Studies on Vermicompost Production of Palm Oil Mill Effluent Sludge Using *Eudrillus eugeniae*

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Abstract

The aim of this study was to determine the important factors in vermicompost of Palm Oil Mill Effluent (POME) Sludge by earthworm species *Eudrillus eugeniae.* Changes of physico-chemical characteristics of vermicompost had been studied for 7 weeks in a laboratory scale experiment. Vermicomposting caused a reduction in pH (1.8%), carbon (C) (1.9%), C/N ratio (12.86%), phosphorus (P) (37.5%), ferum (Fe) (48.5%), copper (Cu) (24.7%), zinc (Zn) (10%), manganese (Mn) (11.6%), and increase in available macro and micronutrients such as potassium (K) (3.8%), nitrogen (N) (11.2%), calcium (Ca) (5.9%) and magnesium (Mg) (15.4%), as compared to those of the initial substrate. The results suggested that sludge from the Palm Oil Mill could be recycled to form a useful compost, as well as fertilizer. Vermicompost is also rich in the micro and macronutrients which are essential elements for plant growth, has good physical properties, low CN ratio, optimal stability and maturity. These characteristics make vermicompost useful and effective in sustainable agriculture.

KEYWORDS : Vermicomposting, POME sludge, physico-chemical changes, *E. Eugeniae*

INTRODUCTION

During agricultural and horticultural production process, a proportion of raw or final product is wasted (e.g. straw from corn, roots and leaves from vegetables). In most cases, the wastes remain in the production site, and subjected to the degradation and rotting processes by macro and microorganisms due to presence of organic matter.

The use of Palm Oil Mill Effluent (POME) Sludge in agriculture has many benefits. Organic matter content of this waste improves the soil structure while the presence of nutrients such as N, P and K increases soil fertility. Hence, this substance is composted and used for agricultural purposes and be a substitute for expensive inorganic fertilizers. Presence of pathogens and content of heavy metals such as cadmium are very low in this, thus, it can be used for agricultural purposes (Rehm and Reed, 2000).

The concept of vermicomposting started from the knowledge that certain species of earthworms consume a wide range of organic residues very rapidly, converting them into vermicompost, a humus-like, soil building substance in short time, so the effective use of the earthworms in organic waste management requires a detailed understanding of the effect of the physico-chemical properties of the substrate (Singh et al., 2005).

Vermicompost is rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, beneficial soil microbes and also contain 'plant growth hormones and enzymes' (Am-Euras, 2009). It also can retain nutrients for a long period of time and deliver the required amount of macro and micronutrients including the vital NPK to plants in shorter time. Vermicomposts also has outstanding chemical and biological properties with 'plant growth regulators' (lacking in other composts) and significantly larger and 'diverse microbial populations' than the conventional thermophilic composts (Edwards and Burrows, 1988; Edwards et al 2004, Tomati and Galli, 1995). Therefore, the aim of this study was to determine the changes of physico-chemical characteristics of vermicompost with POME sludge by varying earthworms stocking density.

MATERIALS AND METHODS

A. Vermicomposting Site

This research was conducted in Malaysian Palm Oil Board Research Station (MPOB-UKM) , Kajang, Malaysia. The bins with length of 54 cm, width of 39 cm, and height of 36 were used as worms' bin.

B. Raw materials

Palm Oil Mill Effluent (POME) Sludge were obtained from Palm Oil Mill, Serting, Negeri Sembilan. The process involved the cooling process of early stage oil palm fruit waste before undergoes mixing process. Later, the waste was stored in an anaerobic pond before transferred into facultative pond as brownish and smelly sludge.

C. Vermicomposting Process

3 kg of POME sludge was filled into each worm bin. 50 earthworms (*Eudrillus eugeniae*) were added into the first bin and 100 earthworms of the same species were added into the next bin while for control, no earthworms were added. Experiment was done in triplicate for each worm bins. Vermicomposting process was done for approximately two months and was done in a closed system to keep the moist of the substrates.

D. Sampling

Samples were randomly picked at different depth and points in each worm bins. Each sample was taken weekly. For this analysis, sample without the addition of worms and sample after processed with worms (i.e vermicompost) were taken and kept in a fridge at 4°C for further analysis.

E. Sample Analysis

The CNS analyzer (LECO, CNS Model 2000,), AAS Spectroscopy (Perkin Elmer, Analyst Model 400) was used to determine the carbon, total nitrogen, nutrients and heavy metal elements respectively. The frequencies of samples were analysed by using Attenuated Total Reflectance (ATR), Fourier Transform Infra Red (Perkin Elmer, Model spectrum 400 FTIR, Range: 4000 cm^{-1} - 650cm^{-1}, Resolution: 4.00 cm^{-1}).

RESULTS AND DISCUSSION

A. Physicochemical Changes of Vermicompost

In Table 1, heavy metal content in three different worm bins E0, E50 and E100 has been reported. The concentration of Ca, Mg, Cu, Zn, Mn and Fe in vermicomposter E0 was higher than vermicomposter in E100 at week 7. At week 1, the concentration of Cu in vermicomposter E0 was statistically insignificant with Cu concentration in week 2 but significantly different with other weeks. The same trend can be found for E50 and E100. According to Edwards and Lofty (1976), if the soil physical conditions are suitable, the abundance of earthworms increases until food becomes a limiting factor. The smaller earthworms that feed on the litter produce cast, that are almost entirely fragmented litter, whereas the larger species consume large proportion of soil, and there is less organic matter in their casts.

The CN ratio of vermicompost obtained was 6.03 (Table 2). The loss of carbon as carbon dioxide in the process of respiration and production of nitrogenous excreta enhance the level of nitrogen, which then lower the CN ratio (Senapati et al., 1980). According to Senesi (1989), a decline in CN ratio to less than 20 indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes. During vermicomposting period, K and Na concentrations were observed to be lower than the initial substrate values. This probably reflects leaching of these soluble elements by the excess water that drained through the mass. Similar results were observed Elvira et al., (1998). Such increases might have been probably attributed to the metal concentrations in the earthworms' tissues which are existed in vermicomposts (Gratelly et al., 1996). According to Alidadi et al. (2007), a biodegradable carbon-nitrogen (C/N) weight ratio of 25 to 35 has been found to provide optimal conditions for compost process. Lower CN ratio increases the loss of nitrogen by leaching (e.g., nitrate mobilization) and ammonia volatilization, whereas higher levels necessitate progressively longer composting time as nitrogen becomes the microbial limiting nutrient. Sludge normally has CN ratios in range of 10 to 20 (Alidadi et al., 2007). According to Karmegan and Daniel (2009), the higher the CN ratio the lower was the process of degradation while the lower the CN ratio the higher was the process of degradation. No change in CN ratio indicated the completion of the composting process.

The amount of nitrogen after vermicomposting also was higher than before vermicomposting. As reported by Edwards and Lofty (1976), there have been reports of increase in the amount of nitrogen in the soil in which the earthworms are reared. This may be due to the decay of the bodies of dead earthworms, which are rich in proteins. Govindan (1998) reported that earthworm body contains 65% protein, 14% fats, 14% carbohydrates and 3% ash. Similarly, Ronald and Donald (1977) reported that 72% of the dry weight of an earthworm is protein and that the death of an earthworm will release up to 0.01 g of nitrate in the soil.

B. Physicochemical Properties of POME Compost and Vermicompost by FTIR Analysis

The IR spectroscopic data before and after vermicomposting is illustrated in Figure 1 and Figure 2 respectively. The most intense broad absorption band in the compost and vermicompost sample was detected at 1030.12 cm^{-1} and 1028.53 cm^{-1} respectively. Grube et al. (2006) reported that peaks around 1034 cm^{-1} could be attributed to C-O stretching of alcohol, sulfoxides, carbohydrates or poly-saccharides-like substance, or Si-O of silicates. According to Smidt et al. (2002), the intensity changes of bands at 1020 cm^{-1} to 1040 cm^{-1} can also be used to evaluate the decomposition of organic components in the composting process. In this study, the intensity of this band (1028.53 cm^{-1} and 1030.12 cm^{-1}) was increased slightly. A peak around 1240.49 cm^{-1} and 1226.87 cm^{-1} in both compost samples could be attributed to C-N stretching of amines. Meanwhile, a peak around 1405.86 and 1407.77 cm^{-1} has been detected in POME compost and vermicompost respectively. The bands were attributed to the alkanes group of C-H scissoring and bending band. In the other hand, the sharp peak around 1630.37 and 1630.73 cm^{-1} in both compost were detected as a medium band of N-H from amines. The reduction of cellulose content was attributed to the microbial consumption, whereas the increment of lignin content could be due to the accumulation of non-degradable compost material and it is assumed that humus is formed mainly from lignin and is not totally mineralized during composting (Tuomela et al., 2000).

A broad and strong range of O-H stretching band was obtained around 3278.43 and 3279.94 cm^{-1} for intermolecular hydrogen bonding (H-bonded OH groups) which is attributed to the phenolic group’s component.

C. pH and Temperature of Vermicompost

Edward and Lofty (1976) and Chan and Mead (2003) have reported that earthworms are pH sensitive and generally most of them survive at pH ranging from 4.5 to 9. At week 1 (Figure 4), pH value for vermicomposter E50 and E100 recorded was 8.3 while for E0, its pH was approximately 8.7. After 7 weeks of vermicomposting, pH value for E50, E100 and E0 dropped to 7.9 and 8.1, respectively. The alteration of pH in the wormbed is due to the fragmentation of the organic matter under a series of chemical reactions. As cited by Edwards and Bohlen (1996) in Chan and Mead, (2002), the soil pH is a major factor limiting the abundance and distribution of earthworms. In the other hand, the trend of temperature in each vermicomposters fluctuated from week 1 until week 7 (Figure 5). The range varies between 25.5 °C to 30.2°C. In vermicomposting, temperatures are kept generally below 35°C (Riggle and Holmes, 1994). Most worm species used in vermicomposting require moderate temperatures from (10 - 35°C). While tolerances and preferences vary from species to species, temperature requirements are generally similar. According to Slocum (2001), earthworms can tolerate cold and moist conditions far better than hot and dry conditions.

CONCLUSION

Vermicompost obtained in this study was rich in the micro and macronutrients which are essential elements for plant growth, had good physical properties, low CN ratio, optimal stability and maturity. These characteristics make vermicompost useful and effective in sustainable agriculture as well as good organic fertilizer.

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REFERENCES

Alidadi, H., Najafpoor, A. A., and Parvaresh, A. (2007). Determination of carbon/nitrogen ratio and heavy metals in bulking agents used for sewage composting. Pak. J. Biol. Sci. 10, pp. 4180-4182

Am-Euras. (2009). Earthworms Vermicompost: A Powerful Crop Nutrient over the Conventional Compost & Protective Soil Conditioner Against the Destructive Chemical Fertilizers for Food Safety and Security. J. Agric. & Environ. Sci. 5 (S), pp. 01-55

Chan, K. Y., and Mead, J. A., (2002). 'Soil Acidity limits colonization by *Aporrectodea trapezoids,* an exotic earthworm', Urban & Fischer Verlag. Available online at http://www.urbanfischer.de/journals/pedo

Dominguez, J., Edwards, C. A., and Subler, S. (1997). A comparison of vermicomposting and composting, BioCycle, 28, pp. 57-59

Esther, 0., and Ugoji. (1997). Anaerobic Digestion of Palm Oil Mill Effluent and Its Utilization As Fertilizer For Environmental Protection, Vol.10, No. 213, pp. 291-294

Edwards, C. A., and Burrows, I. (1988). The Potential of Earthworms Composts as Plant Growth Media. In Edward, C.A. and E.F. Neuhauser (Eds.). Earthworms in Waste and Environmental Management. SPB Academic Publishing, The Hague, The Netherlands, pp. 21-32

Edwards, C. A., Domínguez, J., and Arancon, N. Q. (2004). The influence of vermicomposts on plant growth and pest incidence. In Shakir, S.H. and W.Z.A. Mikhail (Eds.). Soil Zoology for Sustainable Development in the 21st Century, Self-Publisher; Cairo, Egypt, pp. 397-420

Edwards, C. A., and Lofty, J. R. (1976). Biology of Earthworms. Bookworm Publishing Company, Crawfordsville, Indiana.

Elvira, C., Sampedro, L., Benitez, E., and Nogales, R. (1998). Vermicomposting of sludges from paper mill and dairy industries with *Eisenia andrei*. A pilot scale study. Bioresource. Technology 63, pp. 205 – 211

Govindan, V. S. (1998). Vermiculture and Vermicomposting, Ecotechnology for pollution control and Environmental Management, pp. 48- 57

Gratelly, P., Benitez, E., Elvira, C., Polo, A., and Nogales, R. (1996). Stabilization of sludge from a dairy processing plant using vermicomposting. In: Rodrigoez-Barrueco C (ed) Fertilizers and environmental. Kluwer, The Netherlands, pp. 341-343

Grube, M., Lin, J. G., Lee, P. H., Kokorevicha, S. (2006). Evaluation of sewage sludge-based compost by FT-IRspectroscopy. Geoderma, 130, pp. 324-333

Singh, N. B., Khare, A. K., Bhargava, D. S., and Bhattacharya, S. (2005). Effect of initial substrate pH on vermicomposting using P. excavatus (Perrier, 1872). Applied Ecology and Environmental Research 4(1), pp. 85-97

Rehm, H. J. and Reed, G. (2000). *Biotechnology*. 2nd ed: John Wiley Company Inc.

New York.

Riggle, D. and Holmes, H. (1994). New horizons for commercial vermiculture. Biocycle Vol. 35(10), pp. 58-62

Ronald, E. G., and Donald, E. D. (1977). Earthworms for Ecology and Profit, Vol. 1, 'Scientific Earthworm Farming.' Bookworm Publishing Company, Ontario, California.

Senapati, B. K,. Dash, M. C., Rane, A. K., and Panda, B. K., (1980). Observation on the effect of earthworms in the decomposition processs in soil under laboratory conditions. Comp. Physiol. Ecol. 5, pp. 140-142

Senesi, N. (1989). Composted materials as organic fertilizers. Science of the Total Environment 81-82, pp. 521-524

Smidt, E., Lechner, P., Schwanninger, M., Harberhauer, G., and Garzabek, M. H. (2002). Characterization of waste organic matter by FT-IR spectroscopy: application in waste science. Appl. Spec. 56(9), pp. 1170-1175

Tuomela, M., Vikman, M., Hatakka, A., and Itävaara, M. (2000). Biodegradation of lignin in a compost environment: A review. Bioresour. Technol. 72, pp. 169-183

Table 1: Heavy metals content in vermicomposts obtained in different vermicomposters[a]

(mean ± S.D, n = 3).

Vermicomposter	***Week***	***Ca (%)***	***Mg (%)***	***Cu (mg/kg)***	***Zn (mg/kg)***	***Mn (mg/kg)***	***Fe (mg/kg)***
E0	1	17.56 ± 1.34^{a}	3.47 ± 0.08^{a}	25.27 ± 1.52^{a}	125.77 ± 2.71^{a}	1236.1 ± 27.4^{a}	6731.7 ± 217.0^{a}
	7	11.627 ± 1.624^{b}	3.10 ± 0.68^{ab}	17.83 ± 1.20^{b}	129.40 ± 4.47^{a}	929.4 ± 19.2^{b}	6066.1 ± 641.0^{a}
E50	1	21.55 ± 2.46^{a}	5.68 ± 1.25^{a}	24.60 ± 1.00^{a}	108.47 ± 2.91^{a}	1162.9 ± 14.9^{a}	6015.6 ± 89.5^{a}
	7	11.20 ± 0.13^{b}	3.55 ± 0.33^{b}	21.13 ± 0.96^{a}	127.57 ± 4.38^{ab}	946.4 ± 9.6^{b}	5603.4 ± 592.4^{a}
E100	1	18.82 ± 4.62^{a}	3.57 ± 0.3002^{a}	27.27 ± 0.85^{a}	119.83 ± 4.35^{a}	1186.2 ± 15.0^{a}	6766.8 ± 62.3^{a}
	7	13.31 ± 0.73^{b}	3.55 ± 0.47^{a}	22.80 ± 1.49^{c}	121.23 ± 3.15^{b}	908.9 ± 38.4^{b}	5617.9 ± 605.2^{b}

Note:

E0: POME sludge without earthworm; **E50**: POME sludge with 50 earthworms, **E100**: POME sludge with 100 earthworms.

[a] Mean values followed by different letters are significantly different (ANOVA; Turkey's Test, $p < 0.05$)

Table 2: NPK content, CN ratio and pH value of POME vermicompost by using *E. eugeniae* before and after vermicomposting.

Properties	**Before vermicomposting**	**After 60 days of vermicomposting**
C/N	6.92	6.03
pH	8.20	8.05
C (%)	23.53	23.09
N (%)	3.40	3.83
P (%)	6.31	3.95
K (%)	0.76	0.79

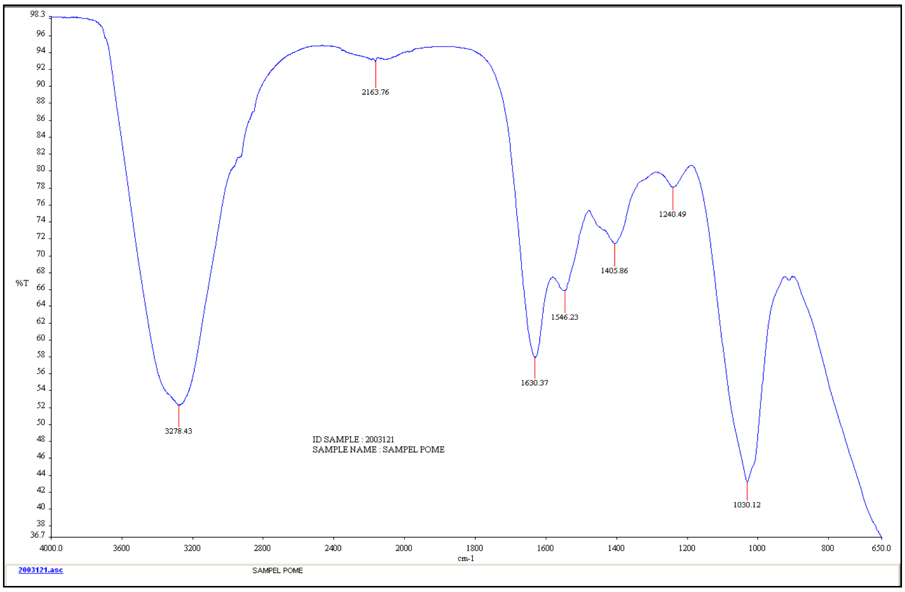

Figure a: POME without earthworm

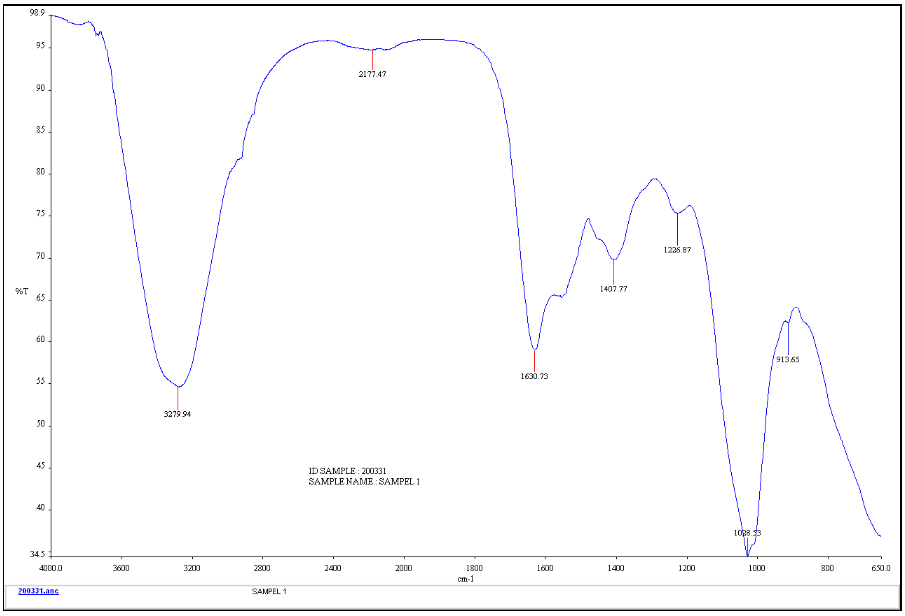

Figure b: POME with earthworm

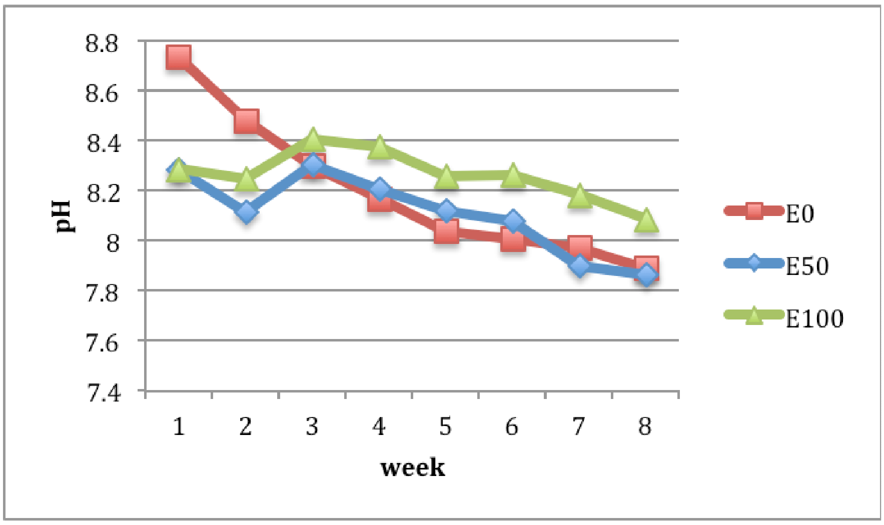

Figure c: pH profile of vermicompost

E0 – control`; E50 – substrate with 50 e/worm; E100 – substrate with 100 e/worms

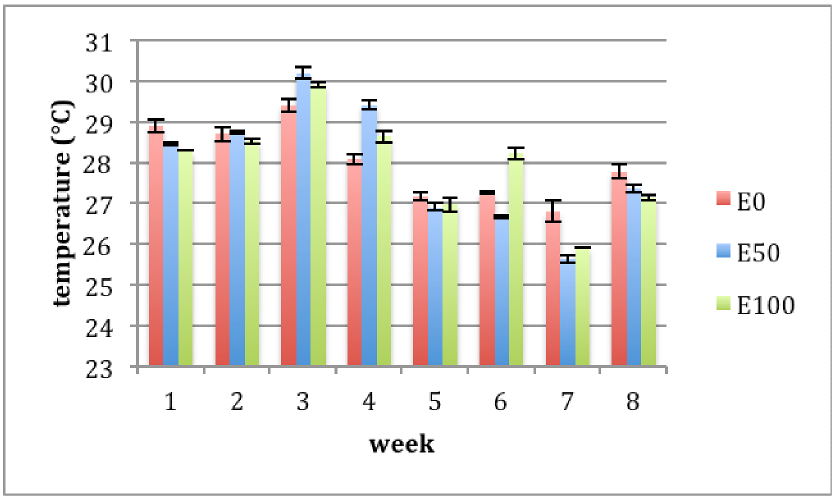

Figure d: Temperature profile of vermicompost

E0 – control`; E50 – substrate with 50 e/worm; E100 – substrate with 100 e/worms