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Sustainable Household Organic Waste Management via Vermicomposting

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ABSTRACT Increasing waste generation in developing countries has alarmed authorities on waste disposal issues. Therefore, various alternatives have been looked into to reduce waste disposed into landfill. Among others are the bioremediation options which may allow the conversion of putrescible wastes into value added products such as compost, biogas and others. This study was aimed to find optimal experimental set-up to conduct small scale vermicomposting suitable for households, since approximately 40-50% (wt) of the waste is putrescible component. The wastes were weighed and exposed to worms namely *Eisenia foetida*. Results indicated that household putrescible waste can easily undergo vermicomposting. However, factors such as high acidity and presence of certain materials in the waste can be detrimental to this process. Worms are very sensitive to pH changes and the vermicomposting process will reduce drastically when pH is lower than 5.0. Experimental set-up with the layering system proved to be the best method of conducting small scale vermicomposting. The layering set-up prevents worms from escaping the vermicomposting system and allows the gathering of the offspring in a safe environment. Different combinations of organic mixture resulted with different rate of vermicomposting completion. The fastest to degrade was the combination of kitchen waste with vermicompost, which come to completion within three weeks. Vermicompost provides the most suitable environment for the worms to flourish in addition to the availability of less complex components in kitchen waste. The average water holding capacity of the vermicompost was 25% (wt) while the total organic content was 12%. In conclusion, vermicomposting of organic components found in the MSW stream can be accomplished by taking into consideration crucial factors such as acidity and presence of hindering components. The identification of the most suitable conditions for vermicomposting will allow the implementation of this alternative biological remedy to reduce waste and tackle the problem in waste management, particularly in developing countries.

ABSTRAK Pertambahan penghasilan sisa di negara-negara membangun membimbangkan pihak berkuasa. Maka, pelbagai alternatif telah dipertimbangkan untuk mengurangkan jumlah sisa ke tapak pelupusan. Antara pilihan yang ada ialah bioremediasi yang membolehkan pertukaran sisa yang mudah terurai kepada produk bernilai seperti kompos, biogas dan lain-lain. Kajian ini bertujuan untuk mengetahui penyediaan eksperimen terbaik bagi menjalankan proses vermi-pengkomposan skala kecil yang sesuai bagi isirumah memandangkan hampir 40-50% (berat) sisa yang dihasilkan terdiri daripada bahan mudah terurai. Sisa ditimbang dan didedahkan kepada cacing jenis *Eisenia foetida*. Keputusan menunjukkan bahawa sisa mudah terurai yang dihasilkan sesuai menjalani proses vermi-pengkomposan. Walau bagaimanapun, faktor-faktor seperti keasidan yang tinggi dan kehadiran elemen-elemen tertentu di dalam sisa boleh membantutkan proses ini. Cacing-cacing ini sensitif kepada perubahan pH dan proses vermi-pengkomposan akan menurun dengan drastik apabila pH kurang dari 5.0. Persediaan eksperimen dengan sistem lapisan terbukti sebagai teknik terbaik bagi menjalankan vermi-pengkomposan skala kecil. Sistem lapisan menghalang cacing keluar dari sistem vermi-pengkomposan dan membolehkan penggumpulan anak-anak cacing dalam persekitaran yang selamat. Kombinasi-kombinasi yang berbeza dalam campuran organik lengkap diproses pada kadar yang berbeza. Campuran sisa dapur dan vermi-kompos paling cepat terurai iaitu selepas tiga minggu. Ini adalah kerana ia menyediakan persekitaran yang paling sesuai bagi cacing untuk membiak di samping terdapatnya komponen-komponen yang kurang kompleks. Secara purata kapasiti air tanah bagi vermi-kompos ialah 25% sementara kandungan organik total ialah 12%. Sebagai kesimpulan, vermi-pengkomposan komponen organik dalam sisa munisipal boleh dijalankan dengan mengambil kira beberapa faktor penting seperti asiditi dan kehadiran komponen penghalang tertentu. Pengenalpastian keadaan yang paling sesuai bagi vermi-pengkomposan membolehkan perlaksanaan rawatan biologi alternatif ini untuk mengurangkan sisa dan menyelesaikan masalah pengurusan sisa terutama di negara-negara membangun.

(Keywords: vermicomposting, kitchen waste, sustainable development**)**

INTRODUCTION

Population expansion resulted with rapid increase in waste generation. It is the effect of improved standard of living and improved health quality [1, 2]. Proper waste management is very crucial and has become the main challenge in many countries particularly the developing nations [3]. Malaysia with 3% (wt) annual municipal solid waste (MSW) increase generates approximately 30,000 tonnes of MSW covering 83% of the country's waste generation. Less than 5% of the waste is diverted by unofficial recycling activities while the remaining 95% goes to the landfill for disposal [4]. The disposal of the ever increasing waste requires approximately RM1 billion (US$26 million) and it is expected to increase with the increase in the price of fuel [5]. In addition, the huge tonnage of waste disposed into landfills resulted with various environmental impacts including leachate contamination, pest problem and others. To make matter worse, approximately 90% of the country's non sanitary landfills lacked geotextile lining material to prevent groundwater contamination. This has called for an urgent need for various alternatives to divert waste from landfill. This not only lengthens the operational period of a landfill but also would reduce the risk of environmental degradation.

Putrescible wastes can be converted into value added products such as compost, biogas and others [6, 7, 8, 9]. The most common and widely practiced bioremediation technique is composting. Composting product i.e. compost consist of necessary minerals which act as organic fertilizer to enhance plant growth and improve soil condition [10, 11]. Countries like Austria and Denmark had implemented the requirement of organic waste composting as an alternative to reduce waste for landfill disposal [12, 13]. Temperature, moisture content, nutrient content, pH, particle size, and oxygen supply are among the factors that will determine the quality of the compost [14]. Various organisms are involved in the composting process which includes microorganism like bacteria, fungi and worms. However, commercial composting is only viable if it is conducted at a large scale. Smaller scale composting particularly in individual households would require various additives and complex compost set-up to prevent offensive odour from degrading waste and to curb pest problem. The application which is more suitable for individual household is vermicomposting since the uncomfortable smell is very minimal and it generates very high quality compost [15].

Various species of worm have been used to digest and break down the organic matters during vermicomposting. It includes *Eisenia foetida, Lumricus rubellus, Perionyx excavatus, Lampito mauritii, Eudrilus euginea,* and *Pheretima elongate* [15, 16, 17]. *Eisenia foetida* is more adaptable to tropical condition to convert waste into vermicompost with various benefits including extra advantages on pest control in soil [15, 18]. Vermicomposting can be carried-out in a smaller scale that it is more applicable to individual household to treat kitchen and garden wastes since approximately 40-50% (wt) of the waste is putrescible. With appropriate yet simple set-up, individual household would be able to carry out vermicomposting which would eventually reduce at least 35% the total waste generation per household. Suitable set-up would ensure the viability of the vermicomposting system which would continuously receive the putrescible component of the domestic waste. Though many publications had discussed the process of vermicomposting and the factors involved, they focused mainly on large scale vermicomposting. Studies on the feasibility of household scale vermicomposting are lacking. Disposal of waste directly into landfill is not environmental friendly. This not only pollutes the environment but also attract pest such as rats, crows, flies and others, to create health-hazard to the nearby residents. The main objective of this study is to determine the viability of conducting small scale vermicomposting in order to divert the organic portion from the household waste stream. This study was aimed to find the most appropriate set-up to conduct small scale vermicomposting suitable for households as a sustainable practice.

MATERIALS AND METHODS

The study involved the analysis of waste composition from household. Wastes were collected from 350 households from Selangor rural, sub-urban and urbans residents. The waste collected were sorted into organic, paper, plastic, metal, and others, and weighed to determine the percentage of each waste group. The results would indicate the possibility of implementing vermicomposting system as an alternative to landfill disposal. The experimental set-up includes the usage of plastic bucket for T1 and ceramic flower pots for T2 and T3. The experimental setup for each trial is shown in Figures 1-3. The function of each material used is detailed in Table 1.

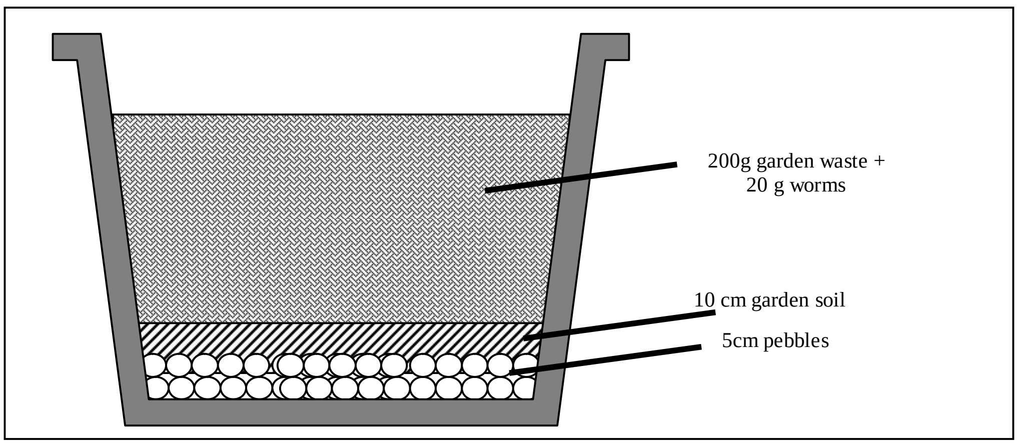

Figure 1. Vermicomposting experimental set-up for System T1

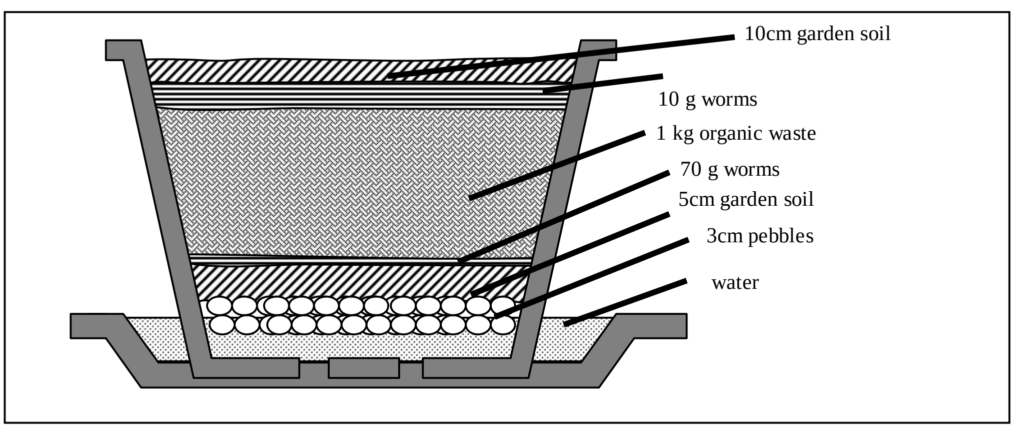

Figure 2. Vermicomposting experimental set-up for System T2

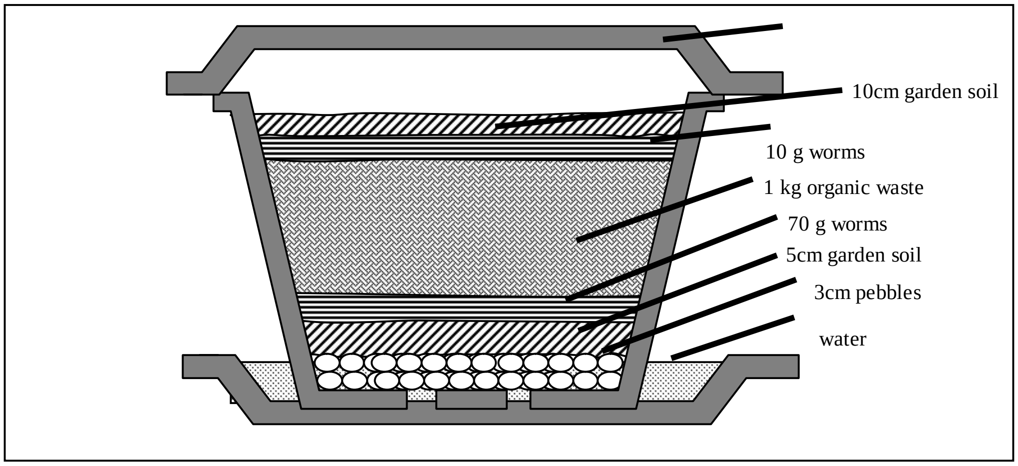

Figure 3. Vermicomposting experimental set-up for System T3.

Table 1. Detailed function of each material in the vermicomposting set-up.

Material	Used in set-up	Function
Pebbles	System T1, T2 and T3	To act as drainage material to collect excess water from the system
Garden soil (bottom)	System T1, T2 and T3	To provide bedding material for worms prior to complete adaptation to new system
Garden soil (top)	System T2 and T3	To cover worms and waste materials, to reduce light penetration and prevent offensive odour from escaping the system
Bottom plate with water	System T2 and T3	To trap worms that escape from the opening of the flower pot base.
Cover plate (top)	System T2 and T3	To prevent worms from getting preyed, to avoid insect from getting into the system, to totally remove the source of light

Organic waste used in the experiment was mainly kitchen waste (67%) with 33% grass clippings, goat manure, garden soil or vermicompost from earlier trials.

For each set-up, approximately 80g of *Eisenia foetida* locally obtained were introduced. The experiment was allowed to take place for five weeks before the final products were analyzed. Physical and chemical analyses were conducted to determine the best combination.

RESULTS AND DISCUSSION

Waste generators from the 350 houses studied consisted of 65% middle income group, 24% high income group and 11% low income group. The studies indicated that approximately 55% of the MSW consisted of organic portion, followed by plastic (19%) and paper (13%). The high organic component in the waste was due to the lack of bioremediation practice among the households to divert these putrescible wastes. Similar results were obtained from previous studies where most households lack composting practice which resulted with high percentage of organic component being present in the waste [19, 20]. The average composition of MSW generated by the households in Selangor is shown in Figure 4.

The organic component featured in Figure 4 consisted of food waste (41%), garden waste (12.3%) and other organic waste (1.76%). The implementation of vermicomposting would reduce at least 40% of waste from being disposed into landfills.

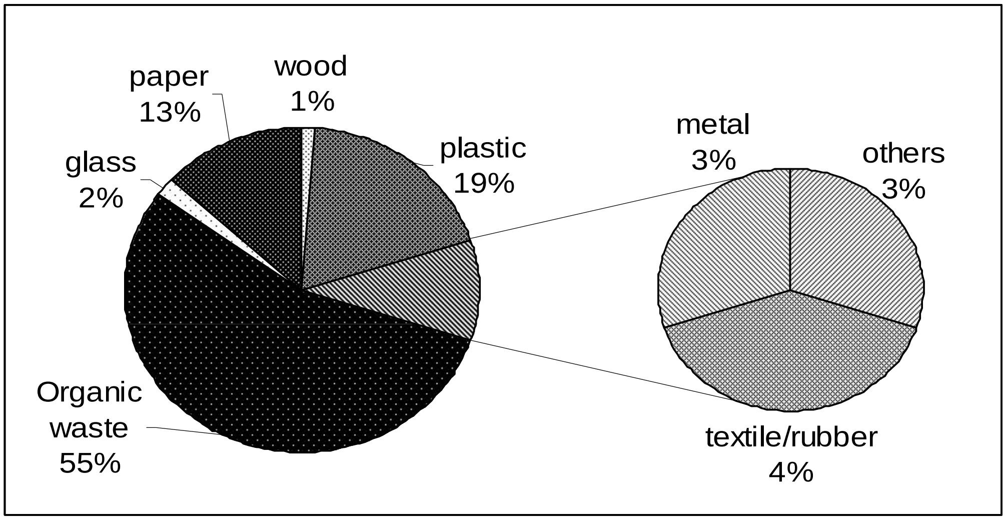

Figure 4. Average composition of domestic waste in Selangor

Vermicomposting in System T1 was relatively slow. Plastic bucket used was not conducive for vermicomposting and the lack of holes resulted with excess fluid being collected at the bottom of the bucket. However, the presence of pebbles helped to drain the system from excess moisture. This system required constant watering since the top layer is often dry. Therefore, approximately 10ml of water were sprinkled every other day. Mixing and turning was avoided to avoid disrupting the existing system. The process of composting was very slow and was completed after 90 days. The main factor contributing to the time-consuming system was raw material used i.e. garden waste which mainly consisted of dried leaves. The lignin and cellulose content of the leaves would require more ingestions by the worm to break it down to simpler structures [21]. Another set-back of this system was the problem of worms coming out from the bucket particularly when the moisture at the bottom layer was too high (more than 50%). To avoid worms from escaping the system, constant monitoring is crucial. Therefore the set-up was found to be inconvenient for household application since it required a long time period (approximately 3 months) and constant monitoring (worms coming out of container).

System T2 was set up using ceramic flower pots with a plate of water underneath to prevent worms from escaping the system. The water not only managed to keep adult worms from escaping but also helped to accumulate the juveniles when they were flushed during the watering of the system. Main material used for the trial was kitchen waste with various combinations. A thin layer of top soil (5cm) was applied to cover the organic waste and curb odour problem. The vermicomposting process completed after approximately 4 weeks with pH ranging from pH 4.9-6.4 and nitrate content 1-2.5%. The low pH value recorded was probably due to the generation of organic acids [22]. However, this system was also not very convenient since it allows various types of insects to breed due to the presence of food waste. Among the main pests were larvae of beetles most likely from genus Cephaloleia. The larvae that look like Maybeetles larvae compete for food. The products also contained large amount of faeces generated by the insect larvae.

System T3 was an improved System T2 set-up where the vermicomposting systems were covered with ceramic plate to prevent the invasion of external insects particularly beetles and flies. The T3 set-ups were allowed to continue for 4 weeks without disturbance except watering. Due to covering of the system, minimum watering is required as evaporated moisture was collected under the cover and driped back into the system. No evidence of pest namely insect was visible in the vermicomposting system. The final products were more homogenous with soil like texture. The analysis conducted is depicted in Table 2.

Table 2. Analysis of the vermicompost generated in System T3.

Combination	Final pH	Water holding capacity (%)	Total organic carbon (%)	Nitrate (mg/kg)	Phosphate (mg/kg)	Total Potassium (mg/kg)	N:P:K
100% Kitchen Waste (KW)	5.8	77.9	12.7	46.5	21.5	18.4	1:1:1
67% KW + 33% Grass Clippings	6.5	65.2	13.2	18.3	53.34	9.7	1:3:1
67% KW + 33% Goat Manure	7.6	76.3	12.4	26.2	321.4	24.8	1:12:1
67% KW + 33% Vermicompost	6.5	78.6	12.2	27.44	33.17	19.1	1:1:1
67% KW + 33% Garden Soil	7.1	74.3	11.1	6.5	65.8	8.8	1:10:1

The combination of 67% kitchen waste and 33% vermicompost was the fastest to complete (21 days). This is due to the utilization of vermicompost which consist mainly of the worms casting. It may have created a more suitable environment for the worms that the adaptation period was shortened and degradation was faster [23]. It was followed by the combination of goat manure and garden soil where degradation process completed after 24 days and 26 days, respectively. The factor which expedited the degradation was the short adaptation period resulting from the raw material used. This is so since the worms were collected from a goat farm.

Kitchen waste without any additives was the slowest to degrade since it contained various materials which were unfavorable factor to worms including oil, spices and others. With additives, this unfavourable has lesser effects as a result to reaction of kitchen waste and the additives. It was also observed that inclusion of certain citrus fruits hindered the degradation of the waste by the worms and eventually killed them. The water holding capacity of the vermicompost ranged from approximately 65% to 79% indicating approximately 12-17% increase from the value at the initial stage. On the other hand, total organic carbon increased 9-14% (wt) from the initial value where final products have a range of 11% to 13%. Analysis of the metal elements in the final products is shown in Table 3.

Table 3. Heavy metals in vermicompost

Samples	Cr (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Zn (mg/kg)	Pb (mg/kg)
100% Kitchen Waste (KW)	nd	0.01	nd	10.03	5.66	nd
67% KW + 33% Grass Clippings	nd	0.02	nd	10.89	17.28	nd
67% KW + 33% Goat Manure	nd	0.01	nd	9.45	16.9	nd
67% KW + 33% Vermicompost	nd	0.04	nd	7.33	42.93	nd
67% KW + 33% Garden Soil	nd	0.02	nd	10.74	22.07	nd
EU limit range*	70-200	70-600	0.7-10	20-200	70-1000	210-4000
USA biosolid limit*	1200	1500	39	420	300	2800

Note: nd = not detected; * [24]

Concentration of Pb, Cr and Cd were below the detection limit while others indicated approximately 32-45% increase from the initial raw materials. All of the concerned elements were within the acceptable range of both EU limit and USA Biosolid limit.

Presence of heavy metal concentration in vermicompost will have detrimental effects upon plant application [25,26]. Though no regular pattern is observed in final vermicomposts in relation to initial concentration, the increase in heavy metal content could probably be attributed to the massive degradation process of the raw materials and the mineralization process. The increase of heavy metal content in vermicompost was also recorded by findings on various types of raw materials [27, 28].

DISCUSSION

Results indicated that household putrescible waste can easily undergo vermicomposting. However, factors such as high acidity and presence of certain materials in the waste can be a disadvantage to this process. The pH reduction is mainly contributed by the generation of organic acid such as fulvic and humic acids [22, 29, 30, 31]. Experimental set-up with the layering system proved to be the most suitable method of conducting small scale vermicomposting. The layering set-up prevents worms from escaping the system and allows the gathering of the offspring in a safe environment. Different combinations of organic mixture resulted with different rate of vermicomposting. The fastest degradation was the combination of kitchen waste with vermicompost, which was completed within 3 weeks. It was so as it provides the most suitable environment for the worms to flourish in addition to the availability of less complex components.

CONCLUSIONS

Vermicomposting of organic components found in the MSW stream can be accomplished by taking into consideration some crucial factors such as acidity and presence of hindering factors. The best experimental set-up is the layering system of organic waste with soil which should cater the suitable environment for the worms as well as not allowing intrusion of other competitive organisms. The set-up is applicable to household vermicomposting since it is fast and convenient with minimal monitoring.

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