Agricultural Wastes Conversion into Bio-fertilizer using Vermicomposting Method

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Abstract- In this study, agricultural waste materials (fresh and dried plantain peels and fresh and dried potato peels) were placed in four plastic bins labelled A1, A2, B1 and B2 respectively and vermicomposted into bio-fertilizer. The earthworms used for the study, *Eudrilus eugeniae,* were introduced into the bins at a ratio of 5:1 (waste/worm) in grams. The moisture content, temperature and pH level in the system were monitored for a study period of 15 days. At the end of the study period, the vermicasts produced were collected from each bin and analysed for Nitrogen, Phosphorus and Potassium concentration. Sample A1 (fresh plantain peel) had the maximum concentration of nitrogen, phosphorus and potassium with a value of 0.20%, 0.05% and 0.40% respectively. While sample B1(fresh potato peel) had 0.11% N, 0.04% P and 0.30% K; A2 (dried plantain peel) had 0.09% N, 0.02% P, and 0.30% K; and B2 (dried potato peel) had 0.13% N, 0.02% P, and 0.10% K. The results also revealed that vermicomposting reduced the mass of all the samples with a reduction of 48%, 45%, 53% and 49% for A1, A2, B1 and B2 respectively. The data obtained were statistically analysed using ANOVA to ascertain the significant effect of the types of peels on the NPK contents; Duncan multiple range test was also used to check if the differences in mean values obtained were significant. The concentration (in ratio) of N-P-K for the vermicompost are; A1 4:1:8, A2 5:1:15, B1 3:1:8 and B2 7:1:5, in comparison with the inorganic fertilizer with ratio 1:1:1. This indicated that the concentration (in ratio) of N-P-K is higher in the vermicompost than inorganic fertilizer. Therefore, vermicomposting is a promising alternative technology for the treatment of agricultural wastes into nutrient rich bio-fertilizer, it is eco-friendly, cheaper and more sustainable.

Keywords- Earthworm, plantain peel, potato peel, vermicast, vermicomposting,

1 Introduction

Degradation of the environment is a major threat confronting the world, and the indiscriminate use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of ozone layer, generation of carbon dioxide (CO_2) and contamination of water resources. According to Aveyard (1988); Wani and Lee (1992); Wani *et al.*, (1995), uncontrolled use of fertilizers may lead to soil salinity which in turn adversely impacts agricultural productivity.

Agricultural waste materials are defined as the residues from the growing and processing of raw agricultural products, such as fruits, vegetables, meat, poultry, dairy products and crops. However, their economic values are less than the cost of collection, transportation and processing for beneficial use. It comprises animal wastes, food processing wastes, crop wastes and hazardous and toxic agricultural wastes (Obi *et al.*, 2016). Poor disposal of agricultural waste materials has caused serious environmental hazards and economic problems according to Ansari and Ismail (2012). Generation of large amounts of agricultural wastes in the society is inevitable due to increase in population and its attendant effects. The management of these large quantities of wastes is therefore becoming a big challenge not only in the urban cities but in the rural areas as well (Uchegbu, 2002; Hemalatha, 2012). Among the possible ways to manage these agricultural wastes, is a simple, cost effective and an eco-friendly method known as vermicomposting that helps re-cycle these wastes into useful substances (Kaviraj and Sharma, 2003).

Vermicomposting, is simply the use of earthworms to breakdown agricultural waste materials into bio-fertilizer (Othman *et al.,* 2012). It is the biological degradation and stabilization of organic waste by earthworms and microorganisms to form vermicompost. Vermicompost is organic manure (bio-fertilizer) produced as the vermicast by earth worm (Sinha *et al*., 2010). Vermicast enriches soil quality by improving its physicochemical and biological properties. It is eco-friendly, non-toxic, consumes low energy input for composting and is a recycled biological product. Organic farming with the use of vermicompost improves the texture, structure, water holding capacity of the soil and to some extent reclaims the problematic soil compared to organic fertilizers. It also improves quality of the produce (Nayak *et al*., 2014).
Agricultural waste production is inevitable, causing pollution to plants and animal life, and also the overuse of inorganic fertilizer being a threat to all living things, a waste management strategy becomes inevitable and vermicomposting could serve the dual purpose of treating the wastes and converting them into bio-fertilizer that is more environmental friendly. The objective of this study was therefore to produce biofertilizer from selected agricultural wastes using vermicomposting.

2 Materials and Methods

2.1 Sample Collection

This study was carried out at the Laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Niger State. The latitude and Longitude of Minna, Niger State are 9.5836^0 N and 6.5463^0 E. Samples of plantain peel and potato peel used for the study were obtained from a restaurant. The earthworms used (*Eudrilus eugeniae*) were obtained from a fish farm at Gidan Kwano village, Niger

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State and taken to Department of Biological Sciences, Federal University of Technology, Minna, Niger State for proper identification.

2.2 Vermicomposting

The methods adopted for vermicomposting of the agricultural waste materials were as reported by Othman *et al.*, (2012) and Rostami (2014). The waste materials (plantain and potato peels) were washed with running water in order to remove any oily substance and then 100 g of each fresh wastes were weighed and the value recorded. Another sample of fresh wastes (plantain peel and potato peel) of about 1kg each was oven dried to a moisture content of 20% for the potato peel and 35% for the plantain peel at 60℃ for a period of 48 hours as seen in literature. 100 g was weighed from the dried samples of each waste. After oven-drying the wastes, the dried and fresh wastes were chopped separately into small particles to allow for easy ingestion and digestion of the waste by the earthworms and they were kept in different containers.

2.3 Bin Preparation

Bin method of vermicomposting was used for the study and the preparation of the bin were as follows: Four plastic containers of dimensions 42 cm x 28 cm x 25 cm were selected and holes were drilled at the top (6), side (12) and at the bottom (6) of each container in order to provide aeration and drainage of excess water. They were thereafter weighed. Bedding materials (shredded paper and soil) were then introduced into each plastic container. The containers were labeled A1, A2, B1 and B2, respectively for identification of the samples in them (Plate I). Non-chlorine water was prepared by exposing the water to the atmosphere for two days and put into a spray bottle. The non-chlorine water was then sprinkled over each bedding material to regulate the moisture content within the level of 50-60 % by using moisture meter and to control the temperature within the range of 15-30℃. pH meter (Ohaus ST400-F portable pH meter) was used to determine the pH level of each prepared environmental condition and the value recorded. The final weights of the bins were then determined. After the preparation of the vermicomposting bins, the four bins labelled A1, A2, B1, and B2 were filled with the fresh plantain peels, dried plantain peels, fresh potato peels and dried potato peels respectively. The non-chloride water was then sprinkled over the wastes so as to maintain the moisture and temperature level as required. Earthworms were then introduced into the prepared bins. Bins A1 and B1 contained 100g of the fresh wastes and 20g of earthworms each, which gave the ratio 5:1 (waste/worm). Bins A2 and B2 contained 100g of pre-composted wastes and 20g earthworms each. Finally, the bins were covered with wet papers for the vermicomposting process to begin and the total weight of each container was measured.

2.4 Determination of Measured Parameters

The duration of the study was fifteen (15) days. During the study, the important parameters such as moisture content, temperature and pH level which could negatively affect the survival of the earthworms in the system were closely monitored and controlled (Mahmud, *et al.*, 2018) every five (5) days. Feeding of the worms were done at intervals of five (5) days for the entire duration of the study with a ratio of 5:1 (waste/worm). Each vermicomposting bin contained 100g of waste and 20g of earthworms in order to ensure quality vermicast production (as seen in previous studies). At the end of the vermicomposting process, manual method according to Munroe (2007) was used to separate earthworms from the produced vermicasts. The manual method was based on hand sorting or picking the worms directly away from the compost by hand. The vermicasts produced were then collected from each bin and taken to the laboratory for analysis to determine their Nitrogen, Phosphorus and the Potassium contents. The vermicomposting set up are shown in Plate I.

Plate I: Front view of the vermicomposting bins (plastic containers)

2.5 Determination of the Chemical Properties of the Vermicast.

The vermicasts produced from each bin were digested and diluted for chemical analysis. The chemical tests that were done on the vermicompost were Nitrogen, Phosphorus and Potassium (N-P-K) content. The Kjeldahl method as described by Kubota *et al.*, (2011) was used to determine the Nitrogen content; the phosohorus content was determined by the Ammonium Vanadomolybdate Absorptiometric Analysis as described by Koshino (1988). While the potassium content was determined using the Flame atomic absorption spectrometry as described by Kato *et al.*, (2010).

3 Results and Discussion

3.1 Results

The results obtained from the study are as presented on Tables 1 to 6

Table 1. Weight Loss in the Agricultural wastes over the study period

Samples	Initial weight(g)	Final weight (g)	Mass reduction (%)
A1	300	155	48
A2	300	165	45
B1	300	140	53
B2	300	152	49

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Table 2. pH values of Samples over the Study Period

Samples	1st day	5th day	10th day	15th day
A1	6.6	6.9	7.2	7.4
A2	6.7	7	7.3	7.7
B1	6.2	6.7	7.1	7.3
B2	6.5	6.7	6.9	7.3

Table 3. Moisture content values of Samples over the Study Period

Day/ Temp(^{0}C)	1st day	5th day	10th day	15th day
A1	22	24	21	23
A2	20	23	25	22
B1	21	25	22	25
B2	22	18	20	23

Table 4. Temperature within the system over the Study Period

Day/Temp (^{0}C)	1st day	5th day	10th day	15th day
A1	22	24	21	23
A2	20	23	25	22
B1	21	25	22	25
B2	22	18	20	23

Table 5. NPK contents of the samples and chemical fertilizer

Mineral content (%)	N	P	K
A1	0.2	0.05	0.4
A2	0.09	0.02	0.3
B1	0.11	0.04	0.3
B2	0.13	0.02	0.1
Average values	0.13	0.03	0.27
Chemical Fertilizer	1	1	1

A1= Fresh plantain peel, B1= Fresh potato peel, A2 = Pre-composted plantain peel and B2= Pre-composted potato peel

Table 6. Comparison of NPK concentration on Vermicomposting of this study with previous studies

	Mahmud et al.,(2018)	Othman et al., (2012)	This study
	28 days	14 days	15 days
	Eudrillus eugenae	*Eudrillus eugenae*	*Eudrillus eugenae*
	Banana peel	AKED café waste	Potato peel/plantain peel
N	3.14	0.197	0.13
P	4.26	0.0285	0.03
K	31.23	0.0136	0.27

3.2 Discussion of Results

Weight

Table 1 showed that there was reduction of weight in all the bins during the fifteen days vermicomposting period. Sample B1 gave the highest percentage of weight reduction of 53% while the others gave 48% (A1), 45% (A2) and 49% (B2). This change may be as a result of earthworms digesting these agricultural waste materials to produce a more homogenous substance.

pH value of samples

Table 2 shows pH behaviour of the fresh and dried (pre-composted) wastes. The pH in this study ranged from 6.2 and 7.4 for the fresh waste and 6.5 and 7.7 for the dried waste. The pH value increased in all the samples from the 1st day to 15th day from a pH initially near the acidity towards slightly alkalinity. Earthworms may be affected by pH; they showed a specific tolerance to acidity which may have influenced the distribution of their species in the soil.

Moisture Content

Table 3 shows moisture behaviour for the dried wastes and the fresh wastes. Results initially showed a value of 52 and 60% for Samples A1 and B1 (fresh wastes) respectively; humidity was maintained between 50 and 60% for this study as shown in Fig 3. The moisture content is an important control parameter in the process due to the fact that values outside of the reported range may generate anaerobiosis if it is excessive, whereas lack of humidity inhibits the microorganisms involved in the pre-composting process.

The initial moisture content for the pre-composted (dried) wastes (Samples A2 and B2) was 55 and 50% respectively, which maintained humidity between 50 and 57%. Moisture is critical for the survival of earthworms because it facilitates the absorption of oxygen, in addition, this parameter is important because it evaporates easily inside the body cavity's earthworm, especially in dry environments.

Temperature

The temperature observed in the bin of the pre-composted wastes (Samples A2 and B2) during the study period can be observed in Table 4. An initial value of 20^{0}C can be observed; within the first few days this value increased to 23^{0}C, it later decreased to 22^{0}C between the first and second week for A2 whereas for B2 the following can be observed; an initial value of 22^{0}C, within few days this value reduced to 17^{0}C, it later increased to 23^{0}C between the first and second week. The waste's temperature was maintained at an average with a gradient difference of 2^{0}C to 5^{0}C.

Table 4 also shows temperature behaviour in the bin of fresh wastes (Samples A1 and B1) during the period of study. The initial temperatures of the two were 21^{0}C and 22^{0}C respectively and remained between 21^{0}C and 25^{0}C. The temperature range for this process was less than what was shown in the pre-composted.

Nitrogen, Phosphorus and Potassium Concentration

Changes were observed in the Nitrogen content for the four samples (Table 5). Sample A1 gave the highest content of 0.20% followed by Sample B2 0.13%, then Sample B1 0.11% and lastly Sample A2 0.09%. According to Nandhini and Sumathi (2017), the Nitrogen enrichment pattern and mineralization activities mainly depend upon the total amount of nitrogen in the initial waste material and on the earthworm activity in the waste decomposition sub-system. Besides releasing nitrogen from compost material, earthworm also enhance nitrogen

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levels by adding their excretory products, mucus, body fluid and enzymes to the substrate.

The Phosphorus content was recorded minimum in all the four samples under this study (Table 5). Sample A1 gave the highest value of 0.05% followed by Sample B1 which gave 0.04%, while Samples A2 and A3 both gave 0.02% in the study. Microorganisms both in the intestinal organ of the worms and the organic waste have the ability to convert insoluble phosphorus into soluble forms (Adhami *et al*.,2014), therefore, the absence of Phosphorus in the agricultural waste may have resulted in the low concentration of Phosphorus.

Table 5 shows that Samples A1, A2 and B1 all gave maximum Potassium value except for Sample B2 which had Nitrogen value higher than the Potassium value. Sample A1 gave the highest Potassium value of 0.4%, followed by Samples A2 and B1 which both gave Potassium value of 0.30% and lastly, Sample B2 which gave a Potassium value of 0.10%. Nandhini and Sumathi (2017) suggested that an increase in Potassium level during vermicomposting may be due to the microbes present in the gut of earthworms which might have played an important role in this process. Premuzic *et al.*, (1998); Garg *et al.*, 2006 reported that acid production by the microorganisms is the major mechanism for solubilizing insoluble Potassium in the agricultural waste. Suthar (2007) have also reported that earthworm processed waste material contains higher concentration of exchangeable Potassium (K) due to enhanced microbial activity during the vermicomposting process, which consequently enhances the rate of mineralization.

3.3 Statistical Analysis

The data obtained from the study (Tables 1 – 4) were subjected to statistical analysis using ANOVA, to ascertain the significant effect the types of wastes had on these parameters (weight reduction, pH value, moisture content and temperature) on the wastes (Table 7). All the factors considered had p-values less than 0.05 which means that they are all significant.

Table 7. ANOVA for Weight, pH, Moisture content and Temperature

Parameters		Sum of Squares	df	Mean Square	F	Sig.
Weight reduction	Between Groups	96.897	3	32.299	775.173	0.000*
	Within Groups	0.333	8	0.042		
	Total	97.23	11			
pH	Between Groups	0.27	3	0.09	15.429	0.001*
	Within Groups	0.047	8	0.006		
	Total	0.317	11			
Moisture Content	Between Groups	169.258	3	56.419	20831.71	0.000*
	Within Groups	0.022	8	0.003		
	Total	169.279	11			
Temperature	Between Groups	13.912	3	4.637	2.778	0.110*
	Within Groups	13.354	8	1.669		
	Total	27.266	11			

*Sig (P ≤0.05)

Table 8. ANOVA for the NPK contents

Parameters		Sum of Squares	df	Mean Square	F	Sig.
Nitrogen	Between Groups	0.021	3	0.007	2945.143	0.000*
	Within Groups	0	8	0		
	Total	0.021	11			
Phosphorus	Between Groups	1.135	3	0.378	0.954	0.459
	Within Groups	3.17	8	0.396		
	Total	4.304	11			
Potassium	Between Groups	0.145	3	0.048	1152.063	0.001*
	Within Groups	0	8	0		
	Total	0.145	11			

*sig (P ≤0.05)

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The Nitrogen, phosphorus and potassium contents (Table 5) were also subjected to statistical analysis and it was observed that both Nitrogen and potassium contents were significantly affected by the types of wastes (P ≤0.05) while phosphorus was not significantly affected (Table 8).

Duncan multiple range test was used to check if the differences observed in the mean values of the parameters were significant (Tables 11 and 12). From Table 9, It was observed that indeed there were significant differences in weight reduction and moisture content of the plantain peels irrespective of type and state (fresh or dry). No significant differences were observed in the pH values of the peels (fresh plantain and fresh potato, dried potato), but there was significant difference in that of the dried plantain peel compared to the others. For the temperature, there were significant differences between the dried plantain peel and fresh potato peel while the fresh plantain and dried potato peels were not significantly different from each other in value.

Table 9. Duncan Multiple Range Test for the Samples

Samples	Weight reduction (%)	pH	Moisture Content (%)	Temperature (°C)
Fresh plantain peel	48.2±0.34^{b}	7.4±0.1^{a}	52.04±0.06^{b}	22.99±1.39^{ab}
Dried plantain peel	45.1±0.17^{a}	7.67±0.05^{b}	55.01±0.017^{c}	22.01±1.9^{a}
Fresh potato peel	53±0.11^{d}	7.3±0.00^{a}	60.02±0.03^{d}	24.97±1.01^{b}
Dried potato peel	49.0±0.05^{c}	7.3±0.00^{a}	50.04±0.08^{a}	23±0.00^{ab}

Means with the same alphabet are not significantly different from each other

Table 10 shows that the nitrogen values for all the peels were significantly different from each other; for potassium, there was no significant difference in the potassium content of the dried plantain and fresh potato peels, while there was significant difference in the potassium content of the fresh plantain, dried plantain and dried potato peels.

Table 10. Duncan Multiple Range Test for the Samples

Samples	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Fresh plantain peel	0.2±0.00^{d}	0.05±0.00^{a}	0.41±0.01^{c}
Dried plantain peel	0.09±0.00^{a}	0.02±0.00^{a}	0.30±0.00^{b}
Fresh potato peel	0.11±0.00^{b}	0.04±0.00^{a}	0.30±0.00^{b}
Dried potato peel	0.13±0.003^{c}	0.75±0.12^{a}	0.10±0.00^{a}

Means with the same alphabet are not significantly different from each other

3.4 Comparison of the Bio-fertilizer to Previous Studies

The average N-P-K content of Samples A1, A2, B1, and B2 (Table 6) were used to compare with previous studies on vermicomposting. This was done using two previous studies by Othman *et al*., (2012) and Mahmud *et al*., (2018). They were reviewed and compared with the result obtained in this study. This is shown in Table 6. From the result it can be seen that time may contribute to the yield of the NPK content, Othman *et al*., (2012) also reported that time can be a factor in determining the yield in vermicomposting, thus, a longer time of vermicomposting may yield more. Another factor that may have contributed to results observed was the type of wastes used.

3.5 Comparison of Bio-Fertilizer Produced from Fresh Waste and Pre-Composted Waste

The comparison of the bio-fertilizer produced from the fresh waste and that of the pre-composted (dried) waste was based on their various N-P-K content. Table 5 shows the N-P-K content of the fresh and pre-composted wastes. From Table 5, it can be observed that the fresh wastes have the highest N-P-K concentration, with the fresh plantain peel (Sample A1) having the maximum concentration. Sample A1 produced the highest Nitrogen, whereas Sample A2 produced the lowest. Sample A1 produced the highest Phosphorus whereas Sample A2/B2 produced the lowest. Sample A1 produced the highest Potassium whereas Sample B2 produced the lowest.

3.6 Comparison of these Properties with that of Chemical Fertilizers

Chemical fertilizers are mixed in diverse ratios but ordinarily the all-purpose chemical fertilizers are mixed in ratio of 1:1:1. Table 5 shows the comparison of concentration (in ratio) of Nitrogen, Phosphorus and Potassium in this vermicomposting study with that of the conventional chemical fertilizers. It can be seen that there is a difference between the bio-fertilizer and chemical fertilizer for Nitrogen, Phosphorus and Potassium in the four samples.

Sample A1 has 75%, 0%, and 88% of N-P-K composition ratio, Sample A2 has 80%, 0%, and 93% of N-P-K composition ratio, Sample B1 has 66%, 0%, and 88% N-P-K composition ratio and Sample B2 has 86%, 0%, and 80% N-P-K composition ratio respectively. Sample B2 has the highest Nitrogen difference of 86%, A2 has the highest Potassium difference of 93%, while the Phosphorus ratio all remain the same. Othman *et al*., (2012) reported something similar in their study; the values they obtained from vermicomposting for nitrogen and phosphorus were greater than the values reported for the chemical fertilizer and the same number for the potassium values for both. Nitrogen has been conventionally reflected as one of the most significant plant nutrients (Nandhini and Sumathi, 2017). It is found in healthy soils and give plants the energy to grow. Nitrogen is part of the chlorophyll molecule that gives plants their green colour and is involved in creating food for plant through photosynthesis (Chaturvedi, 2005).

According to Wang *et al*., (2013) potassium is a vital plant nutrient and it is considered second only to nitrogen, when it comes to nutrients needed by plants. In photosynthesis, potassium regulates the opening and closing of stomata and therefore requires CO_2 uptake.

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Potassium also plays a vital role in the regulation of water in plants. It is also known to improve drought resistance. Potassium deficiency may cause abnormalities in plants. Usually the symptoms are growth related (Wang *et al*., 2013). According to Othman *et al.*, (2012), soils from vermicomposting is very good for plants growth as it contains large amounts of nitrogen.

4 CONCLUSION

The study focused on the conversion of agricultural wastes into bio-fertilizer using vermicomposting method. It can be concluded that agricultural waste materials can be converted into bio-fertilizer with earthworm playing a vital role for this conversion and producing a material that is eco-friendly, non-toxic, and consumes low energy input. There was reduction in weight of all the samples during the vermicomposting process. The N-P-K concentration (in ratio) for the bio-fertilizer is higher than that of the chemical fertilizer. Agricultural waste disposal using earthworms (vermicomposting) looks very promising as it can help to not only be used as a form of waste treatment but also to produce nutrient rich bio-fertilizer.

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