Composting of Solid Waste by Using Indigenous Microorganisms (IMO)

by

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LIST OF ABBREVIATIONS

AFPW	Aerated Fish Pond Water
CD	Chicken dung
DOA	Department of Agricultural
EM	Effective microorganisms
FW	Food waste
GW	Garden waste
IMO	Indigenous microorganisms
K	Kalium/Phosphorus
KW	Kitchen Waste
MSW	Municipal Solid Waste
N	Nitrogen
P	Phosphorus
SWR	Steamed White Rice
TOC	Total Organic Carbon
OM	Organic Matter
UniMAP	Universiti Malaysia Perlis
C:N	Carbon:Nitrogen
CO_2	Carbon Dioxide
$FeSO_4$	Ferrous Sulfate
H_2O	Water

LIST OF SYMBOLS

^{o}C	Celsius
%	Percent
g	Gram
kg	Kilogram
cm	Centimetre
m	Meter
ml	Millilitre
L	Litre
µ	Micro

Pengkomposan Sisa Pepejal dengan Menggunakan Mikroorganisma Asli (IMO)

ABSTRAK

Pengkomposan adalah proses rawatan sisa pepejal organik dan penguraian biologi untuk membentuk bahan mentah kompos. Penggunaan bahan organik asli semasa pengkomposan sisa pepejal organik akan menghasilkan produk kompos yang berkonsepkan mesra alam dan memendekkan proses tersebut. Objektif-objektif bagi kajian ini adalah, untuk mencirikan sifat kimia dan biologi mikroorganisma asli yang disediakan termasuklah pH, suhu, kandungan lembapan dan mengenalpasti bakteria yang terlibat, untuk menilai perubahan fizikal-kimia semasa proses pengkomposan; pH, suhu, kandungan lembapan, nisbah karbon dan nitrogen, jumlah nitrogen, fosforus dan kalium dan untuk mengkaji produktiviti pokok sawi dengan menggunakan kompos produk dari aspek; ketinggian pokok dan ciri-ciri tanah. Terdapat lima fasa terlibat semasa penyediaan mikroorganisma asli (IMO). Bahan-bahan yang berbeza telah dicampur pada setiap fasa dengan melibatkan beberapa nisbah. Terdapat tujuh nisbah berlainan yang digunakan semasa process pengkomposan; 2:3:1 (kompos sis ataman 1), 3:2:1 (kompos sisa taman 2), 2:2:1 (kompos sisa taman 3), 2:0:1 (kawalan kompos sis ataman), 2:4:1 (kompos sisa makanan 1), 4:2:1 (kompos sisa makanan 2), 4:4:1 (kompos sisa makanan 3). Setiap nisbah untuk sisa taman dan makanan diulang sebanyak tiga kali dengan jumlah masa 60 hari dan 30-48 hari untuk sisa taman dan makanan. Kompos akhir telah digunakan ke atas pokok sawi selama 30 hari dengan tiga kali ulangan. Keadaan pH yang berasid diperoleh semasa penyediaan IMO. Suhu pula tetap pada fasa pertama dan kedua dengan 28ºC tetapi mula meningkat pada fasa ketiga, daripada 32ºC kepada 38ºC. Pada fasa keempat, suhu meningkat daripada 38ºC, tetapi di akhir fasa keempat, ia berkurang kepada 44ºC dimana 30ºC dicatatkan pada permulaan fasa kelima, meningkat dan akhirnya menurun kepada 32ºC. Kandungan lembapan pada fasa pertama, kedua dan ketiga IMO adalah dalam lingkungan 35% kepada 42% dan kemudian menurun sehingga fasa keempat IMO, dalam lingkungan 37% kepada 30%. Pada fasa kelima, kandungan lembapan meningkat sedikit dan kemudian tetap dalam lingkungan 35% kepada 46%. Keputusan untuk pengenalpastian bakteria menunjukkan bakteria *Bacillus* sp wujud dalam fasa pertama dan kedua IMO. Pada fasa ketiga IMO, bakteria *Bacillus thuringiensis* diperoleh. Bakteria *Proteus* sp and *Bordetella* sp pula wujud dalam fasa keempat dan kelima IMO. Semasa proses pengkomposan, semua parameter untuk IMO-kompos diperoleh dalam lingkungan seperti; nilai pH 5-9, suhu 29-55ºC, kandungan lembapan 35 - 75%, jumlah nitrogen 1-7%, fosforus 4-15%, kalium 11-23% dan nisbah C:N 5-20. Nisbah terbaik untuk pengkomposan sisa taman adalah pada rawatan GWC2 dan FWC3 untuk sisa makanan disebabkan oleh suhu tertinggi dicatatkan iaitu 48ºC dan 55ºC dan nisbah akhir untuk C:N ialah 12 dan 15 dicatatkan semasa proses tersebut. Penggunaan IMO-kompost terhadap pokok sawi juga menunjukkan keputusan yang baik terhadap tumbesaran pokok dengan menggunakan nisbah kompos akhir GWC2 dan FWC3 tetapi terdapat masalah berkaitan serangga perosak yang perlu dipertimbangkan semasa proses penanaman.

Composting of Solid Waste by Using Indigenous Microorganisms (IMO)

ABSTRACT

Composting is a process for the treatment of organic solid waste and the biological decomposition of raw compost materials to form compost. The utilization of organic additives during composting of organic solid waste will produce an environmentally product of compost and can shorten the process. The objectives of this study were to characterize the chemical and biological properties of prepared indigenous microorganisms (IMO) consists of pH, temperature, moisture content and identification of bacteria, physico-chemical changes during the composting process; pH, temperature, moisture content, carbon: nitrogen ratio, total nitrogen, phosphorus, potassium and to study the productivity of mustard greens plant using the product of compost in term of; plant height and soil characteristics. Five phases involved during the preparation of indigenous microorganisms (IMO) with different materials added in each phase. There are seven different ratios used during composting; 2:3:1 (garden waste compost 1), 3:2:1 (garden waste compost 2), 2:2:1 (garden waste compost 3), 2:0:1 (control garden waste), 2:4:1 (food waste compost 1), 4:2:1 (food waste compost 2) and 4:4:1 (food waste compost 3). Each treatment was triplicate over 60 days and 30-48 days of garden and food waste composting duration. The final compost was applied to the mustard greens plant about 30 days with triplicate. Acidic condition of pH obtained during IMO preparation. The temperature was constant at the first and second phases with 28^{o}C but increases starting at the third phase, from 32 to 38^{o}C. At the fourth phase, the temperature was in a range of 36 to 48^{o}C. Temperature of 30^{o}C was recorded at the starting of fifth phase, increased and then also decreases to 32^{o}C. Moisture content in the first, second and third phase of IMO was in a range of 35 to 42% and then was decreased until phase four IMO, in a range of 30 to 37 %. At phase five, the moisture content increases slightly and then constant at a range of 35 to 46%. Result for identification of bacteria shown that *Bacillus sp* involved in first and second phase of IMO. In phase III of IMO preparation, *Bacillus thurigiensis* was obtained. *Proteus sp* and *Bordetella sp* involved in fourth and fifth phase of IMO. During the composting process, all the parameters of IMO-compost obtained in a range like; pH value 5-9, temperature 29-55^{o}C, moisture content 35-75%, nitrogen 1-7%, phosphorus 4-15%, potassium 11-23% and C:N ratio 5-20 . The best ratio of garden waste composting was at treatments of GWC2 and FWC3 for food waste due to their higher temperature of 48^{o}C and 55^{o}C and the end of C: N ratio of 12 and 15 recorded during the process. Application of IMO-compost towards mustard greens plant also shown a significant result for plant growth using final compost ratio GWC2 and FWC3 but there are some problems with insect pests that need to be concerned during plantation.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

All across the world, the management of solid waste generation is a major problem, which until now, it is still under major discussion globally. Currently, it has become one of the most important environmental issues being discussed and Malaysia is no exception to this phenomenon. Malaysia's rapid population growth is one of the several factors contributing to the increase in the rate of solid waste production. The rapid urbanization and growth in the development and living standards of the community has generated a tremendous amount of municipal solid waste throughout the cities and towns of Malaysia (Tarmudi et al., 2009).

In Malaysia, apart from the local municipalities, environmental management companies such as Alam Flora Sdn. Bhd. and Environment Idaman Sdn. Bhd. are responsible directly or indirectly, in the management of solid waste generated in every state. The management of solid waste also becomes a challenge due to the rapid increase of waste produced daily. Its management becomes challenging, either in urban areas throughout the world, or in the rapidly growing cities and towns of developing countries (Agamuthu et al., 2009).

To permit a recovery of high value added products and prevent negative environmental impacts of solid waste generated, a suitable treatment is necessary before the discharge of solid waste. Various efforts have been made by the government to manage solid waste that is growing daily at a tremendous rate. Rising concern of the

negative impacts of solid waste generated has led to much research in helping the government find suitable treatments or methods to treat solid waste properly. This is because improper management of solid waste is one of the main contributors to environmental pollution.

There are several methods of solid waste management including recycling, reusing, recovery, composting, incineration and landfill as a final disposal. Each type of waste produced requires different waste management options and its own method of disposal. Sekeran et al., (2012) stated that the right method is required to treat the different type of waste generated so as to warrant an environmentally safe disposal of solid waste. However, based on the methods mentioned, a majority of generated solid waste in Malaysia are being disposed directly into landfills without any pre treatment, processing or segregating the waste according to its type.

Recycling and recovery of materials to produce a secondary material would decrease the consumption of raw materials. There are wastes that can be recycled without being disposed, but this is restricted to certain types of solid waste. The types of waste material that can be recycled and reused are glass bottles, aluminium waste, tin, old newspapers, old clothes and scrap metals. These wastes can be sent to facilities that can process them into new materials or products. These waste materials may also reduce the amount of solid waste to be disposed into landfills (Moh and Manaf, 2014).

Organic solid waste contained in municipal solid waste which cannot be recycled or reused, can instead be treated by composting. Organic solid waste is usually disposed directly into landfills without segregation as a final disposal method, because it is mixed with other types of waste. In relation to this issue, the composting process is thus a suitable method to manage this type of organic solid waste.

The process of recycling, reusing or composting is easily employed at home by those who are concerned of environmental problems. However, these practices are rarely pursued or done in the Malaysian society. Various ways have been introduced to promote these methods, but the lacking attitude persists because of the lack of concern for the environment and the management of waste.

Another contemporary waste management effort is the use of incinerators. However, the high cost of building incinerators for the incineration process can raise environmental problems due to the release of various harmful gases like carbon dioxide, dioxin and furan, sulfur dioxide, heavy metals and fine particle (Moh and Manaf, 2014). Ashes from the incineration process are considered as hazardous substances which require highly expensive special treatment. Consequently, this method of disposing solid waste was not successfully implemented in Malaysia.

1.2 Problem Statement

In Malaysia, food wastes are one of the largest components of municipal solid waste. Kitchen and food wastes are organic solid wastes that mostly consist of waste from food preparation and uneaten food, especially from cafeterias, restaurants, residential households and commercial institutions. The average component of municipal solid waste in Malaysia shown in Table 1.1 indicates the average component of municipal solid waste in Malaysia with food waste being the highest contributor.

Table 1.1: Average component of municipal solid waste in Malaysia

Source	%
Food waste	45
Plastic	24
Paper	7
Iron	6
Glass and others	3

Source: Government of Malaysia, Ninth Malaysia Plan (2006-2010)

According to Kathirvale et al., (2003) the rapidly growing population has led to an increase in the generation of municipal solid waste. Usually, the residents in low income households will produce the highest percentage of organic and food waste. This can be proven as shown in Table 1.2, the characterization of municipal solid waste by different income levels of residents in Malaysia.

Residents from low income households produce the highest percentage of organic and food waste. This is because the residents from low income households tend to cook and prepare food themselves in comparison with residents from high or middle income households. Thus, the economic level of the residents is one of the many factors which lead to the increase of solid waste.

Other types of organic solid waste that have contributed to the increasing generation of solid waste are garden waste. The major component of garden waste, especially during the dry season, is dry leaves. Communities from the suburban and rural areas often openly burn these dry leaves. Smoke generated by burning leaves can cause significant health problem, as it may contain hazardous chemicals. Dry leaves at playgrounds and commercial institutions usually are sent to the landfills after the

clearing process. However, landfill sites are being filling up at a very fast rate and other options are needed to dispose organic waste materials (Manaf et al., 2009).

Table 1.2: Typical Malaysia municipal solid waste characterization

Source	Residential high income (%)	Residential medium income (%)	Residential low income (%)
Food/Organic	30.84	38.42	54.04
Mix paper	9.75	7.22	6.37
Newsprint	6.05	7.76	3.72
High grade paper	-	1.02	-
Corrugated paper	1.37	1.75	1.53
Plastic (rigid)	3.85	3.57	1.90
Plastic (film)	21.62	14.75	8.91
Plastic (foam)	0.74	1.72	0.85
Pampers	6.49	7.58	5.83
Textile	1.43	3.55	5.47
Rubber/leather	0.48	1.78	1.46
Wood	5.83	1.39	0.86
Yard	6.12	1.12	2.03
Glass (clear)	1.58	2.07	1.21
Glass (colored)	1.17	2.02	0.09
Ferrous	1.93	3.05	2.25
Non-ferrous	0.17	0.00	0.18
Aluminium	0.34	0.08	0.39
Batteries/hazards	0.22	0.18	-
Fine	-	0.71	2.66
Other organic	0.02	0.00	-
Other inorganic	-	0.27	0.25

Source: Kathirvale et al., (2003)

Directly disposing food waste into landfills without prior treatment can cause environmental problems when these wastes react with other types of waste. Similarly, garden waste which are either openly burned or dry leaves which are disposed in landfill, have a considerable effect on the environment. Open burning will cause the release of various toxic compounds such as nitrogen oxide, volatile organic carbon, carbon monoxide and also pollution particles.

Organic solid wastes that are discarded into landfills will discharge toxic gases like methane, nitrous oxide and high concentration of carbon dioxide. Moreover, they also produce leachate and cause odour emission from the production of ammonia gas and hydrogen sulphide. Decomposition of dry leaves in landfills can also cause air pollution, especially to the surrounding communities. To overcome these matters, the composting process is perceived to be the best method to prevent organic solid waste from being disposed in landfills.

Composting is a natural biological process that turns organic materials into stable and valuable products. There are several advantages in applying composting to manage organic solid waste. According to Adhikari et al., (2009), composting will reduce the production of leachate and greenhouse gas emission, naturally recycle waste into safe compost and generate nutrients to enrich the soil.

Composting can also reduce the volume and mass of solid waste to be transported to landfills. Thus, it indirectly reduces transportation costs. The spreading of parasites, pathogens or weed seeds could be eradicated and eliminated by the composting process. Moreover, the finished compost can be applied in agriculture since organic fertilizers improve soil fertility and stability, and it can be used for land reclamation (Bernal et al., 2009).

Although the composting process turns waste into useable or valuable products, it is unappealing to certain researchers and entrepreneurs because the process is arduous and time-consuming. However, with the increase in the amount of research and studies done over the years, whereby bulking agents, activator and additives are included in accelerating the process, composting appears to be attracting much attention (Gabhane et al., 2012).

Organic additives can be prepared at home without the need to rely on commercially manufactured ones, thus significantly reducing cost. Himanen et al., (2009) stated that, microbial activity of the waste material improved with the utilization of additives because of different amount of various microorganisms, mineral nutrients, enzymes, readily available forms of carbon and pH balancing compounds that are usually contained in additives.

Due to the excessive amount of organic waste being dispose at landfill, this study was conducted to compost garden and food waste with indigenous microorganisms (IMO). The utilization of IMO as organic additives can produced environmentally product of compost, since the study of composting by using IMO as additives was not been well documented.

1.3 Aim

This study was conducted to evaluate the effectiveness of using indigenous microorganisms (IMO) as organic additives to accelerate the composting process. To identify the quality of finish compost produced, the finished product of the compost will be applied to mustard greens for plant growth.

1.4 Objective

This study consists of several objectives:

1. To study the chemical and biological properties of prepared indigenous microorganisms (IMO).
2. To study the physicochemical changes during the composting process such as the pH, temperature, moisture content, carbon: nitrogen ratio, total nitrogen, phosphorus and potassium.
3. To study the growth of mustard greens plant using the finished product of compost respect to plant height and soil characteristics.

1.5 Research significant

The significance of this study is to introduce better ways of accelerating the composting process and producing environmentally safe finished compost through the addition of organic additives during the process. The composting of organic solid waste applied in this study is considered one of the waste management options in the proper treatment of organic solid waste. At the same time, it will decrease the need to discard or dump organic solid waste directly into landfills and incinerators. Besides overcoming the issues related to landfills, finished compost as soil amendment may also be applied to agricultural land since it helps increase the organic matter in soil.

1.6 Scope of Study

Plastic bin composter was used in this study since the study has been done on a small laboratory scale. The types of organic solid waste used for composting were garden and food wastes. Food waste was obtained from restaurant and food stalls near the School of Environmental Engineering, Universiti Malaysia Perlis, (UniMAP). Garden waste was collected from the lawn cleaning and gardening processes at the School of Environmental Engineering, UniMAP. In order to accelerate the composting process of these two types of organic solid wastes, indigenous microorganisms (IMO) was prepared as an organic additive. The preparation of IMO consists of several stages starting from phase I until phase V. The physicochemical properties during composting were determined for pH, temperature, moisture content, carbon: nitrogen ratio, total nitrogen, phosphorus and potassium. The finished compost product was tested on mustard greens in terms of their plant growth and soil characteristics.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Composting

Composting process is not a new technology in the management of solid waste. However, it is the only technique that has been practised in the past several decades for the disposal of organic solid waste. Composting is one of the most promising technologies to treat organic waste in a more economical way.

Bernal et al., (2009) indicated that composting process which has gained interest amongst entrepreneurial prospects is the best and most suitable option in managing organic solid waste. There are several definitions of composting that have been described by several researchers (Tweib et al., 2011a; Kumar et al., 2010; Bernal et al., 2009 and Yvette et al., 2000).

Composting can be defined as a natural process that turns organic material into a dark rich substance known as compost, which is a wonderful conditioner for the soil. During this composting process, microorganisms such as bacteria and fungi break down complex organic materials into an extremely useful humus-like substance (Tweib et al., 2011a).

According to Yvette et al (2000), the composting process is seen as an environmentally acceptable method of waste treatment technology or in the handling of organic solid waste. It is an aerobic, biological process which uses naturally occurring microorganisms to transform biodegradable organic matter into a humus-like product.

Kumar et al., (2010) defined composting as the stabilization and biological or natural decomposition of organic substances under certain conditions that will develop thermophilic temperatures as a result of biologically produced heat. Bernal et al., (2009) argued that in a predominantly aerobic environment, the composting process is a biological decomposition of organic materials.

Compost produced during the decomposition process can be classified as stable, mature and finished. Stability refers to the state of organic matter during composting and is related to the compost microbial activity. Stable compost is expressed as when the microbial activity of an end product is reduced to an insignificant level at certain value. Phytotoxicity and potential of plant growth are associated with maturity indices. When phytotoxins are reduced to a safe level, the compost is considered matured. When the stability and maturity stages are reached, the state of finished compost eventually occurs (Khan et al., 2014).

2.2 Organic Solid Waste

Organic wastes are materials that can be composted. They either compost naturally when discarded into landfill or during the composting process under controlled conditions. Not all solid waste can be composted. Food and garden wastes are categorized as organic solid waste that can be composted. Vegetable and fruit scraps, potato peelings, eggshells, tea bags and tissue papers are examples of kitchen and food waste that can easily be composted at home. Grass clippings, flowers, leaves and roots can be classified as garden waste. These types of organic waste are mainly produced in residential areas, restaurants, institutions and playgrounds.