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Resource Recovery from Municipal Waste and Bio Solids (Digestate) Through Vermicomposting: A Waste Management Initiative

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Abstract - **In this study, municipal waste and anaerobic digestate (bio solids) were co-vermicomposted in a bid to properly manage waste at disposal sites. Municipal waste and bio solids in the ratio 2:1 were vermicomposted in a vermireactor for 45 days. Process parameters such as moisture, temperature and pH as well as the nutrient composition in terms of nitrogen, phosphorous and potassium (NPK) content of the vermicompost were closely monitored. Approximately 250 *Eisenia Foetida*, a species of the red worms was used as the vermicomposting inoculants. After the 45 days, a rich vermicompost with an NPK composition of 6.18%, 3.27% and 8.26% respectively. The optimum conditions for producing this vermicompost were moisture content>27%, temperature >18.6% and neutral pH. An addition of the bio solids to municipal waste during vermicomposting adds value to the nutritional composition of the vermicompost.**

Keywords - **Bio waste, bio solids, municipal waste, vermicompost, vermicasts**

I. INTRODUCTION

Resource recovery from municipal waste is becoming topical in a bid to promote sustainability especially in developing countries where a lot of bio waste is generated from municipal waste and landfills. Other interesting initiatives that have been taken for municipal waste management include instances whereby; municipal waste is anaerobically digestated to produce biogas and a digestate as a byproduct [1]. This digestate also known as bio solids is rich in fertilizer micronutrients and offers an attractive option for use as a bio fertilizer with nitrogen (N) composition ranging from 0.04-6.02% and phosphorous (P) content ranging from 0.0-2.51% [1]. On the other hand, municipal organic waste offers a good source of raw material in vermicomposting technology and combining these two types of bio waste for vermicomposting is an attractive option.

Municipal waste is generated on a daily basis and contributed to the emission of green house gases if not properly managed. On the other hand, with the increased interest on biogas product, a lot of bio solids (digestate) are being generated and have potential to be used as bio fertilizers. There is therefore potential of utilizing the municipal waste and the digestate as potential raw material for vermicomposting as well as a strategy for minimizing landfills problems.

During vermicomposting, mesophilic earthworms are used as the bio conversion agent from organic waste to bio fertilizers at temperatures under 45 °C [1]. The vermicomposting process is an anaerobic process and earthworms feed on the waste causing them to reproduce [2-3]. Vermicomposting is a low cost technology and is easily scalable hence an attractive option for waste management [1; 4].

Earthworms used during the vermicomposting process are temperature sensitive and work best for pH ranges between 5.0-9.0 [5-9]. Moisture content during the bio conversion process must be maintained between 45-75% for optimal reproduction and activity of the earthworms [2]. Figure 1 shows a schematic presentation of the vermicomposting process.

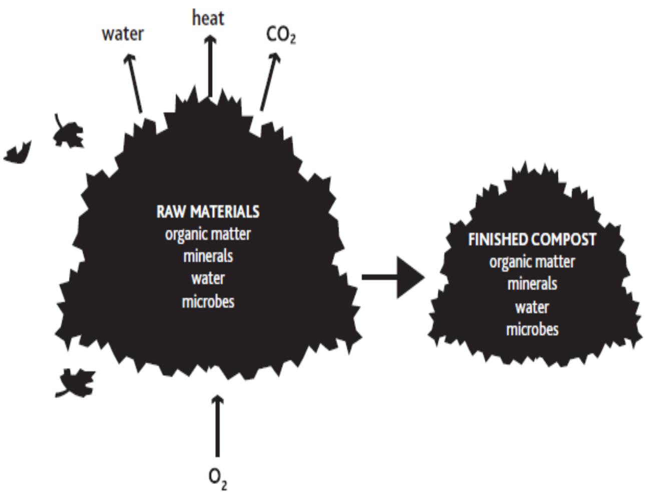

Fig. 1: Schematic representation of the vermicomposting process system [10]

This study, focused on the co-vermicomposting of municipal bio waste and anaerobic digestion digestate (bio solids) in a bid to value add bio waste into a bio fertilizer at the same time improving the nutritional composition of the vermicompost obtained.

II. MATERIALS AND METHODS

A. Materials

Municipal bio waste was obtained from the local landfill. The anaerobic digestate (bio solids) were obtained from an ongoing biogas project. Eisenia Fetida earthworms wee obtained from the local fisherman, 250 earthworms were used as the initial inoculants [11] in this study. A vermicomposting bin from Full Cycle, South Africa was used as the reactor. The pH was measured using an HI 9801 Hanna electrode. Moisture content in the bio waste was monitored using an AND moisture analyzer. A UV 1800 uv-vis was used for determining the nitrogen, phosphorous composition and the trace chemical elements composition in the bio waste and the vermicompost. The potassium content was determined by a Perkin Elmer atomic absorption instrument.

B. Methods

The moisture content was measured at 105 °C by heating a 5g mass for 5 minutes and calculating the change in mass as a percentage. The volatile matter was measured by heating a 5g mass at 900 °C for 3 minutes and the change in mass was calculated as the volatile mass as a percentage whilst the ash content was measured by heating a 5g sample using a burner then noting the change in mass. The fixed carbon was determined by calculating the difference from 100% of the volatile matter, ash content and moisture content.

A sample with 15 kg of bio waste with the ratio 1: 1 for the municipal waste and the bio solids was vermicomposted over a period of 45 days. The bio waste was occasionally watered and turned to maintain adequate moisture content as well as ensuring all parts were subjected to vermicomposting. The bio waste as well as the vermicompost nitrogen, phosphorous and potassium (NPK) composition as well as the trace elements were determined to ascertain the potential of the vermicompost in being used as a bio fertilizer.

The values of the process conditions, the vermicompost and vermiwash composition were measured in triplicates and an average value used over the 45 day vermicomposting period.

III. RESULTS AND DISCUSSION

A. Behavior in the physicochemical parameters during vermicomposting

During vermicomposting of the bio waste, the ash content increased by almost 9 times (Table 1) and this was attributed to the bio conversion of the bio waste to vermicompost [5]. This can also be explained by the increase in the volatile matter by almost 9 times showing a good bio degradation of the bio waste during vermicomposting [2]. This behavior can also be quantified by the decline in the bio waste's fixed carbon content from 58.9% to 9.7% showing efficient vermicomposting.

TABLE 1
PHYSICOCHEMICAL PARAMETERS OF BIOWASTE AND VERMICOMPOST

Parameter	Bio waste (%)	Vermicompost (%)
Volatile matter	1.3±0.01	9.1±0.01
Ash content	10.4±0.10	27.5±1.34
Fixed carbon	58.9±0.59	9.7±0.09

B. Effect of process conditions

The vermicomposting process is a sensitive biological process and its progression must be monitored so that the earthworms continue to perform optimally. A summary of the process conditions are given in Table 2.

Moisture content

The moisture content increased from 26.8% to 51.3% (Fig. 2) due to the generation of the leachate, vermiwash during the microbial processes resulting in its increase. Moisture content values reported in this study correlate with values reported in literature, ideal moisture content is required for the optimal progression of the bio conversation process to vermicompost [2].

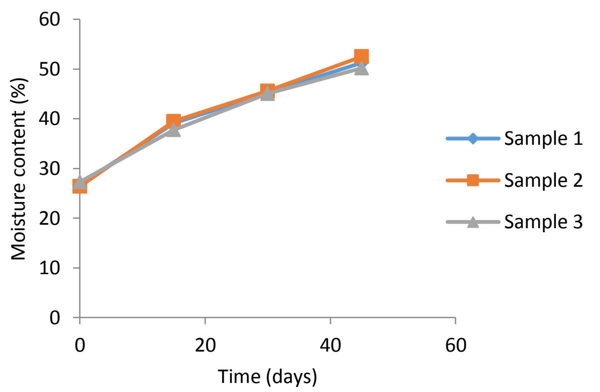

Fig. 2: Moisture content changes during vermicomposting

Electrical conductivity

The electrical conductivity decreased by almost 50% as the bio waste was converted to vermicompost during the 45 days by changing from 575.7 µS/cm to 265.1 µS/cm (Fig. 3). This was attributed to the increased moisture content in the vermicompost, which also allowed for nutrients concentration decrease and the change in pH to almost neutral. Low electrical conductivity values are essential for promoting plant growth and nutrient absorption [4].

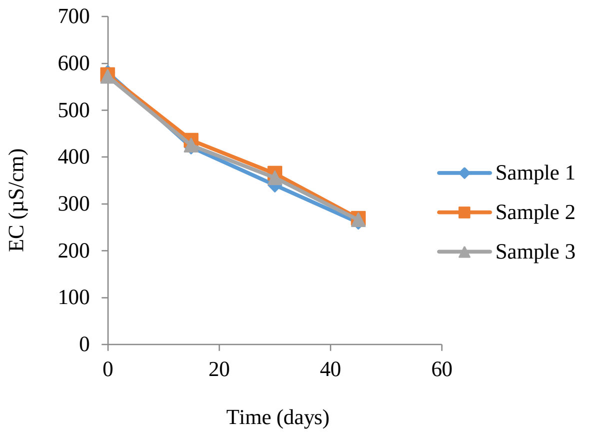

Fig. 3: Electrical conductivity changes during vermicomposting

Temperature

As the vermicomposting process progressed, temperature varied between 18.4 ◦C to 26.2 ◦C in the vermicomposting reactor (Fig. 4). The temperatures observed in this study are ideal for an optimal vermicomposting process as they are idea for earthworm performance and intensification [2, 12]. The slight changes in temperature can be attributed to the variations in temperature by the surroundings as well as due to the metabolic processes that occur when the bio waste is converted to vermicompost.

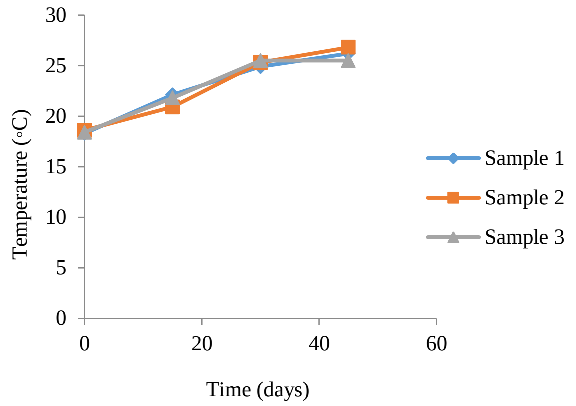

Fig. 4: Temperature changes during vermicomposting

pH

The pH changed from around 5.6 to 6.9 during vermicomposting (Fig. 5). The pH change was attributed to the increase in nitrogenous waste excretion during vermicomposting which had the potential to neutralize the pH [4]. Singh *et al.* [5] reported an almost similar trend with pH changes from 4.3 to 8.2. This pH is ideal for vermicompost as it has potential to improve the soil pH [5, 13].

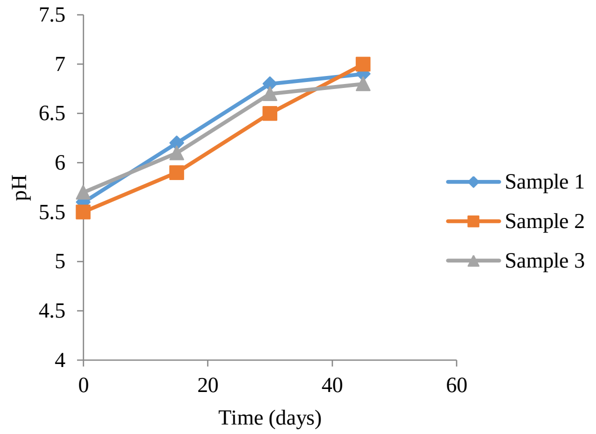

Fig. 5: pH changes during vermicomposting

A summary of the process parameter changes is shown in Table 2.

TABLE 2
PROCESS PARAMETERS DURING VERMICOMPOSTING

Parameter	Initial value	Final value
Moisture (%)	26.8±0.45	51.3±1.15
Temperature (°C)	18.4±1.0	26.2±1.0
pH	5.6±0.1	6.9±0.01
Electrical conductivity (µS/cm)	575.7±4.13	26.1±4.25

C. *Macronutrient composition of the vermicompost*

The vermicompost of the bio waste resulted in significant enhancement of the nitrogen, phosphorous and potassium (NPK) content (Fig. 6). The NPK composition almost increased by a factor of 3 during the 45 day vermicomposting period. The 6.2% of nitrogen in the vermicompost is a result of nitrogenous metabolic products released by the earthworms during vermicomposting as either vermicasts or vermiwash, a liquid leachate released during the vermicomposting process [9]. The increase in total phosphate to 3.3% was attributed to the mineralization and mobilization of phosphate as a result of the earthworms' activity during the bio conversion of the bio waste. The total phosphate in the vermicompost was 3.3% and this is credited to the mineralization and mobilization of phosphorous by earthworm action and activity [4].

The potassium content in the vermicompost also increased to 8.3% and this was assumed to have been boosted by the earthworm actions on the bio waste [4]. The same observation in NPK enhancement upon vermicomposting of vegetable waste was reported by Muthukumaravel *et al*. [9] when they used *Megascolex mauritii*, as the inoculants. In this study, it can also be assumed that addition of the anaerobic digestate which also has some NPK nutrients in it also resulted in the rich vermicompost. The summary of the vermicompost nutrient composition is given in Fig. 6.

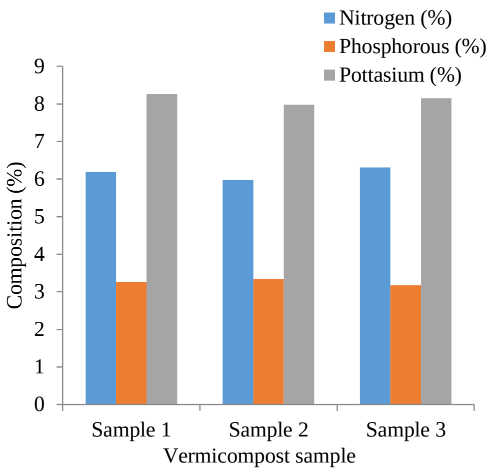

Fig. 6: Vermicompost nutrient composition

A summary of the vermicompost obtained in comparison to the bio waste used is shown in Table 3.

TABLE 3
VERMICOMPOST MACRONUTRIENTS COMPOSITION

Nutrient	Bio waste composition (%)	Vermicompost composition (%)
Nitrogen	2.7±0.08	6.2±0.17
Phosphorous	1.5±0.04	3.3±0.09
Potassium	2.0±0.02	8.3±0.14

D. *Micronutrient composition of the vermicompost*

The vermicompost from bio waste also contained micro nutrients (trace elements) that are also essential in a bio fertilizer for necessary plant growth and these included magnesium (mg), iron (Fe), copper (Cu) and zinc (Zn) (Table 4). The major composition was obtained for Fe with a composition of 164 ppm and mg with a composition of 7.8 ppm.

TABLE 4
MICRONUTRIENT COMPOSITION IN BIO WASTE AND THE VERMICOMPOST

Nutrient	Bio waste composition (ppm)	Vermicompost composition (ppm)
Sodium (Na)	3.6	6.1
Magnesium (Mg)	4.0	7.8
Copper (Cu)	0.7	2.0
Zinc (Zn)	1.6	2.5
Iron (Fe)	68.9	164.5
Manganese (Mn)	1.8	2.9

IV. CONCLUSION

Vermicomposting of municipal bio waste and anaerobic process digestate (bio solids) is an attractive waste management of option that converts bio waste to a bio fertilizer, vermicompost. A dark brown vermicompost which was odorless was produced and can be optimally produced at moisture content of 26.8-51.3%, temperature of 18-26◦C, pH of 5.6-6.9 and electrical conductivity of 260-580 µS/cm. The bio waste vermicompost had a nutrient composition of 6.2%, 3.3% and 8.3% for nitrogen, phosphorous and potassium respectively.

The vermicompost also contained some micro element required for plant growth. Co-vermicomposting of the bio waste does not only offer a solution to waste going to landfills but also provides an alternative source of bio fertilizers that can used to boost the agro sector.

REFERENCES

[1] P. M. Ndegwa and S. A. Thompson, "Integrating composting and vermicomposting in the treatment and bioconversion of bio solids", *J. Bioresourse Technology*, vol. 76, pp. 107-112, 2001.

[2] J. Palsania, R Sharma, J. K Srivastava and D. Sharma, "Effect of moisture content variation over kinetic reaction

rate during vermicomposting process”, *J. Applied Ecology and Environmental Research*, vol. 6(2) pp. 49-61, 2008.
[3] M. Aira, F. Monroy and J. Domínguez, “*Eisenia fetida* (Oligochaeta: Lumbricidae) modifies the structure and physiological capabilities of microbial communities improving carbon mineralization during vermicomposting of pig manure”, *J. Microbial Ecology*, vol. 54, pp. 662-671, 2007.
[4] A. A. Ansari and J. Rajpersaud, “Physicochemical changes during vermicomposting of water hyacinth (*Eichhornia crassipes*) and grass clippings”, *ISRN Soil Science*, Article ID. 984783, pp. 1-6, 2012.
[5] N. B. Singh, A. K. Khare, D.S. Bhargava and S. Bhattacharya, “Effect of initial substrate pH on vermicomposting using *Perionyx Excavatus* (Perrier, 1872)”, *J. Applied Ecology and Environmental Research*, vol. 4(1), pp. 85-97, 2005.
[6] A. A. Ansari and K. Sukhraj, “Effect of vermiwash and vermicompost on soil parameters and productivity of okra (*Abelmoschus esculentus*) in Guyana”, *African J. Agricultural Research*, vol. 5(14), pp. 1794-1798, 2010.
[7] A. A. Ansari and S. Jaikishun, “An investigation into the vermicomposting of sugarcane bagasse and rice straw and its subsequent utilization in cultivation of *Phaseolus vulgaris L*. In Guyana”, *American-Eurasian J. Agriculture and Environment Science*, vol. 8(6), pp. 666-671, 2010.
[8] P.S. Chaudhuri, T. K. Pal, B. Gautam and S. K. Dey, “Chemical changes during vermicomposting (*Perionyx Excavatus*) of kitchen wastes”, *J. Tropical Ecology*, vol. 41(1), pp. 107-110, 2000.
[9] K. Muthukumaravel, A. Amsath and M. Sukumaran, “Vermi-composting of vegetable wastes using cow dung”, *E – J. Chemistry*, vol. 5(4), pp 810-813, 2008.
[10] R. Rynk, “On-farm composting handbook (NRAES-54”, *Cooperative Extension*, N.Y. H11, R1.
[11] S. Indrajeet, N. Rai and J. Singh, “Vermicomposting of farm garbage manure in different combination”, *J. Recent Advances in Applied Sciences*, vol. 25, pp. 15-18, 2010.
[12] C. A. Edwards, J. Domínguez and E. F. Neuhauser, “Growth and reproduction of *Perionyx Excavatus* (Perr.)(*Megascolecidae*) as factors in organic waste management”, *J. Biology and Fertility of Soils*, vol. 27, pp. 155-161, 1998.
[13] K. Tharmaraj, P. Ganesh, K. Kolanjinathan, K. R. Suresh and A. Anandan, “Influence of vermicompost and vermiwash on physicochemical properties of rice cultivated soil”. *J. Current Botany*, vol. 2(3), pp. 18-21, 2011.