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Nutrient Elements of Different Agricultural Wastes from Vermicomposting Activity

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ABSTRACT

Vermicomposting using the earthworm *Lumbricus rubellus* was conducted for 70 days subsequent to 10 days of pre-composting under glasshouse conditions. Five treatments were used as feed materials with 5 replicates per treatment: T_1: goat manure, T_2: paddy straw, T_3: spent mushroom paddy straw compost, T_4: sawdust and T_5: spent mushroom sawdust compost. The treatments were placed in a microcosm or worm bin plastic container (360 mm × 280 mm × 200 mm). The effectiveness of vermicomposting was evaluated through the increment of nutrient elements contained in the vermicompost, growth (biomass weight) and reproduction (total numbers) of earthworms, as a percentage, at the end of the process. The increment of macronutrients in the vermicompost from each treatment was high, especially of organic carbon (C) in T_1 and T_4, and nitrogen (N), phosphorous (P) and potassium (K) in T_3. Regarding micronutrients, copper (Cu) had the highest concentration in T_2 and zinc (Zn) in T_1 and T_2. Therefore, the best vermicompost as a soil fertilizer was T_3, which showed the highest increment and final content of N (+150.73%, 1.50%), P (+387.75%, 1.06%) and K (+886.09%, 2.05%). There was no significant difference between the number and weight of earthworms among the 5 treatments ($P > 0.05$). A C: N ratio < 20 indicates the degree of compost maturity and post-vermicomposting, as noted for T_1 and T_3; T_1 had the lowest C: N ratio (9.86). Based on our findings, the nutritive value of our vermicompost – developed from selected agricultural wastes – can be qualitatively assessed as a value-added material against fertilizers or soil stabilizers.

Keywords: earthworm, goat manure, NPK, organic carbon, spent mushroom compost

INTRODUCTION

Agricultural waste, including animal manure, is a source of solid waste (Macias-Corral 2008). In Malaysia, disposal of solid waste has become a major problem due to the shortage of dumping sites and strict environmental laws; this situation is similar to India (Anshu and Satyawati 2002). Problems related to waste cannot be solved easily, even with the present approach of opening new landfills and high technology incinerators. Furthermore, a longstanding habit of waste disposal also plays a role in the debilitation of these substrates as possible agricultural economic boosters. Thus, it is apparent that new methods of utilizing agro-residues are needed in order to achieve sustainable management of agricultural waste (Vikineswary 2006). According to Prabha *et al*. (2008), recycling of organic wastes is important with the increasing need to conserve natural resources and energy, and recycling organic wastes is of major importance. In addition, organic matter plays a key role in achieving sustainability in agricultural production because it possesses many desirable properties such as high water holding capacity, cation exchange capacity (CEC), the ability to sequester contaminants (both organic and inorganic) and beneficial effects on the physical, chemical and biological characteristics of soil. Earthworms have been successfully used in the vermicomposting of urban, industrial and agricultural wastes in order to produce organic fertilizers and to obtain protein for animal feed (Khwairakpam 2009). Additionally, the vermicomposting of agricultural waste such as cattle manure, spent mushrooms and others, will produce organic fertilizer that can replace chemical fertilizers.

The aim of this study was to compare the nutrient elements in different agricultural wastes following composting and vermicomposting as a tool to further support and promote environmentally friendly agricultural waste management.

MATERIALS AND METHODS

Pre-composting and vermicomposting experiment

The feed materials were obtained from different sources. Goat manure was obtained from the ISB (Institute of Biological Sciences, University of Malaya) Mini Farm. It was dried in the open air before use. Raw paddy straw and spent mushroom paddy straw compost from *Pleurotus sajor-caju* were obtained from the Fungal Biotechnology Laboratory in ISB. Sawdust and spent mushroom sawdust compost from a *P. sajor-caju* were gathered from a mushroom farm in Banting, Selangor. Earthworms (*Lumbricus rubellus*) were picked from a stock culture in the Environmental Science Laboratory, ISB.

The treatments were performed in plastic bins (360 mm × 280 mm × 200 mm) with a net on the lid to allow for aeration. The bins could accommodate 5 kg of feed materials. Five treatments were prepared (5 replicates each; 4 vermicomposting and 1 composting): T_1: goat manure, T_2: paddy straw, T_3: spent mushroom paddy straw compost, T_4: sawdust and T_5: spent mushroom sawdust compost. The control was a treatment in which no earthworms were introduced.

50 clitelated earthworms of approximately the same size were introduced into each bin holding 5 kg of each feed material after 10 days of pre-composting. During the pre-composting period, pH and temperature were monitored until an optimum level of pH 7 ± 1 and temperature of 27 ± 1°C were achieved and stabilized. This period, also termed thermo-composting, effectively inactivates pathogens (Nair *et al.* 2006). Pre-composting was also performed to avoid exposure of earthworms to high temperature during the initial thermophilic stage of microbial decomposition (Loh *et al.*

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2005).

Vermicomposting lasted 10 weeks (70 days). During this process, the moisture content of feed materials was maintained at 60-70% by constantly spraying distilled water on the surface, together with manual turning once every few days to remove any stagnant water. At the end of the study, earthworms were removed manually and the total number and biomass were measured to determine their growth and reproduction rate. Larger numbers indicate growth and the increase in biomass shows an increment in reproduction rate and *vice versa*. The multiplication of earthworms was calculated as:

$$\frac{\text{(Numbers on day-70 – Numbers on day-0)}}{\text{Numbers on day-0}} \times 100.$$

The upper layer of vermicompost produced in the plastic bin was sampled (~500 g) for analysis of nutrient elements before all the earthworms were removed (Nik Nor Izyan *et al.* 2009). The upper layer was sampled because it is the first layer that is converted into vermicast; the lower layer was then sampled. The upper layer is normally fully converted into vermicast within 3 months for the capacity of this worm bin. Since the experiment ran for 70 days, ~5 cm of the upper layer was sampled, which was considered to be vermicast. The number of living earthworms was determined after hand sorting and removal of all extraneous material.

Nutrient element analysis

The production of organic C in vermicompost was determined by the partial-oxidation method (Walkley and Black 1934). N was estimated by Kjeldahl digestion with concentrated H_2SO_4 (1: 20, w/v) followed by distillation (Bremner and Mulvaney 1982). P, Cu and Zn were detected by a colorimetric method using ammonium molybdate in HCl (John 1970). K was measured by the ignition method using a Perkin Elmer model 3110 double beam atomic absorption spectrophotometer (Loh *et al.* 2005). The maturity of the vermicompost was calculated from the C/N ratio.

Statistical analysis

Statistical analysis was carried out using SPSS v. 11.0. A paired sample *t*-test was used to determine significant differences of nutrient element means between treatments. One-way ANOVA was performed to analyze the significant difference ($P < 0.05$) of earthworms' weight and number in percentage between treatments during vermicomposting.portant role in the regulation of secondary metabolic biosynthesis.

RESULTS AND DISCUSSION

Nutrient elements from the 5 treatments are presented in **Table 1**. The quality of a fertilizer depends on the level of N, P and K; highest values occurred in vermicompost of paddy straw-based spent mushroom substrates (i.e. T_3): N, 1.50% (1.5-fold increase); P, 1.06% (3.8-fold increase); K, 2.05% (8.8-fold increase).

These values are relatively high compared to garden waste vermicompost: N = 0.8%; P = 0.19-1.02% (Nagavellama *et al.* 2004). When organic waste was used as the substrate, Hi Wave™ Compo technology – a combination of infrared and microwave technology which enhances the efficiency of fermentation, drying and granulation process where organic waste is converted into dry granular form of organic fertilizer within 7 days without the addition of enzymes or chemical substances – yielded 0.84% K (Pollution Engineering (M) Sdn Bhd 2007). Similarly, vermicomposting of organic waste yielded 0.30-1.50% K (MIF Sdn Bhd 2007). Based on a paired samples *t*-test, N was significantly different in T_2 ($P < 0.05$; t = -2.880; df = 4) and T_5 ($P < 0.05$; t = 8.519; df = 4), P was significantly different in all treatments except for T_1 ($P < 0.05$; t = -1.422; df = 4) and K was also significantly different in all treatments except for T_1 ($P < 0.05$; t = -2.458; df = 4).

C is a source of energy needed by living organisms for self-sustained growth and reproduction. Therefore, increments of C in T_1, T_4 and T_5 are related to a decrease in the number of earthworms due to mortality. Reduction of C in T_2 and T_3 is because of the loss of C as CO_2 released during vermicomposting. According to Suthar (2006), earthworms promote microclimatic conditions in vermireactors that increase the loss of organic C from substrates through microbial respiration.

N content in vermicompost depends on the initial N content present in feed materials and on the degree of decomposition (Crawford 1983). From our results, all treatments showed an increment in N, except for T_5. This increment in N might originate from the addition of N by the earthworm itself in the form of mucus, nitrogenous excretory substances, growth-stimulating hormones and enzymes (Tripathi and Bhardwaj 2004). N, fixed by free-living N-fixing bacteria, can also result in an increased N content in vermicompost (Kale *et al.* 1982).

The increase in P and K was probably due to the direct action of the earthworm gut enzymes and indirectly by stimulation of the microflora (Satchell and Martin 1984). Barois and Lavelle (1986) reported that earthworms produce a huge amount of intestinal mucus – a mixture of glycoproteins, small glucidic and proteic molecules – which is rapidly incorporated into the microbial biomass in the gut. This increment of P was ascribed to changes in sorption complexes induced by competition for sorbing sites between orthophosphates and carboxyl groups of glycoproteins within mucus produced in the earthworm gut (López-Hernández *et al.* 1993). According to Edwards and Lofty (1972), the rise in P during vermicomposting is probably due to P mineralization and mobilization because of bacterial and fecal phosphate activity of earthworms. High water

Table 1 Nutrient element in vermicompost from five different types of treatments.

Nutrient element	Unit	Treatment									
		T_1 GM		T_2 PS		T_3 SMS(PS)		T_4 SD		T_5 SMS(SD)	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
C	ppm	180.032	211.000	304.176	302.775	317.448	168,734	325,241	377,641	344,030	356,193
	*%	+17.20		-0.46		-46.85		+16.11		+3.54	
N	ppm	21.248	21.401	8.205	9.606	6.077	15,237	3, 293	3,516	5,795	4,276
	%	+0.72		+17.07		+150.73		+6.77		-26.21	
P	ppm	15.562	16.562	644	1.372	2.181	10,638	164	248	2,695	1,906
	%	+6.43		+113.04		+387.75		+51.22		-29.28	
K	ppm	5. 245	8.345	12.294	23.199	2. 078	20,491	1,745	2,544	2,537	4,999
	%	+59.10		+88.70		+886.09		+45.79		+97.04	
Cu	ppm	50.40	140.09	<1.00	10.22	9.30	14.14	<1.00	2.86	2.60	11.42
	%	+177.96		<+922		+52.04		<+186		+339.23	
Zn	ppm	172.70	526.43	32.26	96.96	327.10	116.18	16.84	33.58	38.20	55.50
	%	+204.82		+200.55		-64.48		+99.41		+45.29	

T_1: goat manure ;T_2: paddy straw; T_3: spent mushroom substrate (paddy straw); T_4: saw dust; T_5: spent mushroom substrate (saw dust)

*% = percentage of increment noted as + and percentage of decrease noted as -

Table 2 C/N ratio of vermicompost from each treatment.

Vermicompost	C/N ratio
T_1	9.86
T_2	31.52
T_3	11.07
T_4	107.41
T_5	83.30

T_1: goat manure; T_2: paddy straw; T_3: spent mushroom substrate (paddy straw); T_4: saw dust; T_5: spent mushroom substrate (saw dust)

Table 3 Earthworms gain and loss in percentage for five different treatments.

Treatment	Plot	Gain/Loss (%)	
		Weight	Number
T_1	A1	+3.17	-12
	A2	+145.43	+104
	A3	-1.93	-4
	A4	+13.98	+12
T_2	B1	+65.63	-16
	B2	+407.33	+42
	B3	+39.95	-2
	B4	+31.87	-14
T_3	C1	+49.45	+2
	C2	+24.44	-2
	C3	-9.96	-18
	C4	+134.33	+4
T_4	D1	-7.30	-10
	D2	+3.94	+6
	D3	+2.08	-18
	D4	+28.26	-14
T_5	E1	+55.09	-26
	E2	+160.31	+8
	E3	+1.25	-36
	E4	+3.67	-58

T_1: goat manure; T_2: paddy straw; T_3: spent mushroom substrate (paddy straw); T_4: saw dust; T_5: spent mushroom substrate (saw dust)

solubility might result in a reduction of P (Elvira *et al.* 1998).

The level of Cu and Zn was higher at the end of vermicomposting, except for Zn in T_3. Zn is a component of several enzymes (dehydrogenases, proteinases and peptidases) that are involved in the metabolism of carbohydrate proteins, phosphate, auxins, in RNA and in ribosome formation in plants (Mengel and Kirkby 1982). Cu plays a role in several physiological processes in plants (photosynthesis, respiration, carbohydrate distribution, N and cell wall metabolism, seed production), including disease resistance (Kabata-Pendias and Pendias 2001) even though it is classified as a heavy metal, although the final percentage obtained complied with the Malaysian Standard B, Environmental Quality Act of 1974. These findings are also in agreement with those of Elvira *et al*. (1997) and Tajbakhsh *et al*. (2008), who reported increases in total heavy metals of vermicomposting using waste water sludge from the paper-pulp industry and spent mushroom compost, respectively, which complied with the allowed levels of heavy metals for agricultural soils recommended by the CEC (1986).

The C/N ratio is used as an index for maturity of organic wastes. In this study the C/N ratio of T_1 and T_3 was < 20 (**Table 2**). According to Senesi (1989), a C/N ratio < 20 indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes. A high C/N ratio – as in T_2, T_4, and T_5 – reflects a decrease in biological activity and consequently slow degradation (Haug 1993).

There was no significant weight gain or loss of earthworms in any of the 5 treatments (**Table 3**), indicating that the multiplication of earthworms was not influenced by the treatments. This might be due to the nature of feeding materials such as spent mushroom (sawdust-based) which is wet but which contains 40.8% dry matter and putrifies quickly (Kwak *et al.* 2008); paddy straw is a lignocellulostic biomass which is naturally recalcitrant (Balan *et al.* 2008). Amended materials are needed as feed materials in order to influence the multiplication of earthworms. Adi and Noor (2009) noted that the moisture content of kitchen waste is high; moreover, the presence of oil- and fat-based compounds present in the mixture of animal- and plant-based materials in kitchen waste cannot be injected by earthworms; the presence of coffee grounds as amended material (vermicomposting for 49 days after 21 days of pre-composting of cow dung: coffee grounds in 30:70 ratio and cow dung: kitchen waste: coffee grounds in 30:35:35 ratio) resulted a significant increase in earthworm multiplication and helped to enhance the percentage of nutrient elements. Cow dung serves as bedding material for earthworms and also as a food supplement. This bedding is necessary for the early stages of earthworm survival before they acclimatize with whatever feed materials are provided: in our study, we identified the potential of goat manure as suitable bedding material due to its low C/N ratio, although it is low in nutrients, so it needs to be mixed with other materials to be a suitable feeding material. This was further supported by Suthar (2007), who claimed that the chemical nature of organic waste influences the palatability directly or indirectly which consequently affects earthworms' efficiency in decomposing the substrate, although the chemical profile of the organic waste needs further experimental confirmation.

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