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WASTE CONVERSION TO VERMICAST BY *EISENIA FOETIDA* GIVEN FOUR TYPES OF ORGANIC SUBSTRATES IN THE NATURAL MALAYSIAN ENVIRONMENTAL CONDITIONS

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Abstrak: Kajian ini dijalankan bagi menentukan kebolehan cacing tanah *Eisenia foetida* menukar empat jenis sisa organik kepada vermikas pada persekitaran semula jadi Malaysia. Eksperimen dilakukan di rumah cacing dengan suhu persekitaran di antara 26°C–33°C dan kelembapan bandingan sekitar 65%–80%. Kandungan air bahan mentah organik adalah sekitar 71.0%–95.2%. Kandungan air paling tinggi bagi substrat ialah pada carikan batang pisang (95.2%), diikuti oleh sisa kafeteria (91.0%), carikan surat khabar (76.3%) dan najis lembu (71.0%). pH_{KCl} dan pH_{H_2O} sisa kafeteria meningkat masing-masing sebanyak 86.3% dan 90.2% selepas rawatan vermikultur. Peningkatan pH paling tinggi sebanyak 86.3% berlaku pada bahan mentah berasid (4.16). Hanya sedikit peningkatan atau penurunan (iaitu di antara 6.7%–17.2%) berlaku apabila substrat bersifat sedikit alkali (7.40–7.86). Tanpa mengira jenis dan pH awal bahan mentah, vermikas yang terhasil oleh vermikultur menunjukkan nilai pH yang berbeza, bersifat hampir neutral atau lebih alkali (6.49–8.35). Secara am, peningkatan eksponensial tumbesaran cacing tanah dalam semua jenis sisa organik yang dikaji berlaku sehingga hari kelima proses vermikompos dan menurun selepas itu. Corak tumbesaran adalah serupa dalam kesemua jenis sisa organik. Penambahan berat cacing berlaku sebaik sahaja selepas cacing diinokulasi ke dalam media. Cacing tanah yang hidup dalam sisa kafeteria menunjukkan tumbesaran paling tinggi diikuti oleh najis lembu, carikan batang pisang dan carikan surat khabar. Sisa kafeteria juga didapati paling cepat tertukar sepenuhnya kepada vermikas. Bahan mentah tertukar sepenuhnya kepada vermikas dalam masa 36.2 ± 1.3 hari untuk sisa kafeteria, 43.8 ± 1.14 hari untuk carikan batang pisang, 47.4 ± 0.84 hari untuk carikan surat khabar dan 58.2 ± 0.84 hari untuk najis lembu. Penghasilan vermikas ialah 41% berat badan cacing per hari untuk sisa kafeteria, diikuti 34% untuk carikan batang pisang, 32% untuk carikan surat khabar dan 26% untuk najis lembu. Dalam keadaan persekitaran semula jadi di Malaysia, kebolehan *E. foetida* menukar sisa organik kepada vermikas berbeza bagi jenis dan kualiti substrat yang digunakan. Peningkatan pertumbuhan *E. foetida* adalah selari dengan kadar pertukaran sisa buangan kepada vermikas, iaitu peningkatan pertumbuhan mempercepatkan penukaran sisa buangan kepada vermikas.

Kata kunci: Sisa Organik, Vermikompos, *Eisenia foetida*, Vermikultur

Abstract: The present study was carried out to determine the ability of the earthworm *Eisenia foetida* to convert four different types of organic wastes into vermicast in the natural Malaysian environmental conditions. The experiment was carried out in the worm house with the ambient temperature recorded as between 26°C–33°C and relative humidity ranged between 65%–80%. The water content of the raw organic matter ranged from 71.0%–95.2%. The highest water content of the substrates was in the shredded banana trunk (95.2%), followed by cafeteria waste (91.0%), shredded newspaper (76.3%)

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and cow dung (71.0%). The pH_{KCl} and pH_{H_2O} of the cafeteria waste increased 86.3% and 90.2%, respectively after vermiculture treatment. The increase in pH was the highest when the raw material was acidic (4.16). Only slight increase or decrease (i.e. between 6.7%–17.2%) occurred when the raw materials were slightly alkaline (7.40–7.86). Regardless of types and initial pH of the raw materials, pH of vermicast has shifted to near neutral or more alkaline (6.49–8.35). In general, exponential increase in growth of the earthworm in all the organic wastes tested occurred until the 5th day of vermicomposting and declined thereafter. The trend in growth increment was similar in all types of organic wastes. Weight increment commenced immediately after the worms were inoculated onto the media. Earthworms grown on cafeteria waste showed the highest growth increment, followed by cow dung, shredded banana trunk and shredded newspaper. Cafeteria waste was also found to be the fastest to completely convert to vermicast. The raw materials completely turned to vermicast within 36.2 ± 1.3 days for cafeteria waste, 43.8 ± 1.14 days for shredded banana trunk, 47.4 ± 0.84 days for shredded newspaper and 58.2 ± 0.84 days for cow dung. Vermicast production was 41% of the earthworm's body weight per day for cafeteria waste, followed by 34% for banana trunk, 32% for shredded newspaper and 26% for cow dung. In the natural Malaysian environmental conditions, the ability of *E. foetida* to convert organic waste into vermicast vary with type and quality of the substrate used. Growth increment of *E. foetida* was paralled with the rate of waste conversion into vermicast, e.g. higher growth increment resulted in faster conversion of wastes into vermicast.

Keywords: Organic Waste, Vermicomposting, *Eisenia foetida,* Vermiculture

INTRODUCTION

Organic waste is a common commodity present in many ecosystems. The conversion of organic waste into useful products is essential in the recycling of organic matter to sustain soil fertility and avoid environmental pollution. Utilization of the finished product can help in improving soil biological, physical and chemical properties and therefore improve the soil environmental quality (Ismail 2005). Vermicomposting involved feeding of the epigeic earthworms with organic waste for the production of vermicast. Epigeic earthworms such as *Eisenia foetida, Eisenia andrei, Perionyx excavatus* and *Eudrilus eugenia* have been used to convert organic waste into vermicast or the worm feces that can be used as organic fertilizer and soil conditioner (Dominguez *et al.* 2000; Edwards *et al.* 1998; Bansal & Kapoor 2003; Loh *et al.* 2003; Garg *et al.* 2005; Suthar 2006; Nair *et al.* 2006; Garg *et al.* 2006a).

A wide range of the organic waste such as sewage sludge (Dominguez *et al.* 2000), crop residue (Bansal & Kapoor 2003), textile mill sludge (Kaushik & Garg 2003), agriculture, urban and industrial waste (Garg *et al.* 2005; Suthar 2006), vegetable waste (Singh *et al.* 2005), water hyacinth *Eichhornia crassipes* (Gajalakshmi *et al.* 2001), kitchen waste (Nair *et al.* 2006) and guar gum waste (Suthar 2006) have been shown to be suitable substrates for vermicomposting.

Experimental evidence on vermicomposting using animal dung such as cow dung (Kale *et al.* 1982; Reinecke *et al.* 1992; Edwards *et al.* 1998), sheep dung (Kale *et al.* 1982), poultry manure (Kale *et al.* 1982), pig solids (Edwards *et al.* 1998), horse solid (Edwards *et al.* 1998) and turkey waste (Edwards *et al.*

1998), goat and cow dung (Loh *et al.* 2003) as substrates showed efficient conversion of the waste into vermicast.

There were limited scientific studies available on the efficiency of the earthworms in converting organic waste into vermicast under natural Malaysian tropical conditions. The present study was carried out to study the ability of the temperate earthworm *E. foetida* to convert four types of organic wastes commonly found in Malaysia.

MATERIALS AND METHODS

The four types of organic wastes used in the experiments were cafeteria waste, shredded newspaper and banana trunk, collected from around Universiti Sains Malaysia (USM) while the cow dung was obtained from a farmer in Pendang, Kedah. The earthworms (*E. foetida*) were obtained from the Department of Agriculture, Perlis. The cow dung was air-dried for two weeks before treatment with the earthworms while cafeteria waste was shredded manually and used fresh. The banana trunk and newspaper were shredded using the shredder machine. The shredded newspaper was soaked in tap water for two days and strained overnight. All experiments were conducted under shade in the worm house unit School of Biological Sciences, USM. The ambient temperature and relative humidity were determined by using thermo-hygrometer Cole-Palmer 37950-00. The pH and water content of the initial raw materials, the vermicast production and growth increment were determined to relate the ability of the earthworm to consume different types of raw materials and convert them to vermicast.

Vermicast Production

The experiment was carried out in plastic containers measuring 17 × 11 × 6 cm in length, width and depth, respectively. Four different types of wastes were used as the substrates. The experiment was replicated five times, therefore there were 20 containers in total. The containers were arranged in a completely randomized order. A quantity of 300 g of organic waste each was placed in the container. Each container was treated with equal amount of clitellated earthworms weighing about 20.0 ± 0.09 g. The media were sprayed with water once every two days to field capacity. No additional substrate was added into the containers at any stage during the study period. Complete conversion of the waste into vermicast was assumed on the day when the initial raw materials have completely turned into vermicast.

Growth Study

The growth study was conducted in similar size plastic containers measuring 17 × 11 × 6 cm in length, width and depth, respectively. A quantity of 300 g substrates was placed into each container. Since there were four media, five harvest and five replications, there were altogether 4 media × 5 harvest × 5 replicates = 100 containers arranged in a completely randomized order. A quantity of equal weight (20.0 ± 0.09 g) of the clitellated earthworm *E. foetida* was inoculated into each container. The growth increment was measured every five days for 30 days. Destructive sampling was done at each harvest where earthworms were sorted by hand and weighted for weight increment.

pH and Humidity

The pH and humidity of the raw materials and vermicast were determined by adopting the methods of Black (1965).

Statistical Analysis

The data was collected and analyzed statistically by using one-way Analysis of Variance, Sigmastat version 3.5. The significance of difference between means was tested using least significant difference (LSD).

RESULTS

Figure 1 shows the temperature of the worm house determined every three days and recorded for 60 days.

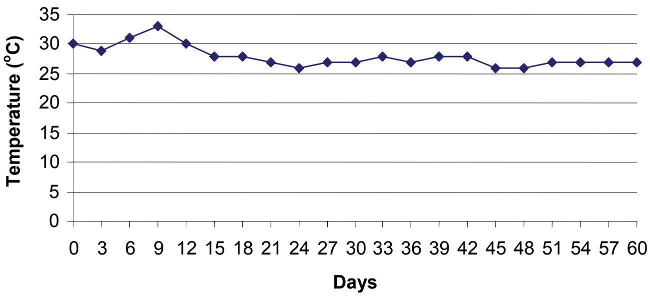

Figure 1: Temperature fluctuation measured in the worm house every three days for 60 days.

The moisture content was highest in shredded banana trunk, followed by cafeteria waste, shredded newspaper and cow dung (Table 1).

The pH of media before and after treatment with the earthworms are presented in Table 2. Initial pH before and after the earthworm treatment showed similar trend in pH_{KCl} and pH_{H_2O}. In all types of organic materials tested, the pH of the organic materials was significantly different at $P > 0.05$, before and after treatment with the earthworms. The pH_{KCl} and pH_{H_2O} of the cafeteria waste increased 86.3% and 90.2%, respectively after vermiculture treatment. The shredded banana trunk and cow dung showed a slight decrease in pH of 6.7% and 17.2% each after the raw materials were treated with the earthworms. In the shredded newspaper, only a slight decrease in pH (13% for pH_{KCl} and 6.6% for pH_{H_2O}) occurred after treatment with the earthworms.

Table 1: The moisture contents of four types of organic substrates as media for vermicomposting.

Type of media	Moisture content (%)
Shredded banana trunk	$(95.20 \pm 0.00)^d$
Cafeteria waste	$(90.97 \pm 0.21)^c$
Shredded newspaper	$(76.33 \pm 0.65)^b$
Cow dung	$(71.00 \pm 2.36)^a$

Table 2: pH_{H_2O} and pH_{KCl} before and after treatment with *E. foetida* for four types of organic wastes.

Media	pH_{KCl}	pH_{KCl}	pH_{H_2O}	pH_{H_2O}
	Treatments			
	Before	After	Before	After
Cafeteria waste	4.16 ± 0.03^a	7.75 ± 0.02^b	4.38 ± 0.02^a	8.33 ± 0.03^b
Shredded newspaper	7.86 ± 0.04^b	6.51 ± 0.05^a	8.09 ± 0.03^b	7.55 ± 0.04^a
Shredded banana trunk	7.36 ± 0.00^a	8.35 ± 0.01^b	7.51 ± 0.03^a	8.47 ± 0.03^b
Cow dung	7.40 ± 0.02^b	6.49 ± 0.01^a	7.52 ± 0.00^b	6.93 ± 0.01^a

Mean value followed by different letters is significantly different (ANOVA); LSD, $P < 0.05$.

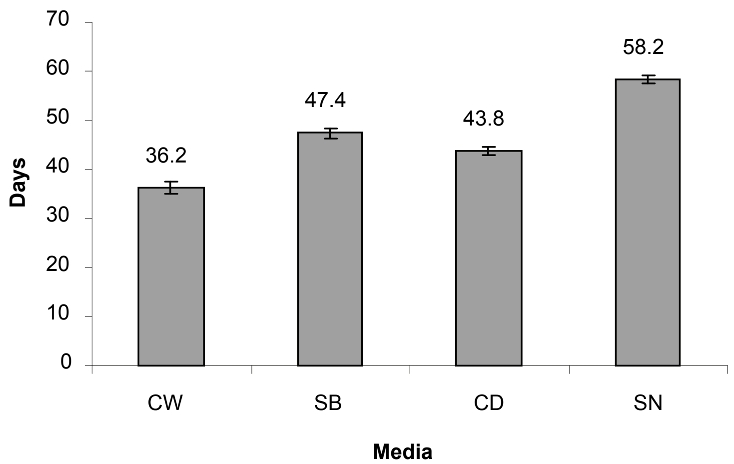

Figure 2: Vermicast production by *E. foetida* given four types of the respective organic wastes (cafeteria waste–CW; shredded banana trunk–SB; shredded newspaper–SN; cow dung–CD).

E. foetida was able to consume all four types of the organic wastes tested and convert them into vermicast. However, the rate of conversion differ with different types of wastes (Fig. 2). Cafetaria waste was found to be the fastest to completely converted to vermicast. The raw materials turned to vermicast within 36.2 ± 1.3 days for cafeteria waste, 43.8 ± 1.14 days for shredded banana trunk, 47.4 ± 0.84 days for shredded newspaper and 58.2 ± 0.84 days for cow dung. Vermicast production was 41% of the earthworm's body weight per day for cafeteria waste, followed by 34% for shredded banana trunk, 32% for shredded newspaper and 26% for cow dung.

The growth increment of *E. foetida* given different types of substrates is shown in Figure 3. The increase in weight occurred immediately after the earthworms were fed with the waste in the order, cafeteria waste > shredded banana trunk > shredded newspaper > cow dung. In general, exponential increase in weight of the earthworm in all the organic wastes tested occurred until the 5th day of vermiculture and declined after the 15th day.

DISCUSSION

The temperature of the worm house fluctuated in a range between 26°C–33°C. The temperature fluctuation was similar with Loh *et al.* (2003).

The raw substrates were converted to vermicast faster when pH_{KCl} was higher (r = 0.80) (Table 3). Therefore initial pH of the raw materials affect the rate of vermicast conversion. Regardless of the types and initial pH of the raw

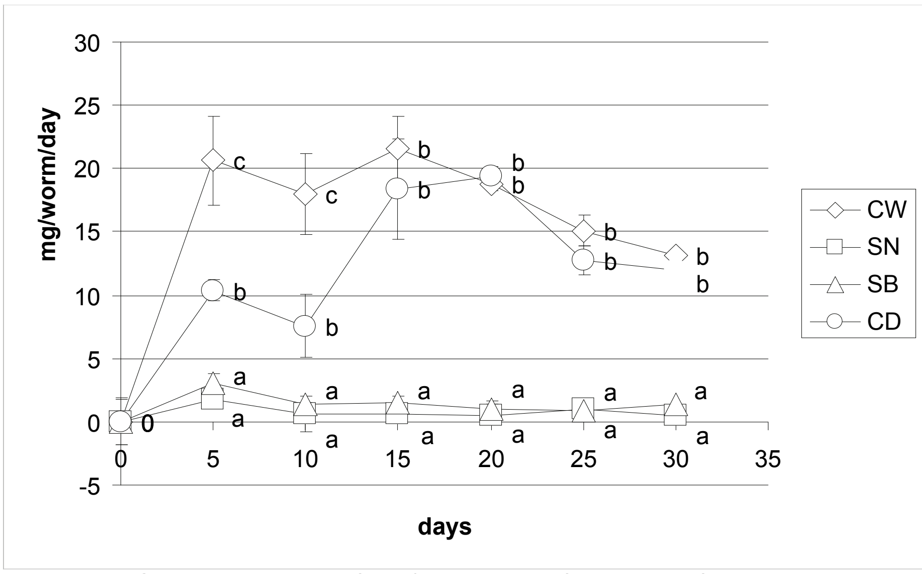

Figure 3: Growth increment of *E. foetida* given four types of the respective organic wastes (cafeteria waste–CW; shredded banana trunk–SB; shredded newspaper–SN; cow dung– CD).

Mean value followed by different letters is significantly different (ANOVA); LSD, $P > 0.05$.

Table 3: Pearson correlation coefficients (r) among the growth parameters, e.g. moisture contents of the raw substrates, pH_{H_2O} and pH_{KCl} before and after treatment with the worms, days taken to convert the raw materials into vermicast and the growth increment of the worms on the 5th day measured during vermiculture of *Eisenia foetida* using four types of the organic wastes as the raw substrates.

	Moisture	pH_{H_2O} before	pH_{H_2O} after	pH_{KCl} before	pH_{KCl} after	Vermicast conversion	Growth
Moisture	1.00	0.48	0.98	–0.48	0.97	–0.37	–0.46
pH_{H_2O} before		1.00	–0.49	0.99	–0.41	**0.82**	0.42
pH_{H_2O} after			1.00	–0.49	0.92	0.28	–0.60
pH_{KCl} before				1.00	–0.41	**0.80**	0.45
pH_{KCl} after					1.00	–0.44	–0.27
Vermicast conversion						1.00	–0.12
Growth							1.00

materials, vermicast produced by vermiculture treatment was near neutral to slightly alkaline (pH 6.49–8.35). The change in pH was the highest when the raw material was more acidic as in the case of cafeteria waste (from 4.0 to 6.5). The increase in pH of substrate was observed to be greater than the decrease value. Ndegwa *et al.* (2000) observed that pH shift occurred during vermiculture and the pH value vary with types of substrates used. Singh *et al.* (2005) observed a shift in pH from acidic in the initial substrates to alkaline and then to neutral during vermicomposting. Other workers have also reported similar observations (Gunadi & Edwards 2003; Ndegwa *et al.* 2000; Atiyeh *et al.* 2000).

The pH shift towards acidic conditions was attributed to mineralization of the organic nitrogen and phosphorus into nitrites/nitrates and orthophosphates; bioconversion of the organic material into intermediate species of organic acids (Ndegwa *et al.* 2000). The pH shift from acidic to slightly alkaline is due to the action of the calciferous gland and the buffering action of the carbonic acid in the gastrointestinal tract of the earthworm (Edwards & Lofty 1977; Morgan *et al.* 2002).

It has also been reported that different substrates could result in the production of different intermediate species and different waste showed a different behavior in pH shift. Loh *et al.* (2003) recorded the pH of vermicast as near neutral (6.72 and 6.8). Haimi and Hutha (1986) postulated that lower pH in the final vermicast might have been due to the production of CO_2 and organic acids by microbial activity during the process of bioconversion of different substrates in the feed given to earthworms.

The high water content in shredded banana trunk and cafeteria waste seemed to contribute to the faster conversion of the substrates to vermicast (r = 0.82). Other studies showed earthworms have the ability to consume a wide range of organic residues such as sewage sludge, animal wastes, crop residues and industrial refuse (Chan & Griffiths 1988; Kale *et al.* 1982; Reinecke *et al.*

1992; Mitchell 1997; Kale 1998; Garg *et al.* 2006a; Benitez *et al.* 2005; Suthar 2006).

The trend in weight increment coincide with the production of vermicast. Garg *et al.* (2006b) showed that different types of organic wastes resulted in different growth rate of the earthworm.

CONCLUSION

Different types of organic wastes showed different ability to be converted into vermicast. The earthworm *E. foetida* showed different ability to consume and convert the wastes into vermicast. At temperature fluctuation between 26°C–33°C, faster production of vermicast paralled with the high growth increment of the earthworms. The initial pH of the raw materials has a strong correlation with the ability of the waste conversion into vermicast where lower pH resulted in faster conversion. Although pH_{KCl} of the raw materials was acidic (4.16 for cafeteria waste) the pH_{KCl} of the finished products was slightly alkaline, i.e. 7.75. This observation implies that vermicast has the potential ability to be used as agent for moderating the acidity of most tropical soils.

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