Sains Malaysiana 41(11)(2012): 1445–1450

Waste Recycling: Feasibility of Saw Dust Based Spent Mushroom Substrate and Goat Manure in Vermicomposting

(Kitar Semula Sisa: Kebolehpenggunaan Habuk Kayu Sisa Bongkah Cendawan dan Tinja Kambing di dalam Pengomposan Vermi)

ADI AINURZAMAN JAMALUDIN*, NOOR ZALINA MAHMOOD & NOORLIDAH ABDULLAH

ABSTRACT

Vermicomposting for 140 days by using Lumbricus rubellus was conducted after 21 days of natural pre-composting. Five treatments in different ratio of goat manure: spent mushroom substrate were prepared as feed materials with four replicates for each treatment namely; 20:80 (TA), 40:60 (TB), 50:50 (TC), 60:40 (TD) and 80:20 (TE). As for control, each treatment without earthworm was prepared. On the basis of nutrient elements, goat manure and spent mushroom substrate can be decomposed through both methods of vermicomposting and natural composting. Findings of this study indicated that the higher usage of goat manure with longer duration resulted in the production of improved organic fertilizer.

Keywords: Composting; goat manure; nutrient element; spent mushroom substrate; vermicomposting

ABSTRAK

Pengomposan vermi untuk tempoh 140 hari dengan menggunakan Lumbricus rubellus telah dijalankan selepas tamat 21 hari pra-pengomposan lazim. Lima kombinasi rawatan antara tinja kambing: sisa bongkah cendawan pada nisbah yang berbeza disediakan dengan empat replikat bagi setiap rawatan iaitu 20:80 (TA), 40:60 (TB), 50:50 (TC), 60:40 (TD) dan 80:20 (TE). Kawalan disediakan bagi setiap kombinasi rawatan iaitu tanpa kehadiran cacing tanah. Berdasarkan kepada unsur nutrisi, tinja kambing dan sisa bongkah cendawan boleh diuraikan melalui kaedah pengomposan vermi dan pengomposan lazim. Seterusnya, penyelidikan ini telah membuktikan bahawa penggunaan tinja kambing pada nisbah yang tinggi untuk jangka masa yang panjang dapat menghasilkan baja organik yang lebih bermutu tinggi.

Kata kunci: Unsur nutrisi; pengomposan; pengomposan vermin; sisa bongkah cendawan; tinja kambing

INTRODUCTION

According to Moore and Chiu (2001), mushroom production is the largest solid substrate fermentation industry in the world. Approximately, 5 kg of spent mushroom substrates also known as spent mushroom compost can be generated from 1 kg of mushroom production (Sample et al. 2001). These spent mushroom substrates are commonly sent to landfill or openly burnt at mushroom farms and could not be reused in the next cultivation due to the possibility of contamination which will consequently affect the mushroom production.

Due to the existing demand in Malaysia, approximately 8,424 metric tons of mushrooms based on 324 gm intake of mushroom per person (Laupa 2008) generates an approximate value of 42,120 metric tons of spent mushroom substrates. This figure is expected to increase in the near future due to plausible changes in consumers' demand which could favour a healthier lifestyle and an increased demand in organic foods. Therefore, an efficient and practical method in managing this valuable organic waste is needed to utilize their optimum usage and ultimately ensuring the safe disposal of spent mushroom substrates.

Vermicomposting has been recognized as one of the potential activities in managing spent mushroom substrates (Bakar et al. 2011; Izyan et al. 2009; Sailila et al. 2010). The presence of earthworms can help to aerate, mix, grind and fragment substrates via enzymatic digestion and assist microbial decomposition of substrate in the intestine of earthworms (Hand et al. 1988; Sharma et al. 2005). Generally, vermicomposting help to reduce the pH, TOC and C/N ratio while increasing the TKN and TP values. Several researchers have reported the reduction of heavy metal contents in vermicompost produced (Shahmansouri et al. 2005). Slight increments in heavy metal contents have also been reported, nevertheless, the amount is within tolerable range since the increase is considered negligible and thus of insignificant value (Wong & Griffiths 1991).

The aims of this study were to identify the potential of goat manure and spent mushroom substrate to be decomposed through vermicomposting and to determine the optimum ratio of these two types of feed materials for the purpose of producing high quality organic fertilizer known as vermicompost.

Materials and Methods

EXPERIMENTAL DESIGNS

The experimental design was adapted from Adi and Noor (2008). Five treatments in different ratio of saw dust based spent mushroom substrate: goat manure were prepared as feed materials namely; TA (20:80), TB (40:60), TC (50:50), TD (60:40) and TE (80:20). Each treatment consisted of five replicates, labeled from 0 to 4, where 0 was earthworm free replicate acted as control. Plastic containers of the size 31 cm × 31 cm × 27 cm were used to accommodate 5 kg of feed materials. Each container had a 123 cm^2 of exposed surface covered with mosquito net to prevent hindrance from small insects and other microorganisms which could hamper the findings of this study.

In order to avoid exposure to high temperature during initial thermophilic stage, the experiment was commissioned only after three weeks of precomposting (Nair et al. 2006), where all feed materials were well mixed together with water to maintain the moisture content on wet basis in the range 60% to 70%. This was followed by vermicomposting, where 60 weighted matured *Lumbricus rubellus* earthworms were introduced in each replicate labeled from 1 to 4 after the temperature was stabilized in the range of 25°C to 30°C in week four. The moisture content was kept within the range of 60% to 70% by sprinkling the surface area with water. The same procedure was conducted for the replicate 0; where in this case the composting process occurred in the absence of any earthworms. The temperature and moisture level were checked everyday by using Testo Mini Penetration thermometer and Testo moisture meter. About 500 g of vermicompost produced at the top layer was sampled for nutrient elements analysis in week 10 and 20 of vermicomposting. In addition, as a control, the compost produced during the same time was also sampled and analysed for nutrient elements.

NUTRIENT ELEMENTS ANALYSIS

The samples were air dried before being subjected to nutrient element analysis using standard procedures. Organic C was determined by the partially-oxidation method (Walkley & Black 1934). N was estimated by Kjeldahl digestion (Bremner & Mulvaney 1982). P was detected by using colorimetric (John 1970). K, Zn and Cu were measured by ignition method using atomic absorption spectrophotometry (Loh et al. 2005). Lastly, to determine the maturity of vermicompost produced, C/N ratio values were calculated and analysed.

Results and Discussion

The mean value (%) of macronutrient elements which include N, P, K, organic carbon and C/N ratio in vermicompost and compost from five different treatments and durations are as presented in Table 1.

Increased use of goat manure which is naturally high in N, P and K content (Loh et al. 2005) resulted in elevated N content in both vermicompost and compost produced in week 20 (Table 1). These were visibly observed in TC, TD and TE with the increments are in the range of 0.38% to 0.62%. While, in other two treatments namely; TA and TB, the percentages of N content decreased by about 0.04% to 0.15% from the initial values in week 0. However, the mean value of compost sampled from TB increased from 1.17% to 1.20% in week 20. Sangwan et al. (2008) claimed, nutrient elements in final end products either in vermicompost or compost was directly influenced by the quality and quantity of organic waste given as feed materials to earthworms at the beginning stage, besides the extents of N fixed by free living bacteria (Kale et al. 1982). According to Viel et al. (1987), the loss of organic carbon in terms of CO_2 as well as water loss by evaporation during mineralization of organic matter may possibly result in a percentage increase in N content. On average, the percentage of N in vermicompost and compost is to some extent similar. Nevertheless, composting showed higher increase of N in the range of 0.25% to 0.62% compared with vermicomposting, which only stated 0.08% and 0.44% of increments in week 10 to 20. There were some reduced percentage of composting in week 0 to 10. Comparable results were obtained in a study conducted by Bansal and Kapor (2000) where nutrient content of vermicompost was not significantly higher than compost prepared without earthworms.

Similar to N, P content in vermicompost and compost was also high with higher percentage use of goat manure. This was clearly observed in TD and TE, where increases of 0.65% to 0.81% were recorded in week 20 compared with initial values in week 0 as shown in column 14 of Table 1. On the other hand, TA and TB only showed small increment as there was some reduction of P content in week 10 for both compost and vermicompost. Additionally, the presence of earthworms in vermicomposting process accelerated the P content compared with composting especially shown in week 20 when the percentage in TD and TE rose in the range of 0.80% to 0.81%, compared with 0.65% and 0.77% for composting. This was more clearly shown by TC; where the ratio of treatment was equal, the P content of vermicompost gradually increased in week 10 and 20. There was also some reduction recorded in week 10 of composting that directly lessen the value of P in week 20.

Overall, the percentage for K continuously increased in all treatments as shown in Table 1. The increment was more perceptible by means in compost compared with vermicompost. Only vermicompost produced from highest ratio of goat manure in TE gave greater percentage of K compared with compost in week 10 and week 20. Beside that, a decrease in K was also recorded in both organic fertilizers of treatments TA and TB sampled in week 10. A similar observation was documented by Sangwan et al. (2008) in vermiconversion of industrial sludge.

TABLE 1. The mean value (%) of macronutrient elements (N, P & K) in vermicompost and compost from different treatments and weeks

Treatment	Organic fertilizer	Nitrogen (N)						Phosphorous (P)						Potassium (K)					
		Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]	Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]	Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]
TA - GM:SM	*Compost*	*0.88*	*- 0.40*	*0.48*	*+0.25*	*0.73*	*-0.15*	*0.45*	*-0.22*	*0.23*	*+0.25*	*0.48*	*+0.03*	*0.28*	*-0.05*	*0.23*	*+0.23*	*0.46*	*+0.18*
(20:80)	Vermicompost	0.88	-0.33	0.55	+0.29	0.84	-0.04	0.45	-0.16	0.29	+0.19	0.48	+0.03	0.28	+0.02	0.30	+0.15	0.45	+0.17
TB - GM:SM	*Compost*	*1.17*	*-0.59*	*0.58*	*+0.62*	*1.20*	*+0.03*	*0.72*	*-0.44*	*0.28*	*+0.39*	*0.67*	*-0.05*	*0.35*	*-0.06*	*0.29*	*+0.40*	*0.69*	*+0.34*
(40:60)	Vermicompost	1.17	-0.41	0.76	+0.34	1.10	-0.07	0.72	-0.31	0.41	+0.48	0.89	+0.17	0.35	-0.04	0.31	+0.28	0.59	+0.24
TC - GM:SM	*Compost*	*1.17*	*-0.16*	*1.01*	*+0.54*	*1.55*	*+0.38*	*0.69*	*-0.22*	*0.47*	*+0.48*	*0.95*	*+0.26*	*0.33*	*+0.02*	*0.35*	*+0.45*	*0.80*	*+0.47*
(50:50)	Vermicompost	1.17	+0.14	1.31	+0.24	1.55	+0.38	0.69	+0.11	0.80	+0.37	1.17	+0.48	0.33	+0.07	0.40	+0.28	0.68	+0.35
TD - GM:SM	*Compost*	*1.31*	*-0.04*	*1.27*	*+0.59*	*1.86*	*+0.55*	*0.81*	*0*	*0.81*	*+0.77*	*1.58*	*+0.77*	*0.35*	*+0.13*	*0.48*	*+0.34*	*0.82*	*+0.47*
(60:40)	Vermicompost	1.31	+0.18	1.49	+0.44	1.93	+0.62	0.81	+0.35	1.16	0	1.61	+0.80	0.35	+0.16	0.51	+0.25	0.76	+0.41
TE - GM:SM	*Compost*	*1.63*	*+0.23*	*1.86*	*+0.37*	*2.23*	*+0.60*	*1.12*	*+0.39*	*1.51*	*+0.26*	*1.77*	*+0.65*	*0.41*	*+0.21*	*0.62*	*+0.26*	*0.88*	*+0.47*
(80:20)	Vermicompost	1.63	+0.31	1.94	0.08	2.02	+0.39	1.12	+0.24	1.36	+0.57	1.93	+0.81	0.41	+0.26	0.67	+0.25	0.92	+0.51

Note :
[a] : The different of mean value (%) between Week 10 and Week 0
[b] : The different of mean value (%) between Week 20 and Week 10
[c] : The different of mean value (%) between Week 20 and Week 0

Referring to Table 2, the value of organic carbon for vermicompost from all treatments decreased at the end of vermicomposting compared with the initial feed materials. The presence of earthworms accelerated the loss of organic carbon where the percentages of loss were higher in vermicomposting compared with composting. According to Suthar (2006), earthworms facilitate the reduction of organic carbon from substrate through the process of microbial respiration. This finding is analogous with reports made by Sangwan et al. (2008), where total organic carbon loss was higher in feed materials containing vermicomposters compared with the ones without. Nevertheless, there were also some percentage increases in week 10 for TA, TB and TC which finally decreased in week 20, as shown in column 4 and 6 of Table 2. In order to determine the quality of compost and vermicompost, C/N ratio is considered as a maturity parameter whereby a C/N value below 20 is indicative of acceptable maturity while a ratio of 15 or lower being preferable (Morais & Queda 2003). As a consequence of high loss of carbon and percentage increase of N, vermicompost and compost produced from TC, TD and TE were preferred as the C/N ratio was found to be in the range of 6.39 and 17.99 (Table 2). Therefore these organic fertilizers are more appropriate to be used and have a better quality compared with the other treatments; TA and TB where the C/N ratio are in the range of 20.59 to 41.10.

Furthermore, by making comparison between vermicompost and compost produced, vermicompost showed a better result (in the range of 6.39 to 31.97) compared with composting (7.74 to 41.10) in all treatments. Referring to TC where the ratio of feed materials is equal, 50:50, the quality of vermicompost is better compared with compost, as shown from the C/N ratio.

Overall, the longer duration either for vermicomposting or composting indirectly enhanced the quality of final end product as a result of the loss of carbon and increased N content (Bansal & Kapor 2000; Kaviraj & Sharma 2003; Sangwan et al. 2008).

The mean value (%) of heavy metal (Zn & Cu) in vermicompost and compost from five different treatments and durations are as presented in Table 3.

As a result of bio accumulation, Zn contents increased in vermicompost and compost produced in week 20 especially with the high use of goat manure in TD (0.039% & 0.047%) and TE (0.045 & 0.048%) as shown in Table 2. TD showed two times of increments compared with initial value in week 0. Whilst, TA and TB showed some reduction in Zn for week 10 in the range of 0.004-0.015% and slightly increased in week 20 in the range of 0.002-0.023% in final products; the vermicompost and compost. These observations were in agreement with previous findings by Wong and Griffiths (1991), whereby it has been reported that the accumulation of Zn in the casts was multiplied at an incredible rate compared in the original pig waste through vermicomposting. In contrast, only composting cause the reduction of Zn content in TC for both weeks and in TD for week 10.

With the presence of spent mushroom substrate; either in higher or equal ratio with goat manure, the values of Cu were reduced in week 10 for TA, TB and TC as shown in Table 3. This happened when the degradation processes of feed materials were not stabilized yet, which is expected in week 0. Various ratio and sources of feed materials was hypothesized to be the reason of unstable degradation process in the earlier stage of both composting and vermicomposting. The value of macronutrient elements (N, P & K), organic carbon, C/N ration and heavy metal (Zn & Cu) in saw dust based spent mushroom substrate and goat manure are presented in Table 4.

Referring to Sailila et al. (2010), the value of Cu should be higher with bigger ratio of goat manure as feed

TABLE 2. The mean value (%) of organic carbon and C/N ratio in vermicompost and compost from different treatments and weeks

Treatment	Organic fertilizer	Organic carbon						C/N ratio					
		Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]	Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]
TA - GM:SM	*Compost*	*32.10*	*+4.30*	*36.40*	*-6.40*	*30.00*	*-2.10*	*36.48*	*+39.35*	*75.83*	*-34.73*	*41.10*	*+4.62*
(20:80)	Vermicompost	32.10	+2.05	34.15	-7.25	26.90	-5.20	36.48	+26.23	62.71	-30.74	31.97	-4.51
TB - GM:SM	*Compost*	*29.80*	*+5.53*	*35.33*	*-7.78*	*27.55*	*-2.25*	*25.47*	*+35.44*	*60.91*	*-37.91*	*23.00*	*-2.47*
(40:60)	Vermicompost	29.80	+2.60	32.40	-9.78	22.62	-7.18	25.47	+18.82	44.29	-23.70	20.59	-4.88
TC - GM:SM	*Compost*	*28.20*	*+4.26*	*32.46*	*-4.58*	*27.88*	*-0.32*	*24.10*	*+8.04*	*32.14*	*-14.15*	*17.99*	*-6.11*
(50:50)	Vermicompost	28.20	+2.16	30.36	-10.15	20.21	-7.99	24.10	-0.84	23.26	-9.64	13.62	-10.48
TD - GM:SM	*Compost*	*30.00*	*-1.32*	*28.68*	*-13.09*	*15.59*	*-14.41*	*22.90*	*-0.32*	*22.58*	*-14.20*	*8.38*	*-14.52*
(60:40)	Vermicompost	30.00	-0.60	29.40	-10.66	18.74	-11.26	22.90	-3.08	19.82	-10.08	9.74	-13.16
TE - GM:SM	*Compost*	*26.70*	*-2.28*	*24.42*	*-7.16*	*17.26*	*-9.44*	*16.38*	*-3.25*	*13.13*	*-5.39*	*7.74*	*-8.64*
(80:20)	Vermicompost	26.70	-3.43	23.27	-10.38	12.89	-13.81	16.38	-4.38	12.00	-5.61	6.39	-9.99

Note :
[a] : The different of mean value (%) between week 10 and week 0
[b] : The different of mean value (%) between week 20 and week 10
[c] : The different of mean value (%) between week 20 and week 0

TABLE 3. The mean value (%) of heavy metal (Zn & Cu) in vermicompost and compost from different treatments and weeks

Treatment	Organic fertilizer	Copper (Cu)						Zinc (Zn)					
		Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]	Week 0	+/- [a]	Week 10	+/- [b]	Week 20	Total +/- [c]
TA - GM:SM	*Compost*	*0.0010*	*-0.0005*	*0.0005*	*+0.0008*	*0.0013*	*+0.0003*	*0.012*	*-0.005*	*0.007*	*+0.002*	*0.009*	*-0.003*
(20:80)	Vermicompost	0.0010	-0.0003	0.0007	+0.0010	0.0017	+0.0007	0.012	-0.004	0.008	+0.002	0.010	-0.002
TB - GM:SM	*Compost*	*0.0020*	*-0.0011*	*0.0009*	*+0.0015*	*0.0024*	*+0.0004*	*0.022*	*-0.015*	*0.007*	*-0.005*	*0.002*	*-0.020*
(40:60)	Vermicompost	0.0020	-0.0007	0.0013	+0.0015	0.0028	+0.0008	0.022	-0.011	0.011	+0.009	0.020	-0.002
TC - GM:SM	*Compost*	*0.0038*	*-0.0025*	*0.0013*	*+0.0026*	*0.0039*	*+0.0001*	*0.022*	*-0.010*	*0.012*	*+0.009*	*0.021*	*-0.001*
(50:50)	Vermicompost	0.0038	-0.0013	0.0025	+0.0006	0.0031	-0.0007	0.022	+0.003	0.025	+0.005	0.030	+0.008
TD - GM:SM	*Compost*	*0.0020*	*+0.0004*	*0.0024*	*+0.0018*	*0.0042*	*+0.0022*	*0.023*	*-0.002*	*0.021*	*+0.018*	*0.039*	*+0.016*
(60:40)	Vermicompost	0.0020	+0.0011	0.0031	+0.0008	0.0039	+0.0019	0.023	+0.008	0.031	+0.016	0.047	+0.024
TE - GM:SM	*Compost*	*0.0040*	*+0.0004*	*0.0044*	*-0.0002*	*0.0042*	*+0.0002*	*0.036*	*+0.009*	*0.045*	*0*	*0.045*	*+0.009*
(80:20)	Vermicompost	0.0040	+0.0006	0.0046	-0.0001	0.0045	+0.0005	0.036	+0.008	0.044	+0.004	0.048	+0.012

Note :
[a] : The different of mean value (%) between week 10 and week 0
[b] : The different of mean value (%) between week 20 and week 10
[c] : The different of mean value (%) between week 20 and week 0

TABLE 4. The value of macronutrient elements (N, P & K), organic carbon, C/N ratio and heavy metal (Zn & Cu) in saw dust based spent mushroom substrate and goat manure (unit is ppm)

Nutrient element	Feed materials	
	Saw dust based spent mushroom substrate	Goat manure
Nitrogen	5.795	21.248
Phosphorous	2.695	15.562
Potassium	2.537	5.245
Organic Carbon	344.030	180.032
C/N ratio	59.367	8.473
Zinc	38.20	172.70
Copper	2.60	50.40

materials in week 0 when the value of Cu in goat manure was 25 times higher than saw dust based spent mushroom substrate as shown in Table 4. By making comparison of both compost and vermicompost from all five treatments in Table 3, the level of Cu continuously increase against duration where the high use of goat manure, resulted in high Cu in week 20.

Rather than bio-accumulation factor, the mineralization process which was considered a result of microbes' activities may be the reason for the increase in heavy metal concentrations as extensively explained by Bakar et al. (2011). The concentration of heavy metals in week 20 was higher than the initial concentration; especially in vermicompost, due to the excretion of worms casts coupled with heavy metals, which primarily reduced the ability of the heavy metal to accumulate in earthworm tissue. Nevertheless, the concentration level of both heavy metals; Zn and Cu, in compost and vermicompost produced in week 20 complied with Malaysia Environment Quality Act 1974. Under this act, the parameter limits for Zn is 2.0 mg/L for both Standard A and B, while for Cu is 0.20 mg/L for Standard A and 1.0 mg/L for Standard B.

CONCLUSION

Based on the nutrient element analysis, goat manure and spent mushroom can be utilized by decomposing through methods of vermicomposting and composting.

This study highlighted the feasibility of goat manure in producing better organic fertilizer despite the slight increase in heavy metal content due to bio accumulation factor and mineralization process. Fortunately, such increase is relatively small in comparison with other macronutrient elements, NPK and thus may be considered inconsequential. Higher ratio of goat manure compared to spent mushroom substrate; 60:40 and 80:20, as feed materials are able to produce higher quality of organic fertilizer with a greater mean value of N, P, K and lower C/N ratio.

ACKNOWLEDGEMENT

The authors would like to thank MIF Sdn. Bhd. for their consultation on vermicomposting, the UM experimental farm and UM Fungal Biotechnology Lab for their full support on supplying goat manure and spent mushroom substrates to be used as feed materials in this study. This work was financially supported by the IPPP, UM under PJP Vot (FS302 2008A) managed by UPDiT.

REFERENCES

Adi, A.J. & Noor, Z.M. 2008. Waste recycling: Utilization of coffee grounds and kitchen waste in vermicomposting. *Bioresource Technology* 100: 1027-1030.

Bakar, A.A., Mahmood, N.Z., Teixeira da Silva, J.A., Abdullah, N. & Jamaludin, A.A. 2011. Vermicomposting of sewage sludge by Lumbricus rubellus using spent mushroom compost as feed material: Effect on concentration of heavy metals. *Biotechnology and Bioprocess Engineering* 16: 1036-1043.

Bansal, S. & Kapoor, K.K. 2000. Vermicomposting of crop residues and cattle dung with *Eseniafoetida*. *Bioresource Technology* 73: 95-98.

Bremner, J.M. & Mulvaney, R.G. 1982. Nitrogen total. In: *Methods of Soil Analysis*, edited by Page, A.L., Miller, R.H. & Keeney, D.R. Madison: American Society of Agronomy.

Hand, P., Hayes, W.A., Satchell, J.E., Frankland, J.C., Edwards, C.A. & Neuhauser, E.F. 1988. The vermicomposting of cow slurry. Earthworm. In *Waste Environment Management* pp. 49-63.

Izyan, N.N., Jamaludin, A.A. & Mahmood, N.Z. 2009. Potential of spent mushroom substrate in vermicomposting. *Dynamic Soil, Dynamic Plant* 3 (Special Issues 2): 87-90.

John, M.K. 1970. Colorimetric determination of phosphorous in soil and plant material with ascorbic acid. *Soil Science* 109: 214-220.

Kale, R.D., Bano, K. & Krishnamurthy, R.V. 1982. Potential of *Perionyxexcavatus* for utilizing organic wastes. *Pedobiologia* 23: 419-425.

Kaviraj & Sharma, S. 2003. Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. *Bioresource Technology* 90: 169-173.

Laupa, Junus. 2008. Bekas doktor tanam cendawan shiitake. *Utusan Malaysia*. Retreived from from http://www.utusan.com.my/utusan/info.asp?y= 2008&dt=1128&pub= Utusan_Malaysia&sec=Agrobiz&pg=ag_01.htm.

Loh, T.C., Lee, Y.C., Liang, J.B. & Tan, D. 2005. Vermicomposting of cattle and goats manures by *Eisenia foetida* and their growth and reproduction performance. *Bioresource Technology* 96: 111-114.

Moore, D. & Chiu, S.W. 2001. Filamentous fungi as food. In *Exploitation of Fimamentous Fungi*, edited by Pointing S.B., Hyde, D. Hong Kong: Fungal Diversity Press.

Morais, F.M.C. & Queda, C.A.C. 2003. Study of storage influence on evolution of stability and maturity properties of MSW compost. In: *Proceedings of the Fourth International Conference of ORBIT Association on Biological Processing of Organics: Advances for a Sustainable Society* Part II, Perth, Australia.

Nair, J., Sekiozoic, V. & Anda, M. 2006. Effect of pre-composting on vermicomposting of kitchen waste. *Bioresource Technology* 97: 2091-2095.

Sailila, N., Bakar, A.A., Mahmood, N.Z., Teixeira da Silva, J.A., Abdullah, N. & Jamaludin, A.A. 2010. Nutrient elements of different agricultural wastes from vermicomposting activity. *Dynamic Soil, Dynamic Plant* 4 (Special Issues 1): 155-158.

Sample, K.T., Reid, B.J. & Fermor, T.R. 2001. Impact of composting strategies of the treatment of soils contaminated with organic pollutants: A review. *Environmental Pollution* 112: 269-283.

Sangwan, P., Kaushik, C.P. & Garg, V.K. 2008. Vermiconversion of industrial sludge for recycling the nutrients. *Bioresource Technology* 99: 8699-8704.

Shahmansouri, M.R., Pourmoghadas, H., Parvaresh, A.R. & Alidadi, H. 2005. Heavy metal bioaccumulation by Iranian and Australian earthworms (*Eiseniafetida*) in sewage sludge vermicomposting. *Iranian J. Env. Health Sci. Eng*. 2(1): 28-32.

Sharma, S., Pradhan, K., Satya, S. & Vasudevan, P. 2005. Potentially of earthworms for waste management and in other uses – A review. *The Journal of American Science* 1(1): 4-16.

Suthar, S. 2006. Potential utilization of guar gum industrial waste in vermicompost production. *Bioresource Technology* 97: 2474-2477.

Viel, M., Sayag, D. & Andre, L. 1987. Optimation of agricultural, industrial waste management through in-vessel composting. In: *Compost, Production, Quality and Use*. Ed. deBertoldi, M. 230-237. Essex: Elsevier Appl. Science.

Walkley, A. & Black, I.A. 1934. Estimation of organic carbon by the chromic acid titration method. *Soil Science* 37: 29-31.

Wong, S.H. & Griffiths, D.A. 1991. Vermicomposting in the management of pig-waste in Hong Kong. *World Journal of Microbiology and Biotechnology* 7: 593-595.

Institute of Biological Sciences
Faculty of Science, University of Malaya
50603 Kuala Lumpur
Malaysia

*Corresponding author; email: adiainurzaman@um.edu.my

Received: 9 August 2010
Accepted: 2 July 2012