains high nitrogen content with easily degradable organic matter, hence making it suitable for the composting process. The improvement of the composting process was carried out with the application of biochar to enhance the physicochemical characteristics of composting process and improve the bacterial community. In this study, the effect of biochar derived from coconut shell on the co-composting process of kitchen waste and sawdust in a small scale (120 L composter) was investigated. Kitchen waste (60 L, v/v) collected from Taman Sri Serdang residential area was mixed with sawdust (60 L, v/v) and added with biochar (4%) and matured compost (4%). Temperature, pH, moisture content and aeration rates were monitored continuously throughout the co-composting process. It was found that the co-composting with addition of biochar improved the physicochemical characteristics of the compost. The co-composting of kitchen waste and sawdust with biochar addition was sustained in the thermophilic phase for longer time (14 days) as compared to compost without biochar, with maximum temperature of 71.5 °C. The C/N ratio of compost with biochar addition was reduced from 33.7 to 11.8, while the contents of nitrogen, phosphorus and potassium were 3.3%, 3.2% and 1.2%, respectively. Higher nitrogen content was obtained from the co-composting with biochar addition as compared to the co-composting without biochar. Biochar appeared to trap the nitrogen from being released. Biochar addition also promoted the changes in bacterial community composition throughout the co-composting process. In order to elucidate the changes of bacterial community structure during co-composting process, polymerase chain reaction-denaturing gradient gel electrophoresis (PCR-DGGE) analysis was carried out. More DGGE bands appeared in the co-composting with addition of biochar, indicating higher bacterial diversity as compared to the co-composting without biochar addition. The results also showed the presence of *Proteobacteria* as the dominant phylum for both treatments with and without biochar addition. Further analysis was then carried out using Illumina MiSeq sequencing to elucidate the shift of bacterial diversity during the co-composting process. At the end of the co-composting process, six major phyla including *Firmicutes*, *Gemmatimonadetes*, *Proteobacteria*, *Actinobacteria*, *Bacteriodetes* and

Chloroflexi for both experiments were detected. The most abundant *Actinobacteria* phylogeny was found at the end of the co-composting process with biochar addition which may function in the degradation of the lignocellulolytic compound contained in the sawdust. In order to support the results obtained, scanning electron microscopy (SEM) analysis was conducted to observe the morphological changes of the bacteria on the surface of biochar and chicken bone. The analysis revealed different bacterial morphology dominated at mesophilic, thermophilic and curing phases of the co-composting. These bacteria appeared to influence the physicochemical characteristics of compost, including temperature and pH. It is therefore suggested that biochar addition reduced nitrogen loss and induced bacterial community composition during the co-composting process
.

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

PENGKOMPOSAN BERSAMA SISA DAPUR DAN HABUK KAYU DENGAN PENAMBAHAN BIOCHAR

Oleh

MOHD HAFIF BIN SAMSUDIN

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Pengerusi : Professor Mohd Ali Hassan, PhD
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Pengkomposan adalah cara yang boleh dilaksanakan untuk mengitar semula sisa dapur menjadi produk berharga, sebagai kaedah yang lebih baik dalam pengurusan sisa dapur. Sisa dapur mengandungi kandungan nitrogen yang tinggi dengan bahan organik mudah terurai, oleh itu menjadikan ia sesuai untuk proses pengkomposan. Penambahbaikan proses pengkomposan telah dijalankan dengan mengaplikasikan biochar untuk meningkatkan ciri-ciri fizikokimia proses pengkomposan dan meningkatkan komuniti bakteria. Dalam kajian ini, kesan biochar yang dihasilkan daripada tempurung kelapa terhadap proses pengkomposan bersama sisa dapur dan habuk kayu dalam skala kecil (pengkompos 120 L) telah disiasat. Sisa dapur (6 L, v/v) yang dikumpulkan dari kawasan kediaman Taman Sri Serdang dicampurkan dengan habuk kayu (60 L, v/v) dan ditambah dengan biochar (4%) dan kompos matang (4%). Suhu, pH, kandungan kelembapan dan kadar pengudaraan dipantau secara berterusan sepanjang proses pengkomposan berlaku. Didapati bahawa pengkomposan bersama dengan penambahan biochar meningkatkan ciri-ciri fizikokimia kompos. Pengkomposan bersama sisa dapur dan habuk kayu dengan penambahan biochar kekal dalam fasa termofilik untuk masa yang lebih lama (14 hari) berbanding dengan kompos tanpa biochar, dengan suhu maksimum 71.5 °C. Nisbah C/N kompos dengan penambahan biochar telah berkurangan dari 33.7 kepada 11.8 manakala kandungan nitrogen, fosforus dan potasium masing-masing adalah 3.3%, 3.2% dan 1.2%. Kandungan nitrogen yang tinggi diperoleh daripada pengkomposan bersama dengan penambahan biochar berbanding pengkomposan bersama tanpa biochar. Biochar dilihat mampu memerangkap nitrogen daripada dibebaskan ke udara. Selain itu, biochar juga menggalakkan perubahan dalam komuniti bakteria sepanjang proses pengkomposan. Untuk menjelaskan perubahan struktur komuniti bakteria semasa proses pengkomposan, analisis tindak balas rantai polimerase-gel elektroforesis penyahaslian kecerunan (PCR-DGGE) telah dijalankan. Penambahan biochar telah meningkatkan kepelbagaian bakteria di akhir pengkomposan bersama berbanding pengkomposan bersama tanpa penambahan biochar. Jalur DGGE juga muncul lebih banyak dalam pengkomposan bersama dengan penambahan biochar, yang menunjukkan kepelbagaian bakteria yang lebih tinggi berbanding pengkomposan bersama tanpa penambahan biochar. Keputusan juga menunjukkan kehadiran *Proteobacteria* sebagai filum yang mendominasi untuk kedua-dua pengkomposan bersama dengan dan tanpa penambahan biochar. Analisis lanjut kemudiannya dijalankan menggunakan penjujukan Illumina MiSeq untuk menjelaskan perubahan kepelbagaian bakteria semasa proses pengkomposan bersama. Di akhir proses pengkomposan, terdapat enam filum utama telah dikesan termasuk *Firmicutes*, *Gemmatimonodetes*, *Proteobacteria*, *Actinobacteria*, *Bacteriodetes* dan *Chloroflexi* untuk kedua-dua eksperimen. Kehadiran filogeni *Actinobacteria* yang paling banyak didapati di akhir proses pengkomposan bersama dengan penambahan biochar yang mungkin disebabkan oleh fungsinya dalam menguraikan kompaun lignoselulolitik yang terkandung dalam habuk kayu. Untuk menyokong hasil kajian yang diperoleh, analisis mikroskopi elektron penskanan (SEM) telah dijalankan untuk melihat perubahan morfologi bakteria pada permukaan biochar dan tulang ayam. Analisis menunjukkan morfologi bakteria yang berbeza yang mendominasi fasa mesofili, termofili dan pematangan semasa proses pengkomposan bersama. Bakteria ini mempengaruhi ciri-ciri fizikokimia kompos, termasuk suhu dan pH. Oleh itu, dicadangkan bahawa penambahan biohar dapat mengurangkan kehilangan nitrogen dan menggalakkan komposisi komuniti bakteria semasa proses pengkomposan bersama.

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I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of (student's name) on his (her) thesis entitled ("Title of Thesis") in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science in Environmental Biotechnology.

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LIST OF ABBREVIATIONS

16S rRNA	16S ribosomal Ribonucleic Acid
BET	Brunauer–Emmett–Teller
cDNA	Complimentary Deoxyribonucleic Acid
C/N	Carbon to nitrogen
DGGE	Denaturing Gradient Gel Electrophoresis
dNTPs	Deoxynucleotide Triphosphates
dsDNA	Double stranded Deoxyribonucleic Acid
FBSB	Faculty of Biotechnology and Biomolecular Sciences
GHG	Greenhouse gases
ISWM	Integrated Solid Waste Management
MSW	Municipal Solid Waste
MHLG	Ministry of Housing and Local Government
PCR	Polymerase Chain Reaction
POME	Palm oil mill effluent
SEM	Scanning Electron Microscope
QIIME	Quantitative Insights Into Microbial Ecology
USD	US Dollar
rRNA	ribosomal Ribonucleic Acid
TE	Tris Ethylenediaminetetraacetic acid

CHAPTER 1

INTRODUCTION

The generation of municipal solid waste (MSW) in Malaysia has increased due to a rise in population. According to Kathirvale et al. (2004), the average generation of solid waste is 0.5–0.8 kg/person/day, but in the cities, the predicted figure is much higher with solid waste generation of 1.7 kg/person/day. As a current practice in Malaysia, most kitchen wastes are collected together with other MSW and disposed at landfills without proper treatment. Since lands for disposing wastes are limited and incinerators are not economic, the issue of improper disposal of MSW has become a serious problem in many areas. This phenomenon has consequently caused problems in the waste management by local authorities.

Due to the characteristics of kitchen waste with high organic content, loose physical structure and high moisture percentage, composting could be one of the alternatives to resolve the disposal issue. Composting is a simple and inexpensive technology that is able to accommodate a high percentage of biodegradable wastes produced in developing countries while require low labour costs. These reasons have made composting particularly favourable in solid waste management system (Elango et al., 2009; Marshall and Farahbakhsh, 2013). Composting is the biological aerobic decomposition of organic materials where conditions are monitored to ensure microorganisms decompose the materials into stable, humus-like product (Rynk, 1992). The application of compost can benefit the agricultural sector by improving soil structure and helping plants to grow healthier. On the other hand, it can kill pathogens within the raw material due to natural generation of heat that can reach thermophilic condition at 50-70 ºC (Airan and Bell, 1980).

However, natural rapid degradation in the kitchen waste results in anaerobic condition due to high oxygen consumption by the microorganisms, hence causing a release of harmful gas as well as disturbing odours. Besides that, kitchen waste can easily turn acidic due to the organic acid formation at the initial stage of composting, hence inhibit the activity of microorganisms. The other issue involved is the presence of fats in the kitchen waste which can inhibit the microbial activity inside the compost. Nakasaki (2004) raised several concerns about maintaining the performance of composting since fats can cover the surface of significant substrates, hence reduced the degradation abilities of microbes. In a previous study by Wang et al. (2016), the bulking agent was applied to the composting of kitchen waste with the benefits of high organic matter and moisture content, hence lead to a successful composting process.

In the past 10 years, there were several reports on the effects of biochar on the improvement of compost. Biochar is a carbon residue material generated from slow pyrolysis at certain temperature using biomass as a feedstock (Lehmann et al., 2011). Biochar can be produced from various types of biomass such as bamboo, coconut shell, oil palm empty fruit bunch, rice straw and coconut coir. It has been widely used for soil conditioning, water remediation, carbon sequestration and other environmental remediation (Mohan et al., 2014). Biochar is advantageous as it is a low-cost adsorbent and has proven to be effective in application to the environment (Yao et al., 2011). While most biochar studies focused on soil and water application, there are several researches done on elucidating the potential benefits of biochar in the composting process.

Extensive researches were done by Czekała et al. (2016), Jindo et al. (2016), López-Cano et al. (2016) and Zhang et al. (2016) to investigate the unique effect of biochar to improve the kitchen waste composting process. A study by Sun et al. (2016) showed that biochar can provide support for cultured microbes whereby the growth of microbial communities on the surface of biochar was much higher than at the adjacent compost. Biochar, which was used as amendment in composting was also found to help in increasing the temperature and CO_2 emission, while shorten the thermophilic phase during composting (Czekała et al., 2016). According to Wang et al. (2016), biochar was found to hasten organic matter degradation during the composting process using wheat straw and pig manure as the feedstocks. Vandecasteele et al. (2016) reported that by the addition of biochar on composting of green waste and municipal solid waste, nitrogen loss was reduced and organic matter degradation was enhanced. Similar findings were reported by López-Cano et al. (2016) who discovered that biochar favours nitrification and enhances mineralisation. It was suggested that the biochar addition to the composting reduced the nitrogen loss by 15% and provided support for microorganisms.

In this study, kitchen waste is co-composted with sawdust with the addition of biochar as a treatment. **Figure 1.1** shows the overview of this study by relating all the raw materials used and analyses conducted.

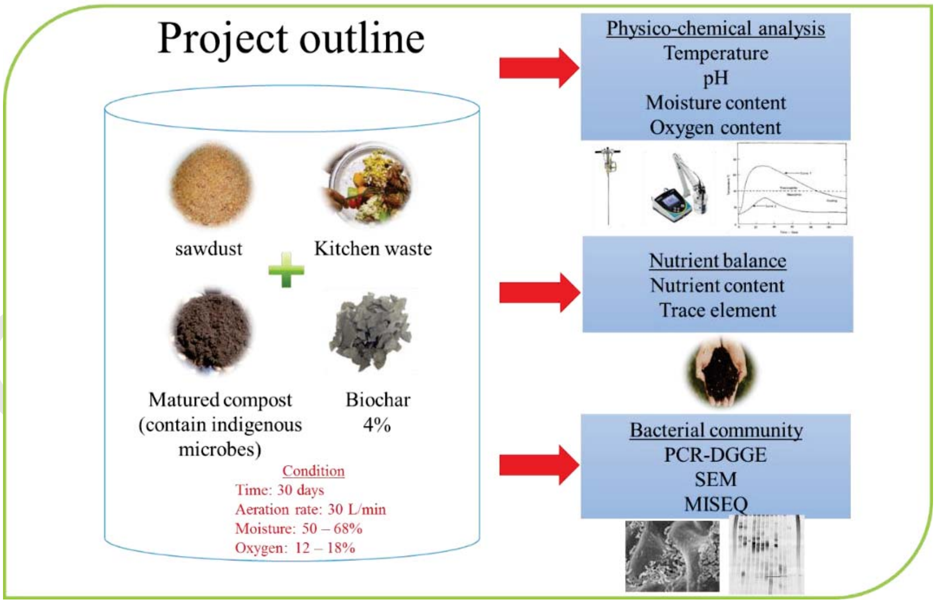

Figure 1.1: Overview of co-composting of kitchen waste and sawdust with addition of biochar

Therefore, this research aims to elucidate the effect of biochar on common parameters in the composting process such as temperature, moisture content, pH and C/N ratio. Further to that, the bacterial community succession has been assessed by using molecular tools prior and after addition of biochar to the compost.

The specific objectives of this study are:

1. To determine the effect of biochar on physicochemical characteristics of co-composting of kitchen waste and sawdust.

2. To investigate the succession of bacterial community structure during co-composting of kitchen waste and sawdust by using molecular tools.

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