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Effects of Vermicomposting Duration to Macronutrient Elements and Heavy Metals Concentrations in Vermicompost

(Kesan Jangkamasa Pengomposan Vermi Terhadap Unsur Makronutrien dan Kepekatan Logam Berat di dalam Vermikompos)

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ABSTRACT

Vermicomposting using Lumbricus rubellus *was conducted in two different durations, 10 and 30 weeks in the same plots. Three different of treatments combination were prepared with eight replicates for each treatment namely cow dung : kitchen waste in 30:70 ratio (T_1), cow dung : coffee grounds in 30:70 ratio (T_2), and cow dung : kitchen waste : coffee grounds in 30:35:35 ratio (T_3). Macronutrients elements in the vermicompost from each treatment were measured in the tenth and thirtieth week. Comparatively longer duration of vermicomposting by using* Lumbricus rubellus *enhanced the quality of vermicompost by the increase of the macronutrient elements while reducing the heavy metal concentration and C/N ratio.*

Keywords: Duration; heavy metals; Lumbricus rubellus*; macronutrient; vermicomposting*

ABSTRAK

Pengomposan vermi menggunakan Lumbricus rubellus *telah dijalankan untuk dua jangkamasa, 10 minggu dan 30 minggu di dalam plot yang sama. Tiga kombinasi rawatan disediakan dengan lapan replikat untuk setiap rawatan iaitu najis lembu : sisa dapur pada nisbah 30:70 (T_1), najis lembu : sisa kisaran kopi pada nisbah 30:70 (T_2), dan najis lembu : sisa dapur : sisa kisaran kopi pada nisbah 30:35:35 (T_3). Unsur makro-nutrien daripada setiap rawatan dianalisis pada minggu kesepuluh dan ketiga puluh. Secara perbandingannya, lebih panjang jangkamasa pengomposan vermi dijalankan dengan menggunakan* Lumbricus rubellus*, dapat meningkatkan kualiti vermikompos melalui penambahan kandungan elemen makro nutrien di samping menurunkan kepekatan logam berat dan nisbah C/N.*

Kata kunci: Jangkamasa; logam berat; Lumbricus rubellus*; nutrien makro; pengomposan vermi*

INTRODUCTION

The rapid increase of solid waste generation especially organic waste in Malaysia was clearly indicated in the Ninth Malaysia Plan 2006-2010 as reported by the Economic Planning Unit (2006). The amount of solid waste generated in Peninsular Malaysia has increased from 16,200 tonnes per day in 2001 to 19,100 tonnes in 2005 or an average of 0.8 kg per capita per day. Solid waste in Malaysia on average consists of 45% of food waste, 24% plastic, 7% paper, 6% iron and 3% glass and others made the rest. Bolt from the blue, 58.3% of all the wastes dumped to landfills composed of valuable organic waste (Rahimah 2007).

Vermicomposting has been widely identified as one of the potential activity to reduce the quantity of solid waste that need to be sent to the landfills. Vermicomposting is classified as biological treatment under intermediate treatment technologies of solid waste management (Department of Local Government 2006) which also consists of physical processing and thermal treatment.

In general, vermicomposting includes physical and biochemical processes when the use of earthworms is able to break down the organic elements of household waste including kitchen waste and coffee grounds. By using *Lumbricus rubellus*, this process tolerance in mesophilic temperature range; 35°C to 40°C with moisture content between 40% to 50% and pH between in neutral range; 7 (Sharma et al. 2005) identified as cost effective and natural alternative method. Furthermore, only short duration is needed to accomplish; 2 to 32 days of vermicomposting (Wang et al. 2007).

Vermicomposting is also a process of bio-oxidation and stabilization of organic matter involving the join action of earthworms and microorganisms. The presence of earthworms doubles the rate of carbon loss due to joint action of earthworms and microorganism activity that accelerates the mineralization of C (Aira et al. 2007). This results in faster decomposition process to convert organic substances to inorganic substances.

According to Edwards and Lofty (1972), about 5 to 10% of ingested material is absorbed into the earthworms' tissue for growth and metabolic activity and the rest is excreted as vermicast. The mixture of vermicast with mucus secretion of the gut wall and microbes transformed it into a value added material; vermicompost which is high in nutrient elements contents (Nagavallemma et al. 2004). In this study, coffee grounds and kitchen waste were selected as feed materials in vermicomposting. Macronutrient elements and heavy metal contents in vermicompost were analyzed and compared between the 10th and 30th week to identify the effect of vermicomposting duration to the quality of vermicompost produced. The potential of vermicomposting as a tool to treat heavy metal contamination in solid waste was also investigated.

MATERIALS AND METHODS

EXPERIMENTAL DESIGNS

Plastic bins of size 45 cm × 30 cm × 30 cm with four plots in each box and small holes at the bottom were used as earthworm bin. Three different combination of treatments were prepared with eight replicates for each treatment namely cow dung:kitchen waste in 30:70 ratio (T_1), cow dung:coffee grounds in 30:70 ratio (T_2), and cow dung:kitchen waste:coffee grounds in 30:35:35 ratio (T_3). The use of cow dung is only for supplement and also as bedding material for the earthworms at their early stage before they are able to climatize with the treatments given.

In each treatment plot, 60 weighted matured earthworms of approximately the same size were introduced after a few days of pre composting of organic wastes to avoid exposure of worms to high temperature during initial thermophilic stage. Moisture content of the treatment was maintained at about 50% to 60% by spraying the surface with mineral water. The duration of vermicomposting was 10 weeks for the first phase and 30 weeks for the second phase. Some of the vermicompost produced in each phase were taken for nutrient elements analyses.

MICRONUTRIENT ELEMENTS AND HEAVY METALS ANALYSIS

The nutrient parameters of vermicompost produced during experiments were analyzed by using standard method (Bansal & Kapoor 2000). Organic carbon was determined by the partially-oxidation method (Walkley & Black 1934). Nitrogen was estimated by Kjeldahl digestion. Phosphorus was detected by using colorimetric. Potassium, zinc, and copper were measured by ignition method using atomic absorption spectrophotometry. The C/N ratio was analyzed through calculation.

STATISTICAL ANALYSIS

Statistical analysis was carried out using SPSS 11.0.1 (Standard Version) computer software package. Paired-Samples T-Test analysis was done to analyze the relationship between macronutrient elements including heavy metals concentrations and duration of vermicomposting.

RESULTS AND DISCUSSION

MACRONUTRIENT ELEMENTS – N, P AND K

The N contents in T_1 and T_2 increased from the 10th week (1.07% & 2.01%) to the 30th week (1.35% & 3.21%) as showed in Figure 1due to inoculation of lignolytic fungi that might enhance decomposition of the organic matter by fungi (Viel et al. 1987) and the extent of N fixed by free living nitrogen-fixing bacteria (Kale et al. 1982). It is

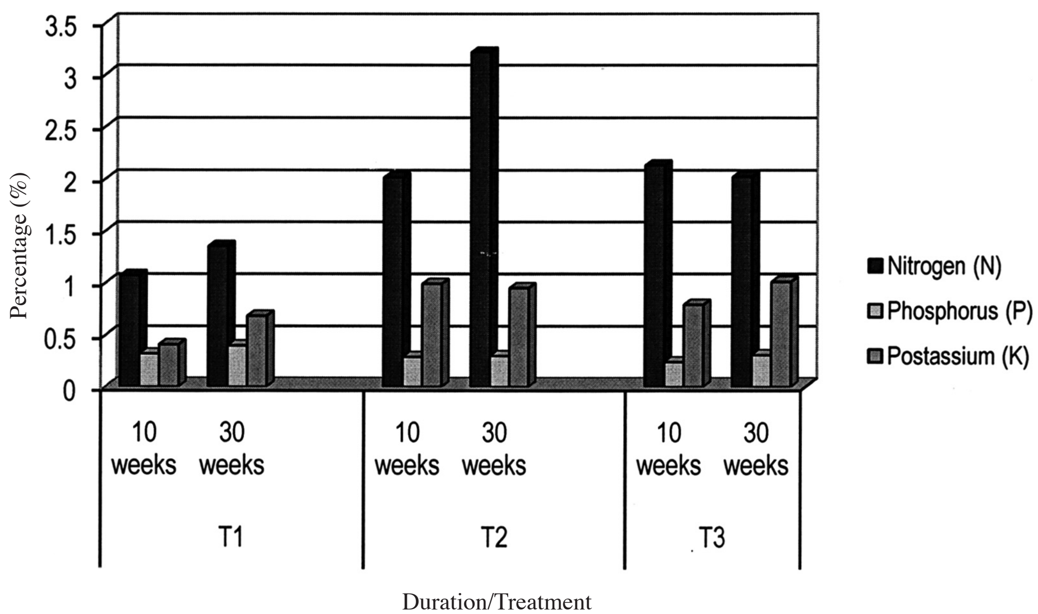

FIGURE 1. Differentiation of macronutrient elements – N, P and K between two different durations – 10 weeks and 30 weeks

also governed by the initial N content of organic wastes used as feed materials (coffee grounds) to the earthworms and by the extent of its decomposition (Crawford 1983; Gaur & Singh 1995; Kaviraj & Sharma 2003). This results is supported by Surendra (2006) where total N of vermicompost showed great increase after 150 days vermicomposting compared to the first day. However, N in T_3 decreased from 2.13% to 2.02%due to stable condition of vermicompost that consumed little N and oxygen (CIWMB 2003).

The longer duration from 10 to 30 weeks of vermicomposting resulted in increasing of P in all treatments; T_1(0.32% to 0.40%), T_2(0.29% to 0.30%) andT_3 (0.24% to 0.31%) as shown in Figure 1.

The same results also showed for K but only in T_1(0.41% to 0.68%) and T_3 (0.79% to 1.01%). The increasing of P and K contents is a direct action of earthworms gut enzymes and indirectly by stimulation of the microflora (Kaviraj & Sharma 2003; Satchell & Martein 1984). As supported by Edwards and Lofty (1972) findings, who stated that the increase in P during vermicomposting is probably due to mineralization and mobilization of phosphorus as a result of bacterial and faecal phosphate activity of earthworms.

In contrast, K in T_2 is experiencing some reduction due to the vermicomposting duration but only in small percentage (0.99% to 0.95%). However, there is no significant difference of all macronutrient elements; N ($t = -1.176$, $df = 2$, $p > 0.05$), P ($t=-2.440$, $df=2$, $p> 0.05$) and K ($t=-1.561$, $df=2$, $p> 0.05$) between two different durations –10th and 30th week as shown in Table 1 and indirectly indicating that longer duration of vermicomposting is not able to enhance the macronutrient elements in vermicompost.

HEAVY METALS CONCENTRATIONS – Zn AND Cu

At the 30th of vermicomposting, the amounts of heavy metal; Zn and Cu generally decreased in from 29% to 60% compared to the amounts in the 10th week although the macronutrient contents tend to fluctuate during the same duration (Figure 1). As shown in Figure 2, the amount of Zn decreased from 0.016% to 0.01% for T_2 and from 0.012% to 0.01% for T_3. Moreover for the Cu, the percentages were decreased in all treatment; T_1(0.006% to 0.003%), T_2 (0.007% to 0.005%) and T_3 (0.005% to 0.002%).

This is supported by Dominguez et al. (1997) who found that the amounts of bioavailability of heavy metals (Zn and Cu) in vermicomposting of pig manure tend to decrease by 35% to 55% in two months. However, in T_1 there was an increase for Zn from the 10th week (0.015%) to 30th week (0.02%) but only in small percentage compared to percentage decrease in the other two treatments, T_2 and T_3.

The study of heavy metal bioaccumulation via earthworms by Shahmansouri et al. (2005), showed that heavy metals concentration including Zn and Cu decreased with increased vermicomposting time. Other than that, Hobbelen et al. (2006) reported that after 54 days of vermicomposting durations, in spite of high availability of heavy metal concentrations in earthworms, Cu and Zn concentrations in vermicompost decreased.

Statistically, there is a significant difference between two different durations – week 10 and week 30 (Table 1) only in Cu ($t=8.000$, $df=2$, $p< 0.05$), indicating that longer duration of vermicomposting is able to reduce the heavy metal concentrations, Cu in vermicompost. Zn, ($t=0.311$, $df=2$, $p> 0.05$) which was not influenced by the longer duration of vermicomposting.

OTHER NUTRIENT ELEMENTS – C, N AND C/N RATIO

The percentage of organic carbon for two different durations (10 and 30 weeks) in T_1 decreased by 21% (from 15.1% to 14.9%) which might due to relative increase in N; 26% (from 1.07% to 1.35%) (Figure 3).

This occured due to the loss of organic carbon as CO_2 as well as water loss by evaporation during mineralization (Viel et al. 1987). The increase in the earthworms' population also led to rapid decrease in C due to enhanced oxidation of the organic matter (Pramanik et al. 2007).

In contrast to other two treatments, where the vermicompost were in stable condition and resulted in an increase of organic carbon from 14.9% to 19.32% for $T_2$and 15.2% to 18.27% for T_3 as the oxidation of organic matter became slower when the vermicomposting almost completed. These conditions enhanced N content in T_2

TABLE 1. Paired-Samples T Test of macronutrient elements and heavy metal concentrations in different duration

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	N week 10th - N week 30th	-.45667	.672632	.388344	-2.12758	1.21424	-1.176	2	.361
Pair 2	P week 10th - P week 30th	-.05333	.037859	.021858	-.14738	.04071	-2.440	2	.135
Pair 3	K week 10th - K week 30th	-.15000	.166433	.096090	-.56344	.26344	-1.561	2	.259
Pair 4	Zn week 10th - Zn week 30th	.00100	.005568	.003215	-.01283	.01483	.311	2	.785
Pair 5	Cu week 10th - Cu week 30th	.00267	.000577	.000333	.00123	.00410	8.000	2	.015
Pair 6	C week 10th - C week 30th	-1.4300	4.06612	2.34757	-11.5308	8.6708	-.609	2	.604
Pair 7	C/N week 10th – C/N week 30th	1.6000	3.60416	2.08087	-7.3532	10.5532	.769	2	.522

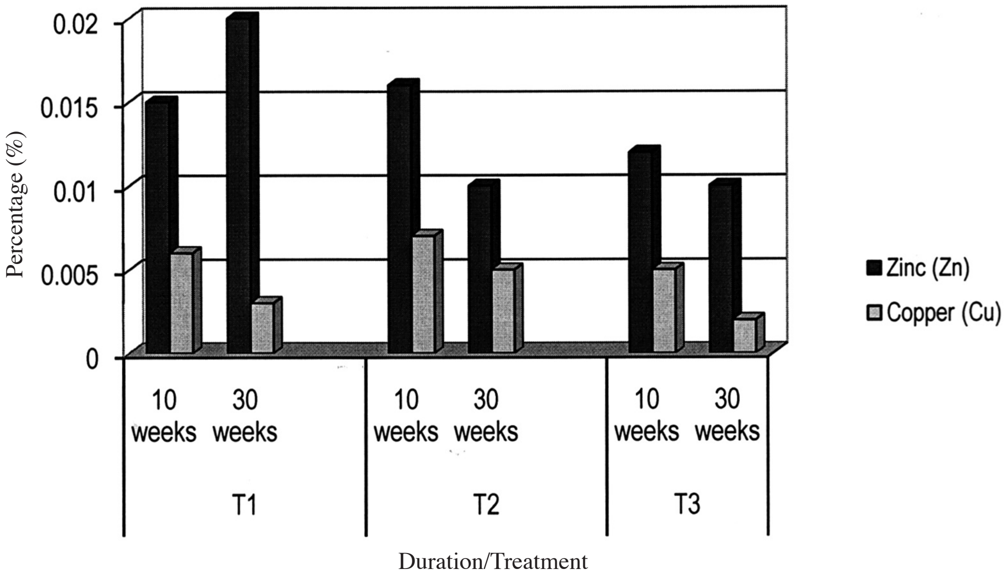

FIGURE 2. Differentiation of heavy metals concentrations – Zn, Cu and Fe between two different durations – 10 weeks and 30th weeks

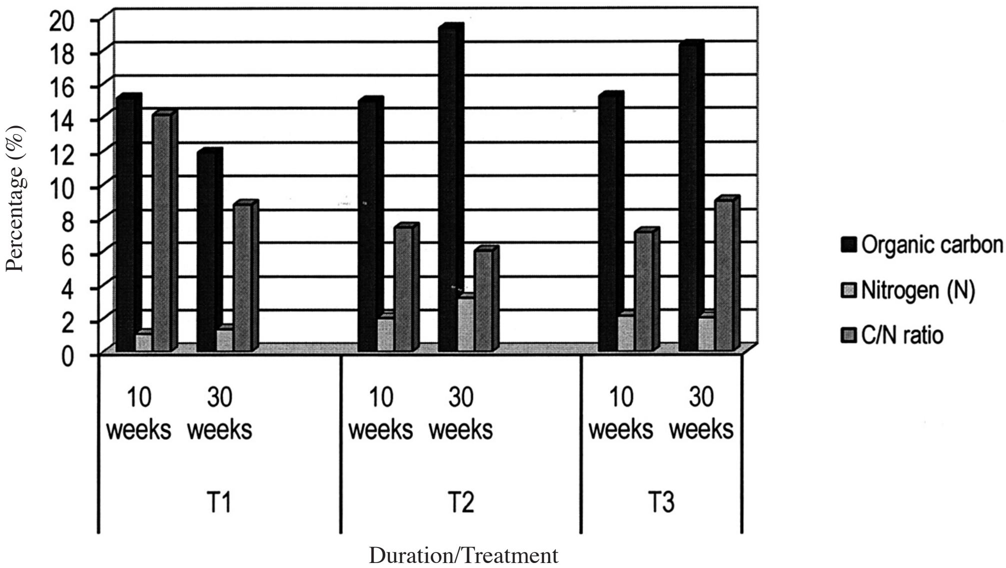

FIGURE 3. Differentiation of other nutrient elements – Organic carbon, N and C/N ratio between two different durations – 10 weeks and 30 weeks

rapidly. According to Kale et al. (1982), N content in vermicomposting also rely on the extent of N fixed by free living nitrogen-fixing bacteria. However, in T_3, there was decrement for N but only in small percentage (5%) due to the maintaining of stable condition of vermicompost which will consume insignificant amount of N and O. As a result, CO_2 and heat will be generated (CIWMB 2003).

The stability of vermicompost is needed to represent the maturity or level of completeness of the vermicomosting process. It can be identified via C/N ratio of vermicompost. According to Morais and Queda (2003), C/N ratio below 20 is indicative of acceptable maturity, while a ratio of 15 or lower being preferable as a better vermicompost. Referring to the results, vermicompost from all treatments either in week 10 or week 30 is classified as a better vermicompost when the C/N ratio ranges from 6.0 to 14.1. C/N ratio in T_1 and T_2 can be referred as declining in ranges 14.1 and 7.4 in week 10 to 8.8 and 6.0 in week 30. However, the C/N ratio for T_3 increased from 7.1 in week 10 to 9.0 in week 30 due to the rapid generation of organic carbon.

Nevertheless, there is no significant difference among C($t=-0.609$, $df=2$, $p> 0.05$), C/N ratio ($t=0.709$, $df=2$, $p> 0.05$) and vermicomposting duration – week 10 and week 30 as shown in Table 1, indicating that longer duration of vermicomposting is not proficient to reduce the C and C/N ratio in vermicompost.

Conclusion

By keeping a side the statistical analysis, longer duration of vermicomposting using *Lumbricus rubellus* is able to enhance the quality of the end product; vermicompost. Certain feed materials for example coffee grounds at specific ratio and suitable conditionwill increase the nutrient elements (N, P & K) while reducing the heavy metal contents especially Cu. Therefore, it can be suggested as one of the methods to treat solid waste that are contaminated with heavy metal.

As for C/N ratio, a combination of feed materials and duration will determine the quality of the vermicompost which enhanced the loss of organic carbon while the N content increased rapidly. Therefore, reducing the C/N ratio in range 15 and below which represents a better quality vermicompost.

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