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Comparison of Bioproduct Quality from Vermiconversion of Spent *Pleurotus sajor-caju* Compost and Commercial Livestock Excreta

(Perbandingan Kualiti Bio Produk daripada Pengolahan Vermi untuk Kompos *Pleurotus sajor-caju* dan Sisa Najis Ternakan Komersial)

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ABSTRACT

Vermiconversion study was conducted to compare the use of commercial livestock excreta i.e. cow dung (CD) and goat manure (GM) in the vermiconversion of spent mushroom compost (SMC) utilising red worms i.e. Lumbricus rubellus *to obtain good quality compost with high nutrient content. This study was performed for 70 days after 21 days of pre-composting at different ratios of livestock excreta and SMC. The highest multiplication and growth of earthworms in number and biomass was recorded in T_E with increment of +296.57 and +484.20%, respectively. Moreover, paired samples t-test indicated a significant difference (p<0.05) in earthworms' number and biomass. The results for non-mixed substrate showed, CD (T_A) bioproduct obtained, contained the highest concentration in exchangeable K (1.98%). However, GM (T_D) vermicompost recorded the highest content of total N (1.66%) and available P (0.64%). In conclusion, 50% of GM is recommended in vermiculture as well as producing nutrient enriched bioproduct compared with CD with SMC as bulking agent. Furthermore, heavy metal i.e. Cd, Cr, Pb, Cu and Zn content in bioproduct produced from all treatments were lower compared to compost limits set by USA, European countries and Malaysian Recommended Site Screening Levels for Contaminated Land (SSLs).*

Keywords: Earthworms; livestock waste; nutrient element; spent mushroom substrate; vermitechnology

ABSTRAK

Penyelidikan pengolahan vermi dilakukan untuk membandingkan beza kegunaan antara sisa najis ternakan komersial iaitu najis lembu (CD) dan najis kambing (GM) dalam pengolahan vermi kompos cendawan terpakai (SMC) dengan menggunakan cacing merah iaitu Lumbricus rubellus *untuk menghasilkan baja kompos vermi yang berkualiti dengan kandungan nutrien yang tinggi. Kajian ini dijalankan selama 70 hari selepas 21 hari pra-pengomposan dalam pelbagai nisbah sisa najis ternakan dan SMC. Peningkatan tertinggi bilangan dan biojisim cacing tanah direkodkan dalam T_E dengan peningkatan +296.57 dan +484.20%. Tambahan pula, ujian-t sampel berpasangan menunjukkan perbezaan yang signifikan (p<0.05) dalam bilangan dan biojisim cacing tanah. Keputusan untuk substrat tidak bercampur menunjukkan CD (T_A) menghasilkan bio produk yang mengandungi kandungan K yang boleh bertukar tertinggi (1.98%). Manakala kompos vermi GM (T_D) mencatatkan nilai tertinggi untuk keseluruhan N (1.66%) dan sedia ada P (0.64%). Kesimpulannya, 50% GM adalah digalakkan untuk dijadikan sebagai agen pukal dalam kultur vermi berserta penghasilan bio produk yang kaya dengan nutrien berbanding CD dan SMC. Selain itu, kandungan logam berat iaitu Cd, Cr, Pb, Cu dan Zn di dalam bio produk terhasil daripada semua perlakuan adalah lebih rendah berbanding had kompos yang ditetapkan oleh USA, negara-negara Eropah dan Cadangan Aras Pemerhatian Tapak untuk Tanah Tercemar Malaysia (SSLs).*

Kata kunci: Cacing tanah; elemen nutrien; sisa ternakan; substrat cendawan terpakai; teknologi vermi

INTRODUCTION

Incessant disposal of organic waste in Malaysia landfills today is a quandary to organic waste management. The organic waste can be recycled into value added product and it is widely known that composting is an efficient method to unravel this problem. Conversely in a more ingenious way, vermiconversion or vermicomposting is acceptably better than the accustomed method of composting whereby the nutritional content of vermicompost is frequently higher. Apart from that, vermiconversion is considered as green technology, an environmentally sound method to practice sustainable development in livestock management and agro-industrial sector.

In 2010, Malaysian government has put in initiatives in Asia-Pacific Economic Cooperation (APEC) by encouraging green technology installation specifically on the production of organic fertilisers from both crop and animal waste as a new source of income to local farmers while maintaining sustainable production system. Consequently, Malaysia remains committed to advance the agriculture sector by increasing food production and generating income for farmers. In response to that, biological treatment approach, i.e. vermitechnology is a competent tool to cope with the waste management as response to the initiatives set by the Malaysian government.

Vermicomposting is an efficient eco-biotechnology tool utilising earthworms, which is viable in converting organic waste into value-added product i.e. vermicompost as final product. Technically the vermiconversion process involves physical/mechanical (mixing and grinding) and biochemical activities (microbial decomposition in the earthworms' intestine) (Loh et al. 2005) producing vermicompost, which is precisely earthworm cast. Vermicompost is a product from aerobic, bioxidation and stabilization by non-thermophilic process of organic waste decomposition that depends on earthworms to fragments, mix and promotes microbial activity (Gunadi et al. 2002).

It is well documented in many studies on vermiconversion of organic waste with livestock excreta but mostly the species employed was *Eisenia foetida* (Bansal & Kapoor 2000; Loh et al. 2005; Yadav & Garg 2010). However, limited data more reported for red worm i.e. *Lumbricus rubellus* in vermiconversion study, though its capability is tested in this study. The selection of sawdust-based spent mushroom compost (SMC) as bulking agent is due to its abundance generated by the mushroom industry in Malaysia which is more than 4000 tonnes per month (Azizi et al. 2013, 2012, 2011). In addition, SMC is currently discarded by means of landfill or frequent open burning after a period of six months of mushroom cultivation and this is considered as waste or non-value substrate.

Hence, the objectives of this study was to focus on the comparion of treatment between cow dung (CD) and goat manure (GM) that is amended to SMC that will result in high content of nutrient elements, multiplication and growth of *L. rubellus*.

MATERIALS AND METHODS

SPENT MUSHROOM COMPOST, LIVESTOCK EXCRETA AND EARTHWORMS PREPARATION

Spent mushroom compost (SMC) was obtained from a mushroom farm at Tanjung Sepat and Jenderam Hulu, Selangor. The SMC discarded after six months of cultivation consists of sawdust and *P. sajor-caju* mycelia in plastic bags of ~600 g each. Cow dung (CD) procured from a livestock farm in Putrajaya and goat manure (GM) obtained from Institute of Biological Sciences (ISB) Mini Farm, University of Malaya. Earthworms (*L. rubellus*) were picked from a stock culture in Earthworms Reservoir, ISB using variety of organic waste as feedstock.

VERMICONVERSION PROCESS

The experiments were performed in microcosms with size of 360 × 280 × 200 mm (length × width × height) and 0.025 m^2 an artificial designed opening on lid covered with net for aerobic ventilation, microclimatic condition and to prevent any interruption of pest (Azizi et. al. 2013, 2012, 2011). Six types of treatment prepared on different ratios, with five replicates each weights 3.5 kg (dry weight) as shown in Table 1. All of the treatments were pre-composted for 21 days prior to *L. rubellus* introduction in the treatments. During the pre-composting process, temperature and moisture content were monitored to ensure that the optimum pH of 7±1 and temperature of 27±1°C were achieved and stabilised by manual turning. Vermiconversion utilised 35 clitelated *L. rubellus* (9.08±0.14 g) were introduced into each treatment after pre-composting period. During the vermiconversion process, the moisture content was maintained at relative humidity, 60-80% by periodic sprinkling of an adequate quantity of distilled water. The distilled water was used to eliminate any foreign elements particularly heavy metal introduced to the earthworms and feedstock. All the microcosms were kept in the Earthworms Reservoir under identical ambient conditions with room temperature 25ºC±3ºC. On day 0 and 70 of vermiconversion period, homogenised compost (free from earthworms, hatchlings and cocoons) and positioned at top layer of vermicompost produced (only day 70) in the microcosms was sampled (100 g, 70% moisture content) in plastics vials (airtight) separately taken from each treatment for laboratory analysis before all of the earthworms were removed. The upper layer was sampled because it is the first layer being converted into vermicompost. On weekly basis, the *L. rubellus* biomass and multiplication were measured and a replenishment amount of the SMC was supplemented based on feeding rate 1.25 kg-feed/kg-worm/day in each replicate (Ndegwa et al. 1999). Controls i.e. 100% of CD and GM were to

TABLE 1. The composition of CD, GM and SMC in each treatment

Treatment	Ratio (kg)[b]	Description
[a]T_A	- (3.5)	CD
T_B	1 : 1 (1.75 : 1.75)	1 part CD : 1 part SMC
T_C	1 : 2 (1.17 : 2.33)	1 part CD : 2 parts SMC
[a]T_D	- (3.5)	GM
T_E	1 : 1 (1.75 : 1.75)	1 part GM : 1 part SMC
T_F	1 : 2 (1.17 : 2.33)	1 part GM : 2 parts SMC

[a]Control treatment- no mixture of the feedstock
[b]Figure in parentheses is dry weight of the feedstock

differentiate ability of the treatment without amendment in vermiconversion compared with mix substrates treatment. Consequent to 70 days, the earthworms were removed manually by hand sorting and total number and biomass of earthworms were determined. The values were determined based on biomass of juvenile (no clitella and red in colour) and clitelated earthworms and those at infant stage were excluded- no correction for gut content.

STATISTICAL ANALYSIS

One-way analysis of variance (ANOVA) was done to analyse the significant difference between treatments on earthworm's number, biomass and heavy metals during vermiconversion at 0.05% level of significance. Paired samples t-test was used to determine any significant difference between the numbers and biomass of earthworms (*L. rubellus*) in each treatment. This statistical analysis was carried out using SPSS 16.0 (Standard version) computer software package.

LABORATORY ANALYSIS

The production of organic C in vermicompost was determined by the partial-oxidation method (Walkley & Black 1934). N was estimated by Kjeldahl digestion with concentrated H_2SO_4 (1: 20, w/v) followed by distillation (Bremner & Mulvaney 1982). P was detected by a colorimetric method using ammonium molybdate in HCl (John 1970). K and heavy metals *viz*., Cr, Cu, Cd, Pb and Zn was measured by the ignition method using a Perkin Elmer model 3110 double beam atomic absorption spectrophotometer after digestion of the sample with concentrated HNO_3 : concentrated $HClO_4$ (4 : 1, v/v) (Loh et al. 2005). The stability of the vermicompost was calculated from the C : N ratio.

RESULTS

The earthworms' multiplication and growth in number and biomass were demonstrated in Table 2. All treatments showed increment on number and biomass of earthworms except T_D. For treatment of 100% livestock wastes i.e. T_A (CD) and T_D (GM), T_A showed increase in both number and biomass of earthworms compared with T_D presented positive result in earthworms' biomass but not for number of earthworms. From all substrate mixtures of livestock excreta and SMC with ratio 50:50 (T_B) and 25:75 (T_C) for CD:SMC and the same ratio for GM:SMC in T_E and T_F, respectively, resulted in an increment after 70 days of experiment, T_E was the highest increment in earthworms number and biomass with mean percentage, +296.57% (~ 3-fold) and +484.20% (~ 5-fold), respectively. One-way ANOVA analysed that all treatments were significant for earthworms' number (F = 75.516, p<0.05, df = 5) and earthworms' biomass (F = 53.507, p<0.05, df = 5). Paired samples t-test indicated that all treatments are significant in numbers and biomass of earthworms on day 0 and day 70 of vermiconversion.

Nutrient elements content in vermicompost are tabulated in Table 3. T_D showed the highest percentage of total N content, 1.66% whereas T_C showed the lowest percentage of total N content, 1.16%. As for available P content similar result obtained as total N, T_D showed the highest percentage with 0.64% but the lowest percentage was T_B, 0.39%. On the other hand, 100% of CD (T_A) showed the highest percentage in exchangeable K content with 1.98% and T_F presented the lowest of exchangeable K content, 1.17%. T_B showed the highest percentage of organic C content, 33.25% and the lowest percentage is T_E with percentage of 29.45%. The lowest C:N ratio recorded was in T_D, 17.83 and the high proportion of organic C content to the total N was in T_B.

Heavy metal content in vermicompost presented in Table 4 showed that the lowest content of heavy metal was Cr (0.0005 mg kg^{-1}) in all treatments and the highest content was Zn (105.30 mg kg^{-1}) in T_D. Cd and Pb resulted in similar content of 0.01 and 0.002 mg kg^{-1}, respectively, in all treatments. However, Cu and Zn resulted in different amounts of content in all treatments within range, 0.001 - 6.57 and 39.24 - 105.30 mg kg^{-1}, respectively.

DISCUSSION

Increment of earthworms' multiplication and growth in livestock excreta alone was based on the nature of excreta. Shahack-Gross (2010) reported that herbivore dung is composed of macroscopic and microscopic organic materials (vegetal, bacterial and animal) of inorganic microscopic minerals (dung spherulites, geogenic particles, diatoms, sponge spicules, calcium-oxalates and opal phytoliths) and is enriched in P, ^{15}N and lignin relative to the ingested components. Thus, these enriched component constituents favour earthworms in its diet and reflected its palatability. Moreover, this is related to the duration of nutrients, which have been stabilised in the long digestive process of the ruminant.

In T_E the highest multiplication and growth of earthworm might be due to N rich content in GM but it was undesirable to be composted alone due to its low C:N ratio and free air space (FAS) values (Kulcu et al. 2008). Thus, the use of SMC in 1:1 is an optimum ratio to GM which provide source of C from composted sawdust and its physical characteristic i.e. high in fibrous material content, which is capable of improving soil physical properties and biological activity. Apart from that, mycelia promotes vermiconversion process to further degrade complex carbon structure in the mixture. T_A (100% of CD) that resulted in the highest content in exchangeable K where T_D (100% of GM) recorded the highest content in total N and available P. According to Plaza et al. (2007) the increase in N content in vermicompost is due to mineralization of C-rich materials and possible due to N-fixing bacteria. Moreover the earthworms itself played a role in contributing to the N content as derived from mucus, nitrogenous excretory substances, growing

TABLE 2. Earthworms number and biomass according to week

Week	[a]T_A		T_B		T_C	
	Number	Biomass (g)	Number	Biomass (g)	Number	Biomass (g)
W0	35.00 ± 0.00a	9.08 ± 0.14c	35.00 ± 0.00a	9.08 ± 0.14c	35.00 ± 0.00a	9.08 ± 0.14c
W1	35.00 ± 0.00b	14.30 ± 1.32a	35.00 ± 0.00b	13.89 ± 0.89a	35.00 ± 0.00b	10.88 ± 0.42ab
W2	36.00 ± 0.32c	15.61 ± 1.28d	35.60 ± 0.40e	16.13 ± 0.36f	35.60 ± 0.40e	14.43 ± 1.07c
W3	39.80 ± 0.66ad	16.93 ± 1.27f	37.20 ± 0.80a	18.16 ± 0.49d	37.80 ± 1.16c	17.96 ± 2.07e
W4	40.00 ± 0.71bd	17.20 ± 1.15a	37.80 ± 0.80e	17.75 ± 0.19f	38.00 ± 1.10d	18.62 ± 1.90c
W5	40.80 ± 2.99e	17.36 ± 1.02c	41.20 ± 0.86f	18.76 ± 0.27c	40.20 ± 0.66f	19.34 ± 1.84d
W6	41.60 ± 2.84c	18.43 ± 1.06a	42.20 ± 0.92b	19.35 ± 0.55a	41.00 ± 0.71bd	19.98 ± 1.86f
W7	42.60 ± 2.62d	19.04 ± 0.93a	44.00 ± 0.84c	20.08 ± 0.58a	46.20 ± 0.92bf	21.64 ± 1.55f
W8	43.40 ± 2.71f	19.43 ± 1.02af	47.00 ± 0.84e	21.69 ± 0.65c	50.80 ± 0.58ce	23.66 ± 1.26e
W9	44.20 ± 2.42bd	20.12 ± 1.16bf	52.00 ± 0.71ad	23.24 ± 0.70de	58.20 ± 1.91de	25.79 ± 1.33cd
W10	44.80 ± 2.63ac	20.35 ± 1.11de	52.20 ± 1.02af	23.76 ± 0.64bd	60.80 ± 3.12df	26.95 ± 1.56bc
Week	T_D		T_E		T_F	
	Number	Biomass (g)	Number	Biomass (g)	Number	Biomass (g)
W0	35.00 ± 0.00a	9.08 ± 0.14c	35.00 ± 0.00a	9.08 ± 0.14c	35.00 ± 0.00a	9.08 ± 0.14c
W1	35.00 ± 0.00b	11.13 ± 0.80d	35.00 ± 0.00b	13.46 ± 0.68a	35.00 ± 0.00b	10.78 ± 0.29e
W2	35.20 ± 0.20f	12.20 ± 0.88af	36.00 ± 0.45b	17.41 ± 0.88bf	35.60 ± 0.40e	14.25 ± 0.27f
W3	36.00 ± 0.63e	13.22 ± 1.05bd	38.00 ± 0.84c	21.37 ± 1.45cd	37.40 ± 0.81b	17.73 ± 0.37a
W4	36.00 ± 0.63cd	13.63 ± 1.03ac	38.60 ± 0.75d	23.43 ± 1.11ae	37.60 ± 0.81f	19.10 ± 0.21b
W5	36.20 ± 0.58bf	13.98 ± 1.33de	58.40 ± 3.31de	26.12 ± 1.36de	42.00 ± 1.30a	20.72 ± 0.45ac
W6	36.40 ± 0.51ab	14.35 ± 1.38ef	59.20 ± 2.87ef	28.06 ± 1.76cd	43.00 ± 1.14e	21.53 ± 0.44de
W7	33.80 ± 0.73cd	14.12 ± 1.44ab	72.40 ± 3.93cd	33.47 ± 1.99ed	50.20 ± 0.49dc	23.42 ± 0.39f
W8	32.00 ± 1.22de	13.62 ± 1.62bc	92.00 ± 5.81ad	42.04 ± 3.15ef	59.20 ± 2.20be	26.43 ± 0.40ab
W9	28.60 ± 1.57ab	12.63 ± 1.74de	110.20 ± 8.83ac	48.47 ± 4.09cd	68.60 ± 3.52bd	30.60 ± 0.63cf
W10	27.00 ± 1.14df	12.13 ± 1.68ef	138.80 ± 9.28ef	54.73 ± 4.86bc	73.20 ± 3.84ab	33.65 ± 0.55de

[a]Refer to Table 1 for treatment description
Values are mean and standard error (mean ± S.E.M. n = 5) followed by different letters are statistically different (ANOVA; Tukey's test, p<0.05)

TABLE 3. Nutrient elements; N : P : K and C : N ratio in initial and final day

Treatment	N : P : K ratio		C : N ratio	
	Initial (day 0)	Final (day 70)	Initial (day 0)	Final (day 70)
[a]T_A	1.45 : 0.57 : 1.98	1.48 : 0.59 : 1.98	20.86	22.75
T_B	1.17 : 0.41 : 1.67	1.18 : 0.39 : 1.22	21.65	28.18
T_C	1.10 : 0.39 : 1.15	1.16 : 0.41 : 1.22	31.09	26.38
T_D	1.54 : 0.67 : 1.19	1.66 : 0.64 : 1.18	21.11	17.83
T_E	1.11 : 0.60 : 1.35	1.21 : 0.49 : 1.28	26.59	24.34
T_F	1.20 : 0.49 : 1.30	1.17 : 0.47 : 1.17	22.98	25.26

[a]Refer to Table 1 for treatment description
Values are in percentage (%)

TABLE 4. Heavy metal content (mg kg^{-1}) in vermicompost produced

Heavy metal	T_A	T_B	T_C	T_D	T_E	T_F
Cd	0.01 ± 0.0f	0.01 ± 0.0e	0.01 ± 0.0d	0.01 ± 0.0c	0.01 ± 0.0b	0.01 ± 0.0a
Cr	0.0005 ± 0.0b	0.0005 ± 0.0c	0.0005 ± 0.0e	0.0005 ± 0.0f	0.0005 ± 0.0a	0.0005 ± 0.0d
Pb	0.002 ± 0.0d	0.002 ± 0.0f	0.002 ± 0.0a	0.002 ± 0.0b	0.002 ± 0.0c	0.002 ± 0.0e
Cu	6.57 ± 1.05a	0.13 ± 0.12ad	0.001 ± 0.0ad	5.23 ± 0.33f	1.62 ± 0.11ad	0.27 ± 0.27ad
Zn	80.66 ± 14.72f	43.19 ± 10.91a	57.82 ± 17.92d	105.30 ± 4.36bf	52.64 ± 1.47b	39.24 ± 4.28c

Values are mean and standard error (mean ± S.E.M.; n = 5) followed by different letters are statistically different (ANOVA; Tukey's test, p<0.05) stimulating hormones and enzymes (Triphati & Bhardwaj 2004). Basically, N content in vermicompost depends on the initial N content present in feedstock and on the degree of decomposition (Crawford 1983). On the other hand, the decrease in N might be caused by most of the available N in the initial substrate which would be used and transform into earthworms protein, leading to lower nitrogen content in the final vermicompost (Fernández-Gómez et al. 2010).

The increase in available P in vermicompost was due to the phosphorous in the organic matter that passed through the earthworms' gut and converted into a more available form (Lim et al. 2012). The release of P in available form is performed partly by earthworms gut enzymes i.e. acid phosphatases and alkaline phosphatases which converted some P into more available forms in gut intestine and further release of phosphorous that might be attributed by the P solubilizing microorganisms present in the earthworms casts (Le Bayon & Binet 2006; Prakash & Karmegam 2010; Suthar 2008). The decrease in nutrient elements content was possibly due to the fact that part of the N, P, K and micronutrients were assimilated by the earthworms, which were removed from the compost before analysis (Bansal & Kapoor 2000). On the other hand, the decrease in available P content is probably due to nature of the amendment material and activities of P mineralizing microflora in decomposing wastes (Suthar 2010).

The increase in the content of exchangeable K suggests that earthworms has symbiotic gut microflora with secreted mucus and water to increase the degradation of ingested substrates and release of easily assailable metabolites (Khwairakpam & Bhargava 2009). Additionally, Suthar (2010) proposed that when organic waste passes through the gut of worm some fraction of organic materials is then converted into more available species of nutrients (i.e. exchangeable forms) due to the action of endogenic and/or exogenic enzymes. However, slight decrease of exchangeable K in particularly T_D, T_E and T_F (GM treatments) could be due to initial content of the substrates mixture in the experimental microcosms and rate of mineralization determined by the inoculated earthworms' activities and microbes present in the substrates mixture. This requires further study.

Loss of C in T_C, T_D and T_E might have been resulted from earthworms action i.e. fragments and homogenizes the ingested material through muscular action of their foregut. In addition, secretion of mucus and enzymes to ingested material increases the surface area for microbial action and microorganisms perform the biochemical degradation of waste material by providing some extra-cellular enzymes within the worms' gut. Therefore, the co-operation between microorganisms and macroorganism (earthworms) brings about C loss from the feedstock as CO_2 (Dominguez & Edwards 2004). Slight increment of C in T_A, T_B and T_F could be due to extensive mineralization of nutrient elements under microclimatic conditions. Similarly to the increase of C:N ratio recorded in T_A, T_B and T_F which might be due to certain chemical characteristics of the livestock waste which were not adequate for composting and could limit the efficiency of the process, for example excess of moisture, low porosity and high N concentration for the organic-C, which gives a low C:N ratio and in some cases high pH values, even though this needs further experimental confirmation (Bernal et al. 2009). However, all treatments recorded C:N ratio below 30 which is considered as adequate because the microorganisms require 30 parts of C per unit of N (Bishop & Godfrey 1983). In a nutshell, vermiconversion of livestock excreta and SMC are viable and ratio 1 : 1 of GM : SMC approved the functionality of SMC as bulking agent.

The concentration of heavy metal in all treatments compared to limits set by United States of America, European countries and Malaysian Recommended Site Screening Levels for Contaminated Land (SSLs) are presented in Table 5. The results were lower and within the acceptable amount of heavy metal content in vermicompost. Accordingly post application of the vermicompost, as fertiliser or soil stabiliser will not have adverse impact related to the heavy metal content.

TABLE 5. Comparison of heavy metal (mg kg^{-1}) contained in vermicompost with EU, USA compost limits and Malaysian Site Screening Levels (SSLs)

Heavy metal	EU limit range[a]	USA biosolids limit[b]	Malaysian Site Screening Levels (SSLs)[c]		Vermicompost[d]
			Residential soil	Industrial soil	
Cr	70 - 200	1200	70	810	0.0005
Cd	0.7 - 10	39	280	14000	0.001
Pb	70 - 1000	300	400	800	0.002
Cu	70 - 600	1500	3100	41000	0.001 – 6.57
Zn	210 - 4000	2800	23000	310000	39.24 – 105.30

[ab]Limits set for compost applied in European countries and United States (Brinton 2000).
[c]Recommended levels for Malaysian contaminated site screening based on Contaminated Land Management and Control Guidelines No. 1 (DOE 2009).
[d]Mean of heavy metal content in vermicompost from the experiment on week 10

Conclusion

This work approved the feasibility of epigeic *Lumbricus rubellus* in vermiconversion and SMC with livestock excreta as amendment to be biotransformed into a value added material such as organic fertiliser or soil stabiliser. Even though the highest nutrient content was in non-amended treatment i.e. T_A (CD), the other substrate mixture treatment yielded adequate nutrient elements ratios for agriculture operation. Heavy metals content in the vermicompost produced was below the limit set by USA, European countries and Malaysian Recommended Site Screening Levels for Contaminated Land (SSLs). Thus, the heavy metal content reflecting safe application for human in environment and provides agronomic importance. Apart from that, vermiconversion of SMC and livestock excreta i.e. GM (1 part SMC:1 part GM) provide a good medium for worm culture. Hence, vermiconversion is an efficient and sustainable tool for organic waste management particularly in the agricultural industry.

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