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Effective Use of Indigenous Microorganism (IMO) in Composting a Mixture of Food and Yard Wastes on an Industrial Scale

(Penggunaan Mikroorganisma Effektif (IMO) dalam Pengkomposan Campuran Sisa Makanan dan Sisa Taman Berskala Industri)

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ABSTRACT

The aim of this research is to determine the performance of effective microorganisms (EM) in the composting of mixed food and yard wastes on an industrial scale. Composting parameters such as temperature, moisture content, pH, and the carbon to nitrogen ratio (C:N), as well as the maturity of nitrogen, phosphorus and potassium (NPK), were determined. For this purpose, the type of EM used to accelerate the composting process is Indigenous Microorganism (IMO). The study, which was conducted using the best EM, accelerated the composting process, wherein it only takes approximately 13 weeks for the decomposition process to occur in each heap. The results show that the final temperature for each heap is between 25.57 and 28.03°C, the percentage of moisture content is between 45.55 and 60.49%, the pH is between 6.81 and 7:41, the ratio of carbon to nitrogen is between 17:1 and 23:1, the NPK value for nitrogen ammonia is between 0 mg/L and 0.56 mg/L, the potassium content is between 2.25 and 3.25 ppm, and the value of phosphorus is between 0.56 and 0.76 ppm. Based on these results, it can be concluded that the quality of the compost produced for all piles is high. Due to the slight differences in parameters between all piles, the effectiveness of EM IMO was not conclusive for either open or closed aerated piles, and further research needs to be done.

Keywords: Effective Microorganism (EM); Indigenous Microorganism (IMO); composting; yard waste; food waste

ABSTRAK

Tujuan utama kajian ini adalah untuk menentukan keberkesanan mikroorganisma efektif (EM) dalam proses pengomposan campuran sisa makanan dan sisa taman pada skala industri. Parameter pengomposan seperti suhu, kandungan kelembapan, pH, nisbah karbon kepada nitrogen (C:N), logam berat, kematangan dan nilai nitrogen, fosforus dan kalium (NPK) ditentukan. Untuk tujuan ini, EM yang digunakan bagi mempercepatkan proses pengomposan adalah Indigenous Microorganism (IMO). Kajian yang dijalankan dengan menggunakan EM yang terbaik untuk mempercepatkan proses pengomposan hanya mengambil masa selama 13 minggu untuk proses penguraian berlaku bagi setiap timbunan. Keputusan menunjukkan bacaan akhir suhu bagi keempat-empat timbunan adalah di antara 25.57 hingga 28.03°C, pera)tus kandungan kelembapan adalah antara 45.55% hingga 60.49%, nilai pH berjulat di antara pH 6.81 dengan pH 7.41, nisbah karbon kepada nitrogen adalah di antara 17:1 dengan 23:1, dan nilai kandungan NPK untuk Kalium adalah di antara 2.25 dengan 3.25 ppm, dan untuk Fosforus ia adalah di antara 0.56 dengan 0.76 ppm. Berdasarkan keputusan yang diperoleh, dapat disimpulkan bahawa semua jenis kompos berada dalam keadaan optimum dan kualiti yang baik. Disebabkan perbezaan keputusan yang ditunjukkan adalah sangat sedikit, perbezaan antara kaedah terbuka dan tertutup sukar ditentukan dan memerlukan kajian lanjut.

Kata Kunci: Mikroorganisma Efektif (EM); Mikroorganisma Indigenous (IMO); pengomposan; sisa taman; sisa makanan

INTRODUCTION

Growing populations and rapid economic development have resulted in the ever-increasing generation of solid waste. Therefore, efficient solid waste management is crucial for ensuring the sustainable development of cities. This is because good solid waste management can reduce the amount of solid waste being disposed of in landfills in the future. The rate of solid waste generated in certain areas has led to a variety of treatment methods being developed to reduce the volume of solid waste. Solid waste management concerns the generation, storage, collection, transfer and transport of solid waste to a suitable disposal location. However, the main factor that drives solid waste management is its exorbitantly high cost. Noor Ezlin Ahmad Basri et al. (2015) developed an expert system prototype for the selection of a composting system. This system covered the reception facilities, materials handling equipment, storage facilities, pretreatment processes, feedstock conditioning, composting process control, post-treatment processes, site requirements, operational considerations, market planning and environmental considerations.

The management of various types of solid waste is becoming increasingly troublesome and costly, especially in densely populated metropolitan areas. Because of this, composting has become a widely used treatment process for one type of solid waste, i.e., sewage sludge. Composting can also be used for the treatment of organic fractions of municipal refuse, including household garbage, most yard waste, and various organic industrial wastes. Composting can be defined as the biological decomposition of organic matter under controlled aerobic conditions to produce a stable, humus-like product.

The benefits of composting are that, based on the living microbes present during decomposition, the results can be good for the environment. Thus, composting can be classified into two categories: aerobic composting and anaerobic composting. The aerobic biological conversion process is a method in which oxygen is supplied to organic material during decomposition. Energy is produced aerobically by microorganisms as organic material undergoes exothermic reactions to facilitate the breakdown of particles of material (Worrell & Vesilind 2012). Agamuthu (2001) noted that in this process, aerobic bacteria will also use carbon from organic waste as an energy source while simultaneously recycling nitrogen.

Anaerobic biological conversion processes use anaerobic bacteria to convert organic materials. The end products of this conversion are new cells, CO_2, CH_4, NH_3, H_2S and humus, which are also known as compost. Using an anaerobic process to produce compost could potentially save costs compared to using an aerobic composting system (Vigil & Tchobanoglous 1994). The materials decomposed under anaerobic conditions tend to be more acidic. Additionally, the anaerobic process takes longer in comparison to aerobic decomposition. Hence, the biological treatment used in this research is the aerobic composting method.

The natural decomposition of organic waste by EM produces compost that can be used as organic fertilizer in agriculture. EM also contains both aerobic and anaerobic microbes at a pH of 3.5 (Higa 1991), and they are widely used in agriculture, animal husbandry, aquaculture, wastewater treatment, and solid waste treatment to increase the quantity and quality of the end product and to improve the treatment of certain contaminants (Higa & Parr 1994). This study aims to investigate the performance of effective microorganisms (EM) in composting mixed food and yard waste on an industrial scale. The methods used in this study are the open aerated (windrow) and closed aerated (windrow) methods to determine which method between the two is the best for composting. The compost was turned manually without using machinery. Important parameters of the final compost were monitored and tested in the laboratory, namely, temperature, pH, moisture content, C:N ratio, NPK value, heavy metal concentration, and maturity.

METHODOLOGY

COLLECTION AND SEPARATION OF ORGANIC WASTE

The amount of yard waste generated at Universiti Kebangsaan Malaysia (UKM) is approximately 2.36 t/day. An estimated 3.36 t of yard and food waste is generated per day at UKM (Zarina Shahudin et al. 2013). The collected yard and food wastes are usually mixed with materials that are not suitable for use as feedstocks in the composting process, such as plastic, stone, empty tins, trees or glass. Hence, the separation of solid waste must be performed based on a suitable particle size to increase the efficiency of the microorganism's activity during the decomposition of organic waste. Garden waste and bulky leftovers must be ground or cut into sizes as small as 0.1-10 cm by using a shredder or cutter.

The optimum volume and size of a heap for a pilot experiment of aerated composting is approximately 1 cubic meter. Each heap used for aerated composting is constructed with the optimum dimensions of approximately 1 meter wide, 1.5 meter long, and 1 meter high, which is approximately 1.5 cubic meters in volume. The type of organic waste included in the heap is yard waste, which has been shredded into small pieces and then mixed with food waste in a weight ratio of (2: 1). EM IMO was then added to the waste, and the final mixture was formed into a pile using the aerated (windrow) method.

TABLE 1. The Content of Each Pile

Pile	A	B	C	D
	Open + IMO	Closed w/o IMO	Closed + IMO	Closed w/o IMO

SAMPLING OF THE COMPOST HEAPS

Compost is a dark, earthy mixture of decayed organic materials, such as livestock manure, remains of plants, or food waste. These wastes were decomposed by the microorganism's activity. Using compost is a good way of enriching soil with nutrients and reusing organic waste. Therefore, the samples sent for analysis must be a composite of materials collected from several locations and depths within the pile being sampled. The number of sampling points will depend on the size and configuration of the pile. In most situations, materials should be collected from at least 5 locations or points around the pile and from three depths at different locations. The equipment required to take samples of compost to be sent to the laboratory are a clean, residue-free plastic container; a spade or pitchfork; a compost turner; a permanent marking pen; and a pair of gloves. For each pile, three sample locations were established independent of the overall pile size, namely, core (30 cm from the bottom of the center of the pile), edge (30 cm from the outside), and middle (half-way between the outer edge and the core location); five grab samples were taken from each location, and the process was repeated for each zone (William et al. 2012).

DETERMINATION OF PHYSICAL AND CHEMICAL PARAMETERS

Preliminary experiments were carried out on food and yard wastes either on site or at the research laboratory to determine the moisture content, temperature, pH, carbon-nitrogen ratio (C:N), nitrogen ammonia, and contents of phosphorus, potassium, and heavy metals such as Fe, Zn, Mn, Ni as well as other heavy metal elements that are required for composting. Each parameter investigated must be monitored with regard to physical or chemical changes, such as the C: N ratio, temperature, pH, and changes in the compost before it reaches maturity.

DETERMINATION OF THE QUALITY OF COMPOST

The final quality of the compost is crucial because it determines the nutrient content of the compost at the end of the composting process. In addition to the nutrient content of the compost, the quality and structure of the composted pile must be examined to determine the ratio of C:N, nitrate, phosphate, potassium, sulfate and heavy metals. This is necessary because the quality and quantity of the final compost must be suitable for use as plant fertilizer.

ANALYSIS OF RESULTS

After obtaining complete and sufficient data from laboratory and on-site tests, the experimental data were plotted in graphs. Each graph of experiment data was reviewed and recorded prior to preparing the final report.

USES OF EFFECTIVE MICROORGANISM (EM) INDIGENOUS MICROORGANISM (IMO)

The potential benefits of microorganisms, when used in combination with EM technology in organic or natural farming open immense opportunities for industrialists and farmers to transition to more sustainable and cost-effective agricultural practices and, therefore, offer a better future to humankind. When appropriately packaged and applied, EM technology can be a potentially valuable tool that could help farmers develop farming systems that are economically, environmentally, and socially responsible. Beneficial indigenous microorganisms (IMO) occur naturally and were collected and cultured. They were used to enhance soil fertility and nutrient uptake by plants through the introduction and proliferation of a beneficial soil microbes or mycorrhizae. IMO are classified as IMO1, IMO2, IMO3 and IMO4 depending on their stage of production and effectiveness as inoculums for various applications.

IMO1 was obtained by placing cooked rice in a container approximately 8 cm deep, which was then left under a bamboo clump in an isolated area for 2-3 days for natural inoculation by water and air-borne microbes. The inoculated rice was then mixed with molasses or brown sugar at a ratio of 1:1. The resultant mixture, called IMO2, was fermented for 5 days, after which 1 g/100 ml IMO2 was added to 10 kg rice bran and rice water until the mixture was 65% moist. The new concoction, IMO3, was left to ferment for 3-5 days, after which 1 part IMO3 was added to 1 part soil and fermented further for 3-5 days to obtain IMO4. IMO4 was covered with mulch to maintain a moisture of 65% for later use in a wide variety of applications, including as the inoculums for compost. The most important step in organic or natural farming is preparing IMO4, which can be described as a soil additive made from indigenous microbes cultured in a rice bran or a wheat bran base.

RESULTS AND DISCUSSION

TEMPERATURE

Temperature is an important parameter that determines the level of decomposition, whether it occurs at the mesophilic or thermophilic level, or even reaches the level of maturity to produce natural plant fertilizer at all. Figure 1 shows the temperature of each pile; it shows that for the first three weeks, the B and C compost piles had a higher temperature of 30°C. The high temperatures in the early stages of composting for piles B and C indicate the minor effectiveness of the closed aerated method for both piles during composting. The temperatures for piles A and D were slightly different; the temperature recorded in the third week dropped to 27°C because these piles were composted using the open aerated method. The slight decline in the temperature of piles A and D was due to their exposure in an open area; thus, the heat produced during the decomposition process was quickly transferred into the air compared to closed piles B and C, where the produced heat was trapped and circulating inside the pile while transferring to the air mainly when the pile was open during the manual turning process. The temperature decreased in all piles due to the effect of weather and then increased again in the seventh week, which was the mesophilic phase. Based on this observation, it can be concluded that all piles were considered to have optimum temperature values throughout the decomposition process. Furthermore, pile C, which consisted of mixed food waste and yard waste with the addition of EM IMO using the closed aerated method, was slightly more conducive to bacterial decomposition. This is because the temperature recorded in the early stage up to the end of the process was maintained at optimum values between 21°C and 49°C, as recommended by Cooperband (2000).

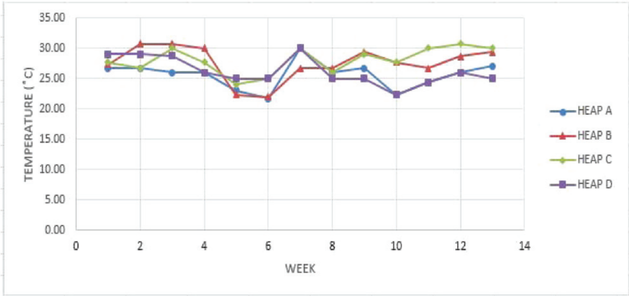

FIGURE 1. Temperature vs week

MOISTURE CONTENT

The graph in Figure 2 shows that compost pile A had the lowest percentages of moisture of 34.90%, 28.07%, 25.52%, 59.13% and 50.36% from the fourth week to the eighth week, respectively, compared to the moisture in compost piles B, C and D. Although the compost was an open aerated pile that contained EM IMO, the percentage of moisture content was not at the optimum value required, except in weeks seven and eight. This was because the compost was too dry, which might have prevented the microorganisms from functioning effectively in decomposing the pile. For composting to occur, the moisture content must be between 45% and 60% (Cooperband 2002). The moisture contents of compost piles B and C, which are the closed aerated piles, were much higher than the optimum value, i.e., ranging between 60.62% and 69.60%, due to the little water content of these piles lost into the air. Furthermore, these piles had a higher water capacity than piles A and D, which were open piles. The moisture contents of all four piles were closely controlled by manually watering each pile twice a week to ensure that their moisture contents remained at an optimum level.

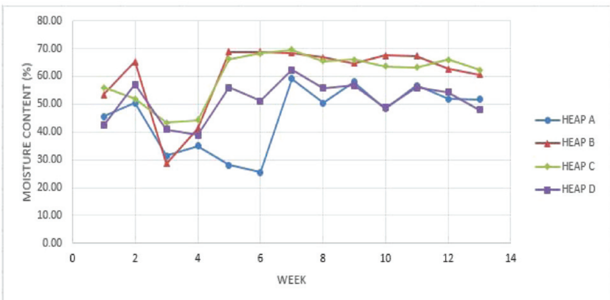

FIGURE 2. Percentage of moisture content vs week

pH

The pH value is another important parameter that must be investigated to determine the quality of the compost product. Cochran & William (1914) stated that the most suitable pH range for the composting process is between 6.5 and 8.0. However, the recommended pH for bacterial decomposition is between 6.0 and 7.5, while the recommended pH for decomposition by fungi is between pH 5.5 and 8.0. Figure 3 shows the pH recorded from the first to the thirteenth week. All the compost piles reached an optimum pH value, as recommended by Cochran & William (1914). However, compost pile A was considered to be slightly better than other piles because the initial pH value at the beginning of the process was 6.5. This was because the microbial activities of the microorganism present in the open aerated compost pile A decomposed the pile very well. This optimum value was then later attained by piles B and C in the second week and finally attained by pile D during the fifth week. The pH values for all four compost piles were alkaline from the fifth week to the tenth week and gradually decreased to neutral from the eleventh week until the thirteenth week, but the average pH remained at the recommended optimum value.

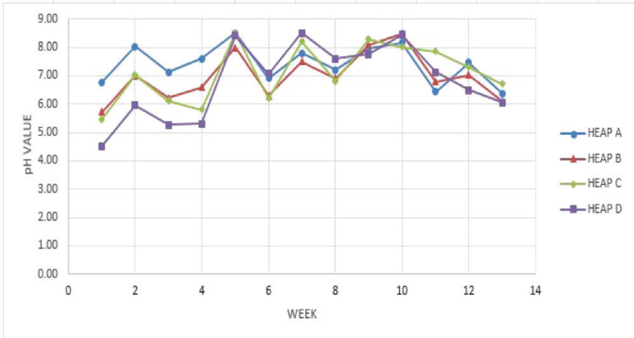

FIGURE 3. pH vs week

CARBON TO NITROGEN (C:N) RATIO

The carbon to nitrogen ratio is very important in the composting process. Hence, decomposition needs to be observed during the early stages of the composting process and at the end of the process when the product has reached maturity. This is because carbon can serve as a source of energy to microbes and allows them to decompose actively. Nitrogen can increase the growth of microbial populations during the production process. The ratio of carbon to nitrogen recorded in this research is presented in Table 2.

TABLE 2. The ratio of C:N

Pile	A	B	C	D
Carbon Content	24.87	30.30	28.94	33.03
Nitrogen Content	1.44	1.57	1.28	1.81
Ratio C:N	17:1	19:1	23:1	18:1

The results show that, at the end of the process, the C: N ratios for compost piles A, B and D were less than 20; the ratio for compost pile C was the highest at 23:1. This is because the organic waste used to build each pile contained a higher carbon content, which was stored in the foods high in carbohydrate as well as the yard waste, which contained more lignin that also had a higher carbon content. The yard waste that was shrinking, dry and neglected in this study was also one of the factors that led to the rapid increase in the carbon content of pile C. However, the compost products were determined to be in their mature phases.

NPK NUTRIENTS AND HEAVY METAL CONTENTS

According to Eghball and Gilley (1999), compost products contain a small amount of NH_3-N and nitrogen if 40% of the nitrogen is used during the composting process. The amount of NH_3-N recommended for a sample volume of 50 milliliters is between 20 mg/L and 50 mg/L. The NH_3-N content presented in Table 3 shows that all four piles of compost had lower NH_3-N levels than the recommended optimum level. This was due to the low nitrogen content in each pile, which in turn resulted in very low ammonia levels. It is important to maintain the moisture content of the compost pile to ensure that it is within the optimum range. This will lead to an increase in phosphorus and potassium concentrations due to the reduced volume of organic waste. Additionally, heavy metals are also natural elements of nutrients that could increase the productivity of the compost product prior to it being used as a fertilizer. The amount of heavy metals, however, must not exceed the optimum range because this could have a negative impact on the environment. Table 4 shows that the amount of heavy metals is below the optimum range, thus making the compost suitable for use on plants, as they provide higher amounts of nutrients for plants to thrive.

TABLE 3. NPK content in the compost pile

Pile	A	B	C	D
Nitrogen Ammonia mg NH_3-N, mg/L	0.56	0	0	0.56
Potassium (K), ppm	3.09	2.25	2.34	3.25
Phosphorus (P), ppm	0.56	0.63	0.59	0.76

TABLE 4. Heavy metals in the compost pile

Heavy Metals (mg/L)	Pile			
	A	B	C	D
Cd	0.36	0.50	0.49	0.63
Cr	32.81	31.41	20.92	33.79
Cu	18.39	15.33	11.45	18.62
Pb	31.62	21.31	23.65	30.95
Hg	0.74	1.08	0.28	0.98
Ni	6.21	4.20	3.85	5.04
Zn	210.20	197.36	178.50	166.26

CONCLUSION

This research was carried out for almost 4 months to obtain a compost product that can be used as plant fertilizer. Based on the findings of this study, it can be concluded that the composting process is a viable method that can be used to reduce the amount of waste generated at UKM and sent to landfills. The amount of waste generated at UKM increases each year due to the increasing number of students and staff. Composting is an alternative biological treatment that can reduce the amount of organic waste, such as yard waste and food waste. In this research, the length of time required for microorganisms to decompose the mixture of compost in open aerated and closed aerated methods with the use of EM IMO is 13 weeks. The effectiveness of this method in composting the piles in both open and closed aerated methods is similar. Based on the results obtained, it can be concluded that the quality of compost produced from all the piles is good. However, due to slight differences in parameters between all the piles, the effectiveness of EM IMO was not conclusive for both open and closed aerated piles.

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