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ORIGINAL RESEARCH

Vermicomposting evaluation of different combinations of organic waste using *Perionyx excavates*

Sona Huntley[1], Abdullah Adil Ansari[1*]

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Abstract

Purpose Organic waste is a serious concern across the globe contributed by human activity that can be managed by efficient process like vermicomposting which can reduce the waste that is dumped in landfills into useful product vermicompost. This research was conducted to study the bio-conversion of organic waste (fruit and vegetable waste) using *Perionyx excavatus* into quality vermicompost.

Method Three organic waste treatments were used for the vermicomposting process: FW [Fruit waste + Cow Dung], VW [Vegetable waste + Cow Dung], FVW [Fruit waste + Vegetable waste + Cow Dung]. A control group was set up without earthworms for each treatment. The compost was harvested after 38 days, weighed and the rate of production per day was calculated. The harvested compost was then subjected to physico-chemical analysis to determine the nutrient status.

Results The experimental group had a significant rate of production with higher quantity than the control groups. Vermicompost produced from vegetable waste was 515.45 g (51.55%) which was the highest among all the treatments. The lowest amount of compost was produced by the Fruit + Vegetable waste treatment in the control group (184.16 g). The nutrient status was within the acceptable range for the experimental groups.

Conclusion Epigeic earthworm *Perionyx excavatus* is highly efficient in reducing organic waste (fruit and vegetable waste) into vermicompost enriched with nutrients necessary for plant growth.

Keywords Production, Harvest, Decomposition, Processing

Introduction

1.3 billion tonnes of food is wasted in Latin and Caribbean region based on information from regional representative (Benítez 2019). In Latin America, the highest wastage rates (40-55%) are from fruits, vegetables, roots and tubers (FAO 2016). Usually, when food is thrown away, it is collected and taken to landfills where it is allowed to decompose. The disposal of food waste in a landfill site contributes to global warming through the generation of the greenhouse gas like methane (David 2013). It is therefore pertinent that alternative solutions for food waste disposal should be explored and one such method is Vermicomposting. This technique helps not only in reduction of food waste that would normally go to landfill sites but also it is useful in production of organic soil amendment.

The use of compost on farmlands may reduce farmers' dependence on inorganic fertilizers which often leached from the soils into waterways overloading them with nutrients and eventually resulting in eutrophication. Additionally, if implemented on a large scale, vermicomposting can reduce the potential greenhouse gas emissions liberated from decomposing organic waste in landfills as the amount of waste dumped decreases. There is now a shift happening worldwide where more consumers are demanding organically produced food and are willing to pay top dollar for such goods. Therefore, the use of vermicompost for crop production will allow farmers to market their produce under the 'organic' banner, thus making it more appealing to health conscious consumers which will in turn benefit

✉ Abdullah Adil Ansari
abdullah.ansari@uog.edu.gy

[1] University of Guyana, Georgetown, Guyana

them economically. The research was carried out to assess the efficiency of the composting earthworm *Perionyx excavatus* in converting different combinations of organic waste into vermicompost. In order to fulfill this aim, the research was conducted to specifically observe the (i) rate of compost production, (ii) productivity of composting units and (iii) physico-chemical characteristics of compost produced.

Materials and methods

This research was conducted in the year 2019 at Eccles, East Bank Demerara, Guyana. Three organic waste treatments were utilized for the experiment; FW [500 g Fruit Waste + 500 g Cow Dung], VW [500 g Vegetable Waste + 500 g Cow Dung], FVW [250 g Fruit Waste + 250 g Vegetable Waste + 500 g Cow Dung]. The following abbreviations were used for organic waste treatments: E: Experimental group, C: Control group, FW: Fruit waste, VW: Vegetable waste, FVW: Fruit and Vegetable waste. The fruit waste, vegetable waste and cattle dung used were dried before being used in different treatments.

A total of twelve (12) units were set up using perforated plastic bins; nine (9) units were experimental group and three (3) units were control groups. The design of each unit followed as per guidelines of Ramnarain et al. (2018). Each unit consisted of 4 layers: **Layer 1:** pebbles and sand (6 cm), **Layer 2:** Moist loam soil (15 cm)**,** **Layer 3:** Semi Dry Cow dung, **Layer 4:** Fruit and/ or Vegetable waste. The units were arranged using a randomized block design (Fig. 1 and Fig. 2).

Forty- two (42) clitellated *Perionyx excavatus* earthworms were inoculated into the second layer of each of the nine experimental vermicomposting units one day prior to the addition of the fruit and vegetable waste layer. The criteria for using 42 earthworms is based on processing rate of fruit and vegetable waste in terms of quantity and volume (high reproductive rate and short life cycle of *Perionyx excavatus* (Ismail 2005) with doubling time of 10.71 days for density and 14.06 days for biomass). The next day, 300 g of food waste + 300 g of cow dung was added to the respective units. The addition of waste continued for two more weeks at the rate of 100 g of food waste and 100 g of cow dung per week for each unit. The waste was not added in week 4 and 5. The pattern of addition of waste in control units was done in a similar way as in other treatments.

All units were moistened with water, covered with mesh fabric and kept in a shaded area so as to protect the units from any pests as well as prevent rapid moisture loss which could have resulted in earthworm mortality. In order to maintain moisture content, each of the units were sprinkled with water once per week. Temperature was monitored on a weekly basis using the REOTEMP compost thermometer. Layers three and four were also turned once per week to aerate the material.

Three days prior to harvesting, watering of units was discontinued. After thirty-eight (38) days, the finished compost was harvested, sieved using ¼ mesh and placed in labelled sections to air dry. After two days of air drying, the samples were weighed in grams using an electronic balance to determine the amount of compost produced.

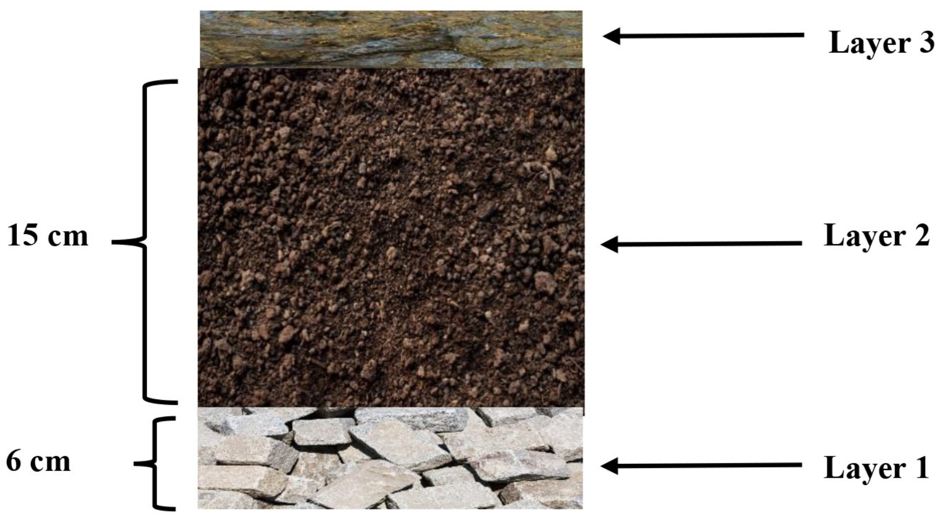

Fig. 1 Schematic diagram illustrating the set-up of each vermicomposting unit

Block 1

C VW	E FVW1	C FW	E VW1	C FVW	E VW3

Block 2

E FVW2	E FW3	E FW3	E FW1	E VW2	E FW2

Key
E: Experimental group
C: Control group
FW: Fruit waste
VW: Vegetable waste
FVW: Fruit and Vegetable waste

Fig. 2 Schematic of the randomized block design in which the vermicomposting units were placed

The rate of production per day was calculated using the formula:

$$\text{Rate of production (g/day)} = \frac{[\text{weight of harvested compost (g)} / \text{weight of original substrate (g)}]}{\text{Time taken to decompose (days)}}$$

Productivity was calculated in percentage using the formula (Ramnarain et al. 2018): Productivity of vermicompost = (Harvested vermicompost /Initial mass of organic waste) x 100%.

The finished compost from each unit was also subjected to physico-chemical analysis in order to establish its suitability for agricultural use (quality control). The parameters tested were moisture content, pH, electrical conductivity, nitrogen, organic carbon, potassium and phosphorus. pH and electrical conductivity were determined using electronic meters. Moisture content was calculated gravimetrically. Nitrogen content was measured using the Kjedahl method. Organic carbon was recorded by using Walkley – Black method and Phosphorus analysis was done by using Bray and Kurtz P-1 method and Potassium assessment was done by using Ammonium acetate extraction.

Statistical Package for Social Sciences (SPSS) was used for statistical analysis of data obtained from the experiments. The weight of vermicompost from different treatments as well as the physico-chemical parameters of the different vermicompost were subjected to One way analysis of variance (ANOVA) and the post hoc Tukey's test ($P < 0.05$).

Results and discussion

Rate of compost production

The experimental treatments were observed for higher rate of production when compared to the control treatment groups without earthworms (Fig. 3 and Fig. 4).

Overall, the calculated production rates were found to be considerably less when compared to Shultz (1981). Since Shultz took earthworm weight into consideration, a more accurate representation of production rate per day was shown; multiplying 0.13 by the 1450 lbs. of earthworms in that study gave an estimation that 188.5l bs. of waste was processed per day which

Fig. 3 Composting units after first addition of organic waste

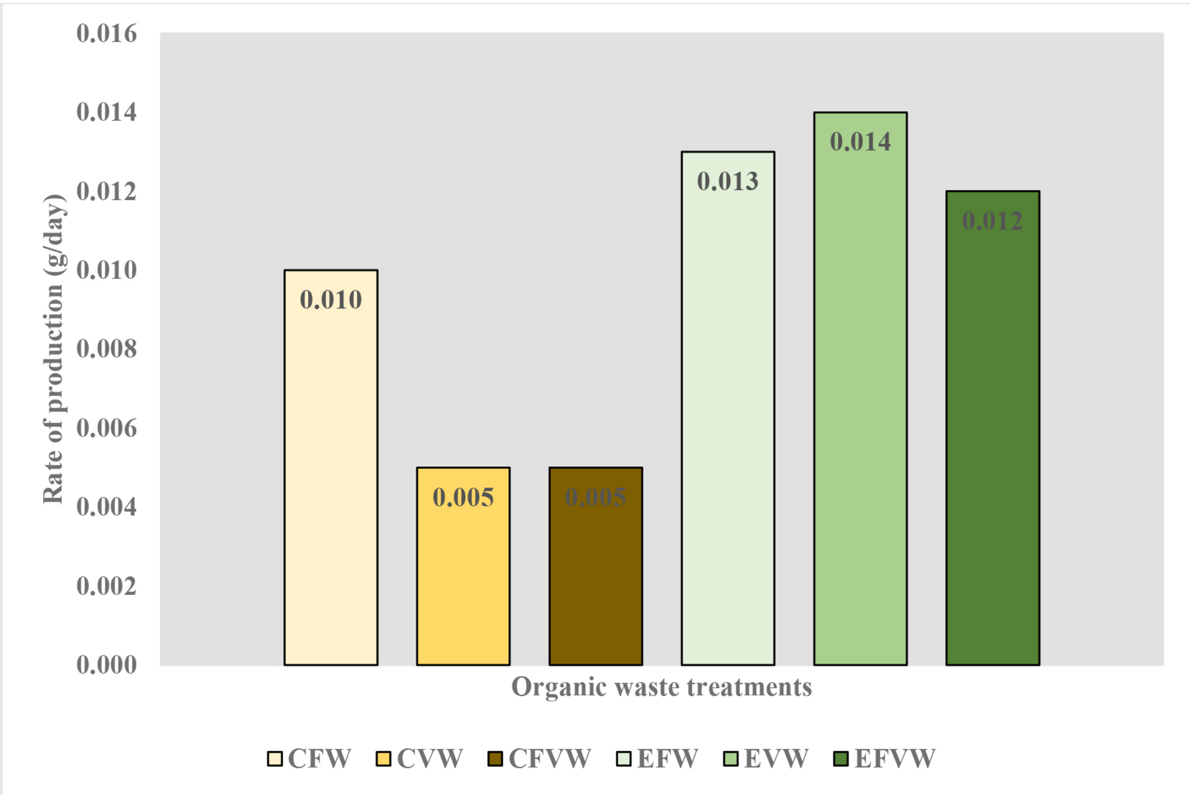

Fig. 4 Rate of compost production in the control and experimental treatment groups

when multiplied by 110 days bringing very close to the amount of organic waste said to be processed. The formula used in this research was therefore flawed because if the daily rates calculated were indeed accurate then multiplying each rate by 38 days was supposed to reflect the amount of compost harvested at the end of the experiment which it did not. However, if the formula by Schultz (1981) was used in this study then rate could not have been calculated for the control group which did not have earthworms and therefore one would not have been able to identify whether the presence of the *Perionyx excavatus* resulted in compost being processed faster daily or not.

Despite this flaw, the general trend observed in this study can still be used to paint a general picture of the rate at which composting occurred in the control versus experimental groups since the harvest data (weight of compost) used in the calculations was specific to the individual treatments. Moreover, the higher rate of production which was observed for treatments with earthworms is supported by past studies (Aira et al. 2007; Sinha et al. 2010; Ansari et al. 2016).

Productivity of composting units

The results of the three organic waste treatments belonging to the experimental group showed that the treatment with Vegetable waste generated the largest quantity of vermicompost at the end of the thirty-eight (38) day composting period followed by the treatment with Fruit waste when compared to the treatment with combination of Fruit + Vegetable waste. The total quantity of vermicompost harvested from these treatments were 515.45 g, 480.09 g and 468.57 g, respectively, thereby resulting in productivity percentages of 55.55% for Vegetable waste, 48.01% for Fruit waste and 46.86% for Fruit + Vegetable waste. These results are consistent with the productivity percentages reported by Ansari (2011), Murali et al. (2011) and Ramnarain (2018).

In the control group on the other hand, the Fruit waste treatment produced 385.14 g of compost which was the highest followed by 194.9 g of compost for the Vegetable waste treatment and 184.16 g for the Fruit + Vegetable waste treatment. The productivity percentages for the control group were 38.51%, 19.49% and 184.16%, respectively, which are significantly lower when compared to those of the experimental group. The trend observed in the rate of production are shown in Table 1 indicate higher production of vermicompost in experimental groups.

Therefore, it can be inferred that the decomposition of organic waste and by extension production of compost, occurred slower in the absence of a composting earthworm in this study (Fig. 5).

In addition to presence of earthworms, another factor which may have affected the productivity of compost in this study was the choice of substrate. Aynehband et al.

Table 1 Harvest data of compost

Harvest Data	Control Group			Experimental Group		
	FW	**VW**	**FVW**	**FW**	**VW**	**FVW**
Initial amount of organic waste (g)	1000	1000	1000	1000	1000	1000
Weight of compost harvested (g)	385.14	194.9	184.16	480.09	515.45	468.57
Productivity %	38.51	19.49	18.42	48.01	51.55	46.86

Abbreviations: FW: Fruit Waste, VW: Vegetable Waste, FVW: Fruit + Vegetable Waste

(A) (B)

Fig. 5 Comparison of material harvested from control units (A) and experimental units (B)

(2017) suggested that the variations in productivity percentages which were observed throughout their study is an indicator of how substrate choice can be influential in determining the amount of compost produced during vermicomposting.

Physico-chemical composition of compost

The physico-chemical parameters measured for this study were pH, Electrical conductivity, Moisture content, Temperature, Organic carbon, Nitrogen, Phosphorus and Potassium (Table 2).

Higher pH was observed in control group treatments with CFW (7.55) followed by CFW (7.51) and CFVW (7.47). For the experimental group, the highest pH recorded was 7.38 for EFW followed by 7.34 for EVW and 7.26 for EFVW. The pH values recorded for all the treatments were within the recommended range for compost meant for agricultural use which is 6.5 – 8 (Rostami 2011; David 2013; Chrohn 2016). Furthermore, these pH results are consistent with several other past vermicomposting experiments that also observed compost pH to be within neutral range (Chaudhuri et al. 2000; Pattnaik and Reddy 2009; Huang et al. 2012; Chin et al. 2018). Amouei et al. (2017) proposed that the pH of compost shifts toward the alkaline side as decomposition occurs due to microbial metabolic activity which results in the production of alkaline products such as ammonium. Additionally, Huang et al. (2014) suggested that compost with pH values close to neutral, as recorded in this experiment, can be beneficial in the remediation of acidic soils.

Table 2 Physico-chemical parameters of Control and Experimental treatment groups

Parameters	Control Group			Experimental Group		
	FW	VW	FVW	FW	VW	FVW
pH	7.51	7.55	7.47	7.38	7.34	7.26
Electrical conductivity (dS/m)	5.22	7.55	5.58	1.55	2.14	1.46
Moisture content (%)	78	89	62	68.66	69.33	71.3
Organic Carbon (%)	25.3	22.2	19.3	13.83	15.43	17.57
Nitrogen (%)	2.03	2.48	2.66	1.29	1.73	2.28
C:N	12.5	8.9	7.3	10.7	8.9	7.7
Phosphorus (%)	0.0196	0.0154	0.0179	0.0147	0.0168	0.0166
Potassium (%)	0.519	1.06	0.769	0.25	0.29	0.28

Abbreviations: FW: Fruit Waste, VW: Vegetable Waste, FVW: Fruit + Vegetable Waste

NB: Mean ± SD could not be calculated for control group since only a single measurement was done for each treatment.

Similar to the observed trend for pH, the electrical conductivity (EC) values recorded in this study show the control group with a higher EC than the experimental group. The EC values in descending order for CVW, CFVW and CFW were 7.55 dS/m, 5.58 dS/m and 5.22 dS/m, respectively. The experimental group with EVW, EFW and EFVW had the values 2.14 dS/m, 1.55 dS/m and 1.46 dS/m, respectively. From the results detailed above, it is safe to suggest that the salt concentration was considerably higher in traditional compost (control group) as opposed to vermicompost (experimental group). The control group treatments may have required more processing time to become stabilized in order to lower the EC value as suggested by Chin et al. (2018). Nevertheless, the values obtained were similar to the study by Huang et al. (2017); their control group had a higher EC value of 504 mS/m than their experimental group with an EC value of 261.1 mS/m (Note that 1 dS/m = 100 mS/m). The percentage moisture content of all vermicompost harvested from the experimental group were found to be consistent with the 65 – 75% range suggested by Rostami (2011) (Table 2).

In the control group, however, Vegetable waste compost (CVW) and Fruit waste compost (CFW) had moisture contents of 89% and 78%, respectively, which is notably higher than suggested range. Yadav and Gupta (2017) highlighted that moisture content can vary depending on substrate chosen for composting as all substrates may have different levels of moisture.

Initial temperature for the control and experimental treatment groups ranged from 87° F – 91° F. Throughout the five (5) weeks composting period, there were fluctuations in temperature for all treatments. The fluctuations were between 86° F and 90° F. The most significant fluctuations were observed in the control-Fruit + Vegetable waste treatment (CFW) (Fig. 6).

In week 3, a temperature rise was observed for both control and experimental treatment groups. However, in weeks 4 and 5, temperature in both the groups stabilized. According to Ansari and Hanief (2015), the temperature fluctuation that occurs during the composting process is due to the microbial activity during the decomposition of organic waste. Due to the fact that temperature in this experiment ranged from 86° F – 91° F, the researchers posit that the mid-range mesophillic bacteria were most active throughout composting. According to Ansari and Hanief (2015), mesophillic bacteria thrive in temperatures ranging from 21° C – 32° C. The spike in temperature in week 3 could be attributed to increased microbial activity as reported

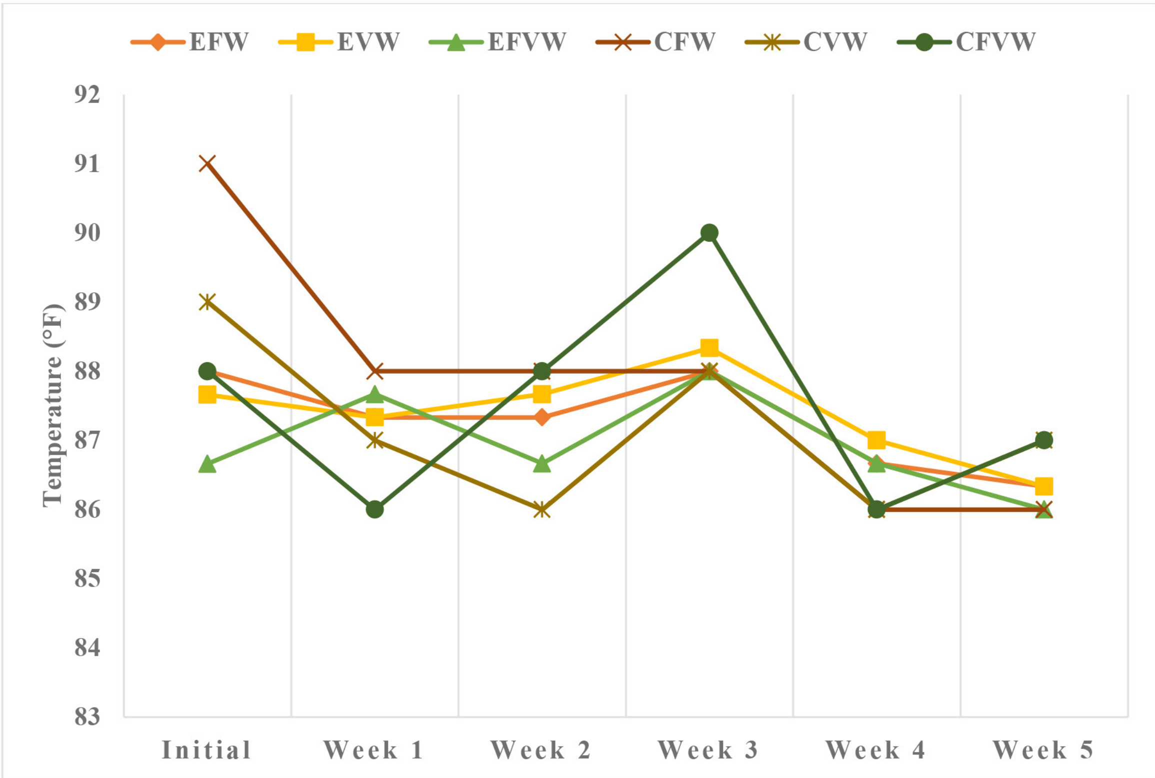

Fig. 6 Fluctuations in temperature throughout composting process for each of the treatments

by Jara-Samaniego et al. (2017). Total organic carbon was observed to be less in experimental group vermicompost when compared to control group compost. Higher percentages of organic carbon were observed in the control group (Table 2).

These results are contradictory to studies where the findings were that vermicompost has higher amounts of available potassium than traditional compost (Ansari and Jaikishun 2011; Cai et al. 2018). The amount of available potassium (exchangeable K) in vermicompost is usually attributed to increased microbial activity in the earthworm's gut which in turn causes high mineralization (Yadav and Gupta 2017). Garg et al. (2006) and Yadav and Gupta (2017) stated that the primary process which causes the transformation of insoluble potassium into available potassium is acid production by microorganisms. It was also suggested by Zhi-wei et al. (2019) that a low microorganism presence can inhibit the mineralization process. Taking these details into consideration, it is possible that the microbial biomass present in earthworm gut is not very effective in mineralizing potassium and phosphorous.

Conclusion

This research sought to assess capacity of composting earthworm *Perionyx excavatus* in recycling organic waste into usable vermicompost. This was done by determining the rate of production, measuring quantity of vermicompost produced and examining the overall nutrient status of the finished product. Higher rates of production were observed for all treatments that contained the *Perionyx excavatus* which is an indication that earthworms present resulted in faster decomposition of organic waste. The elevated organic carbon content in the treatments without earthworms also implied that composting occurred at a slow rate in these treatments. In addition to the peak production rates, there was also a corresponding higher quantity of vermicompost harvested from the treatments with earthworms. Although the vermicompost had a more ideal pH and Electrical Conductivity to allow for release and uptake of available nutrients by plants, higher quantity of Nitrogen, Phosphorus and Potassium were observed overall in the treatments without earthworms. Based on these findings, it is clear that the *Perionyx excavatus* is indeed capable of transforming organic waste into vermicompost.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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