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Research Article

Comparison of the compost bin and vermicomposting methods for residential waste management

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ABSTRACT

Solid waste management continues to be a serious environmental issue due to the increase in industrialization, population growth, and urbanization. However, recycling organic wastes through composting techniques provides an opportunity to mitigate the impacts on the ecosystem and the pressure on landfills and be economically feasible and sustainable. Composting bins and vermicomposting techniques experimented with within this project have exhibited excellent results in nutrients and conditions conducive to plant growth. However, the enhanced nutrient composition was recorded for nitrogen (N) in the vermicompost bin (VB) (57.27±3.13 ppm) than compost bin (CB) (31.96±3.72 ppm), potassium (K) VB (1154.56±78.71) than CB (1000.4±139.04 ppm), magnesium (Mg) VB (1217.3±126 ppm) than CB (525.3±138 ppm), iron (Fe) VB (3.76±0.27 ppm) than CB 1.32±0.25 ppm) and copper (Cu) VB (11.01±3.14 ppm) than CB (3.31±0.09 ppm). Moreover, statistical analyses have indicated a significant difference ($p>0.05$) in N, Mg, Ca, and Cu between the compost produced from VB and CB, respectively. It is important to note that both processes can produce the quality of compost sustainably, vermicompost with a higher amount of N progressively will reduce the processing and will boast plant growth and development and hence higher crop production and yield.

Keywords: Biodegradable, compost, earthworms, organic waste, vermicompost, waste management

INTRODUCTION

The issue of solid waste management concerns all habitations across the globe. Waste may comprise biodegradable, non-biodegradable, or a mixture of both. How solid waste is managed varies from non-collection and disposal to dumping at various sites inclusive of landfills, incineration (whether regulated or not), or even disposal into various waterways (Ansari & Hanief, 2015; Ozbay et al., 2021; Sewak et al., 2021). Biodegradable organic waste can account for up to 46% of all solid waste generated globally and poses a serious risk of pollution to soil and water environments (Ansari et al., 2020). The increased volume of organic waste produced globally and its potentially adverse impact on health and the environment necessitates that this problem is addressed urgently sustainably and holistically (Karim & Wetterhan, 2020).

Organic waste is biodegradable, making it easily recyclable. Composting is an approach that can effectively remedy the problem (Ansari et al., 2016; Zhao et al., 2022). Large scale composting has taken root in North America and Asia (Ansari et al., 2020) however; residential composting is also being encouraged. Residential composting can divert as much as 30% of household waste away from the garbage and thus, reduce the amount of waste dumped at landfill sites. Composting in essence is the accelerated natural process

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of decomposition of organic matter, by providing optimum conditions for decomposing organisms to function (Zhao et al., 2022). Composting benefits include reduced waste stream, reduced methane emission from landfills, improved soil health and reduced erosion, water conservation and a reduction in personal food waste (Agamuthu & Law, 2020).

All compostable materials are either carbon or nitrogen-based and may comprise agricultural waste, animal waste, urban solid waste and waste from agro-industries (Ansari et al., 2020). The best approach to composting depends on where you live, the kind and amount of waste to be composted, how much space is available, and the amount of time dedicated to the process (Karim & Wetterhan, 2020; Kutsanedzie et al., 2021). Composting can be passive which takes 1-2 years, or active which takes 4 weeks to 12 months. The former entails leaving the material to decompose naturally undisturbed, while the latter necessitates the use of decomposing organisms or regularly turning the material to accelerate the process (Yuvaraj et al., 2021). Composting options include but are not limited to vermicomposting (worm bin), enclosed bin or compost tumbler (Alshehrei & Ameen, 2021).

The heap and pit composting are two methods common in Bangladesh and the heat generated over the 2–3 month process is enough to destroy pathogens, weed seed and pests (Ansari et al., 2016). The duration for these composting methods depends on material type, the surface area of materials, how often the pile is turned and the size of the pile. The most efficient pile is between 3-5 ft, with smaller piles taking longer than larger ones (Ansari et al., 2020). Vermicomposting on the other hand utilizes the action of earthworms to break down organic waste into compost (Alshehrei & Ameen, 2021; Ansari et al., 2016). Earthworms eat around half their body weight in a day and as such vermicomposting is faster than conventional composting methods(Ansari et al., 2020; Yuvaraj et al., 2021).

Composting provides a partial solution to an issue of great concern in many communities. Landfills are filling up all around the country, garbage incineration is becoming increasingly unpopular, and other waste disposal options are becoming difficult to ascertain (Agamuthu & Law, 2020; Ozbay et al., 2021). Composting provides a way to reduce the amount of waste that needs to be disposed of and convert it into a product that is useful for gardening, landscaping, or house plants (Domínguez & Gómez-Brandón, 2012; Edwards, 1998). Ansari and Hanief (2015), address the solid waste disposal in urban Guyana and suggested vermicomposting as an efficient remedy. The objectives were to vermicompost water hyacinth, bermuda grass and vegetable waste, and to provide knowledge and skills to farmers in Guyana (Ansari & Hanief, 2015). Three units were set up and tested with all being successful, reflecting a 30% reduction in waste volume. It was helpful to see the success of the vermicomposting research. However, the composted materials did not reflect the waste generated by the average urban resident (Ansari & Ismail, 2001).

Ramnarain et al. (2019) researched vermicomposting using epigeic earthworm *Eisenia foetida* and different organic materials. The objectives were to build a vermicomposting station, import worms and produce vermicompost (Ansari et al., 2020). Rice straw and grass were successfully composted and data garnered on temperature, humidity and pH will prove very useful in successfully undertaking this research. Although grass is more of a ubiquitous residential waste, rice straw is not and it is suggested that other types of waste should be explored in future studies (Ramnarain et al., 2019). Ansari et al. (2016), highlighted the importance of biofertilizers such as vermicompost on crop sustainability and productivity and the potential benefits to a country's economy. This is significant since it suggests that similar success and benefits can be seen in Guyana, having a similar push towards a green economy.

High dependence on chemical fertilizers in the agriculture sector and the large amount of solid waste generated globally seem to be the trend (Ansari et al., 2020). The research highlighted the sustainability of vermicomposting and its economic and environmental benefits. The information contained in the vermicomposting process is important to this research. Similarly, research was also done on composting to demonstrate the effectiveness of residential composting (Ferreira et al., 2018). They evaluated the composting of household organic waste as a substitution for cattle manure, with a view to its application in the fertilization of cherry tomatoes (*Solanum lycopersicum* Mill., var. cesariforme) (Darwin et al., 2003; Ferreira et al., 2018).

The efficiency of food-waste composting using a simple and small-scale domestic composter. Three composting trials were also performed using food waste and wood chips in 10 l plastic bins in various filling systems. This research is beneficial since it explains the process of composting and examined the effect of temperature on food waste composting (Vich et al., 2017).

Moreover, a study carried out in India with significant producer of waste due to poor waste disposal management. The goal was to make it easier for households to practice composting, whereby the problem of their fruit and vegetable wastes can be mitigated. A compost bin was designed, that was easy to operate and did not attract insects or rodents, for home composting. The compost recipe was formulated alongside the nutrition composter using fruit and vegetable peels or herbs and succulents (Chetty & Sum, 2021).

Lekammudiyanse and Gunatilake (2009) examined the efficacy of the compost bin as a waste management technique for household waste, to define the physical parameters of compost (colour, odour, texture, pH, moisture, bulk density and particle size), and to identify particular problems associated with the compost bins. Based on the findings it was concluded that compost bin is not a 100% efficient waste management technique (Lekammudiyanse & Gunatilake, 2009).

MATERIALS AND METHODS

Vermicomposting process and bin preparation

The vermicomposting unit was set up using three 200 l plastic barrels and following guidelines and methods from Ansari and Ismail (2001). The earthworms were first cultured then fed with residential waste. The following steps was followed in the construction of a unit vermicomposting unit:

1. The bottoms were perforated, and the opening covered to allow for adequate aeration.
2. The barrels were positioned in a shaded area to prevent them from receiving direct sunlight and rainfall.
3. A layer of stone was placed followed by a layer of sand and a layer of moistened garden soil.
4. Earthworms were then introduced to the layer of soil with a layer of cow dung then a layer of chipped grass.
5. The barrels were covered and left for 8 weeks to allow worms to grow and multiply.
6. After earthworms' proliferation, layers of chopped residential waste was added weekly and moistened when necessary.
7. At the end of 10 weeks, compost was ready and harvested, sieved, collected & placed in bags.
8. The compost produced can be mixed with 75% of the soil and be added to plants.

Compost bin construction

The compost bin was set up at the end of the culture period of the vermicomposting units for both methods to progress simultaneously.

1. The bottom and sides of the barrels was perforated to allow for aeration and appropriate amounts of residential wastes mixed.
2. The barrels were positioned in a levelled open area. A layer of waste was added to the barrel and topped with a thin layer of cow manure until the desired volume was attained.
3. Layers was moistened and the covers were secured on the barrels.
4. The contents of each barrel were turned to mix and aerate after being left for 2 weeks. Barrels were turned once a week until the process was completed (10 weeks).
5. At the end of 10 weeks, compost was harvested, sieved and transferred to the bags.

RESULTS AND DISCUSSION

pH and temperature

Over the six weeks composting period, the temperature and pH were recorded for each of the three vermicomposting bins and the three composting bins. The average temperature over the six weeks did not vary much and stayed within a 3° F range (between 84° F to 87° F), while actual temperatures recorded had a 5° F range (between 85° F to 88° F). Average pH values recorded over the composting period held constant at pH 7.0 except for the first week when it was pH 7.2. The average pH range was pH 7.0 to pH 7.2, while the actual pH range across the three units was pH 7.0 to pH 7.5. In the worm bin, a pH of 6 to 7 is optimum.

For the compost bin, average temperatures showed moderate fluctuations with a 22° F range (between 85° F to 107° F), while the actual temperature range across the three compost bins was 31° F (from 85° F to 116° F). The average pH over the composting period moved from neutral to slightly acidic then back to neutral. Average pH values ranged from pH 6.5 to pH 7.1, while actual pH values across the compost bins ranged from pH 6.4 to pH 7.5.

The average temperature changes for the vermicomposting bins (VB) and composting bins (CB) over the six weeks composting period are depicted in Figure 1. The average temperature for VB shows very little variation. However, average temperatures for CB displayed more variations with two distinct peaks with a dip at weeks 3 and 4. It should be noted that at week 3 the area the CB were located flooded as a result of inclement weather and this could have possibly had an effect on the temperature. The three CB had to be subsequently elevated to avoid further flooding in that area. The VB was not affected by flooding during the composting period.

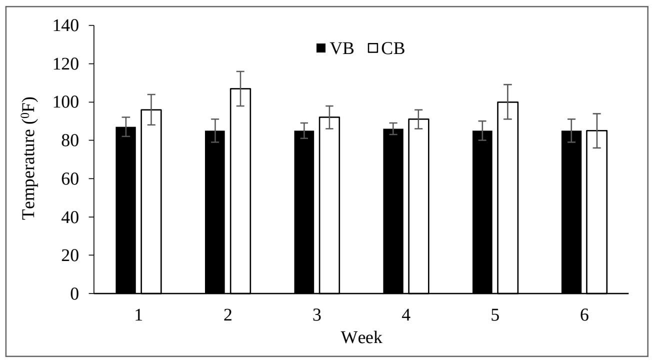

Figure 1: Average temperature change in vermicomposting and compost bin

The average pH for VB showed an initial dip then a constant neutral value throughout. CB pH values on average, however, showed a steady decline from neutral to slightly acidic, then a sharp return to neutral. The flooding that affected CB may have also affected the pH values (Figure 2).

Composting is a type of integrated waste management strategy for turning organic waste into a valuable product. Composting processes differ in terms of decomposition, potency, maturity, and sanitation (Mengistu et al., 2018). Temperature is an aspect of the composting process that is described as crucial since it might indicate how

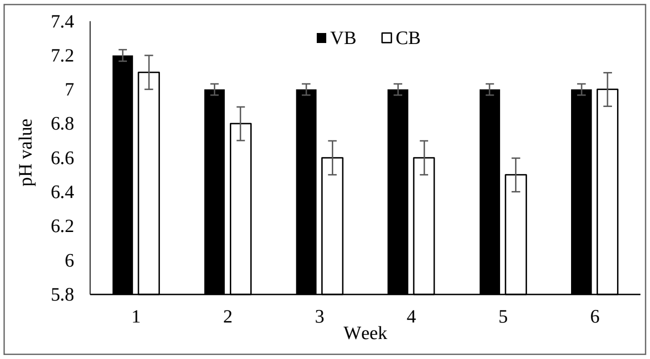

Figure 2: Average pH in vermicomposting and compost bin

effectively the process is progressing. It was found that the average temperature for vermicomposting was 85.5°F and 95.2°F for composting. Rostami (2011), stated that temperature plays an important role in earthworm survival. Since *E. foetida* was used in this unit, the preferred temperature range was 35-88°F. Earthworms are more productive when the temperature is between 65 and 80° F. The temperature that is too hot or cold will stress the worms. The worms slow down and become less productive if the temperature drops below 50° F. Also, the worm may be too hot to survive if the container is closed with a temperature rising above 90° F (Domínguez & Gómez-Brandón, 2012; Pisaheba et al., 2013; Wang & Shen, 2018). In the case of the compost bin, pathogenic organisms and unwanted weed seeds require high temperatures to be destroyed. In addition, in the thermophilic temperature range, the breakdown is quicker. Temperatures between 135 and 160° F are ideal. Because few thermophilic species actively decompose over 160° F, temperatures above this for long periods are undesirable. A gradual fall in temperature towards the end of the process indicates the depletion of nutrients and the process is approaching stability (Kutsanedzie et al., 2021).

For various aspects of soil fertility and plant growth characteristics, the pH of the soil or potting mixture used to grow plants is also crucial. Based on the findings recorded over six weeks, an average pH of 7.0 was found for vermicomposting unit and 7.7 for composting. The pH from both units varied depending on the type of raw materials used in the process. Ansari et al. (2020) highlighted that pH ranges from 5-9 during the vermicomposting process and reaches neutral as it reaches harvest. This is a result of the production of CO_2 and organic acids being produced during microbial metabolism. Mladenov (2018) also suggested that the pH is significant because the worms require neutral soil that is neither too alkaline nor too acidic. If the pH is too high or too low, it will be unhealthy for the worms. An earthworm's gut also deodorizes food waste and adjusts the pH of castings to around 6-7, which is the perfect pH for most plants to access soil minerals. For composting the bacteria usually thrive in neutral to acidic environments, with pH levels ranging from 5.5-8. Organic acids are generated during the early phases of degradation. Fungi thrive in acidic environments, which aid in the degradation of lignin and cellulose. Organic acids are neutralized as composting progress, and mature compost typically has a pH of 6-8 (Pisaheba et al., 2013). It is also important to note that the pH value of compost is an indicator of the process of decomposition and stabilization; but is not however an absolute indicator (Chefetz et al., 1997; Gebeyehu & Kibret, 2013).

Criteria of maturity

Over the six-week composting period various types of residential waste were added to VB and CB inclusive of grass clippings, dried leaves, cow manure, sawdust, newspaper, fruit and vegetable scraps, ground provision peals, garden clippings and tissue paper (Figure 3 & 4).

The composting obtained from both units at the end of harvesting based on the experiment carried out produced an earthy smell, with a dark black colour forming a crumbly texture. Mature vermicompost should have a dark black appearance and can be made up of fine granular material such as peat that has an outstanding physical, chemical, and biological qualities that affect the soil (Pisaheba et al., 2013; Ramnarain et al., 2019).


Figure 3: Vermicomposting bin


Figure 4: Composting bin

This is because earthworms eat waste material that goes through their guts and mixes with gut microflora, which is churned with bacteria found in the composting material (Ansari et al., 2020; Domínguez & Gómez-Brandón, 2012; Kutsanedzie et al., 2021).

Primary nutrient

The nitrogen values for VB ranged from 53.95-60.16 ppm with an average of 57.27 ppm, while those for CB ranged from 29.29-36.21 ppm with an average of 31.96 ppm (Table 1). The average nitrogen value for VB was almost double that for CB (Figure 5). VB phosphorous values ranged from 539.1-742.3 ppm with an average of 636.13 ppm, while the range for CB was 595.9-717.3 ppm with an average of 659.63 ppm. Both phosphorous averages had a high test rating since they were greater than 96 ppm (Figure 6). Potassium values for VB ranged from 1098-1244 ppm with an average of 1154 ppm, while the range for CB was 841.2-1098 ppm with an average

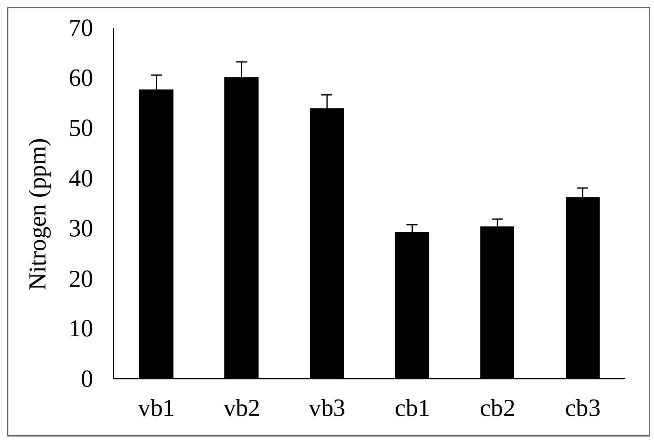

Figure 5: Average nitrogen content in vermi-composting and compost bins

Table 1: Soil test ratings and critical limits

Nutrients	Low	Medium	High	Critical Limit
Nitrogen	<10 ppm	10-240 ppm	>240 ppm	-
Phosphorus	<10 ppm	10-96 ppm	>96 ppm	-
Potassium	<40 ppm	40-200 ppm	>200 ppm	-
Calcium	-	-	-	2500 ppm
Magnesium	-	-	-	100 ppm
Iron	-	-	-	45 ppm
Copper	-	-	-	0.2 ppm

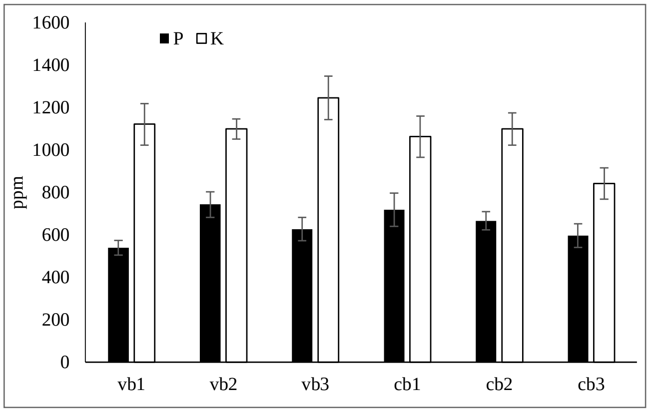

Figure 6: Average P and K content in vermicomposting and compost bins

of 1000.4 ppm. As with phosphorous, both averages for potassium had a high-test rating greater than 200 ppm (Figure 6).

Traditional composting and vermicomposting are very different processes, especially in terms of ideal temperatures and the types of decomposing microbial communities that predominated during active processing. Vermicompost has superior chemical and biological features, including plant growth regulators (which are absent in other composts) and substantially larger and more diversified microbial communities than thermophilic composts (Sinha et al., 2009), compost, on the other hand, uses nitrogen fertilizers and manure to hasten decomposition and they are typically applied in big quantities. Compost nitrogen is released gradually and in little amounts. After bacteria and fungi have consumed readily degraded components in the maturation phase, actinomycetes invade organic materials and play a key role in the degradation of natural polymers. Their enzymes allow them to break down difficult materials like woody stems, bark, and newspaper. The availability and abundance of nutrient supplies, as well as their acquisition, influence the interplay between the diverse functional roles of microbes (Gebeyehu & Kibret, 2013). It was found that vermicompost had the higher nutrient content with the following readings: (N: 57.27 ppm, K: 1154 ppm, C: 1220 ppm, Cu: 11.01 ppm, Fe: 3.76 ppm). Sinha et al. (2009) provided a bit more detail outlined that "vermicompost contains enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil (to release the nutrients and make it available to the plant roots) even after they have been excreted" while conventional compost fails to deliver the appropriate amount of macro and micronutrients, including the essential NKP (nitrogen, potassium, and phosphorus) to plants promptly than vermicompost does. Ansari et al. (2020) posted that because of the increased mineralization and humification process caused by earthworm activity, vermicompost has a higher nutritional content than regular compost. They also have a larger concentration and diversity of microbiota that contribute to the creation of plant growth regulators, enzymes, and phytohormones (auxin and cytokinin) (Domínguez & Gómez-Brandón, 2012; Gebeyehu & Kibret, 2013; Pathma & Sakthivel, 2012).

The standard values for total nitrogen should be 2-3% and with pH 6-9 based on WHO standards (Koning & WHO, 1987). The results indicated that vermicompost had total nitrogen of 0.006% and a pH of 7.0 while compost bin had total nitrogen of 0.003% and a pH of 7.7. These two comparisons show that the total nitrogen obtained from the experiment is much lower than the standard values obtained from WHO but the pH is well within range (Koning & WHO, 1987; Pisaheba et al., 2013).

Khaliq et al. (2004), concluded that the C:N ratio of the vermicompost produced was at a more appropriate level than that of the aerobic compost produced. Further, the level of both nitrogen and phosphorous was higher in vermicompost than in aerobic compost. Pisaheba et al. (2013), also concluded that composting residential waste with the *E. foetida* worm is an effective solution in integrated solid waste management.

The reduction of nitrogen content could be due to the utilization of inorganic nitrogen by bacteria in the composting process and the conversion of nitrogen into bacterial proteins (Gebeyehu & Kibret, 2013). Nitrogen losses ranging from 9-68% have been reported during the composting of cattle manure (Gebeyehu & Kibret, 2013). Wang and Shen (2018), also stated that microbial decomposition of nitrogen-containing organic matter into ammonia nitrogen is the main way nitrogen is lost in the composting process. Nitrogen percentage is also essential for fertilizer value (Borah et al., 2007).

Secondary nutrient

For the secondary nutrients, calcium values ranged from 3200-3800 ppm for VB with an average of 3416.7 ppm, while the range for CB was 4800-6000 ppm with an average of 5400 ppm. Both averages for calcium were well above the 2500 ppm critical limit (Table 1). Magnesium values for VB ranged from 1090-1342 ppm with an average of 1220 ppm, while the range for CB was 366-610 ppm with an average of 525 ppm. The magnesium average for VB was more than twice that of CB but both were well above 100 ppm critical limit. VB Iron values ranged from 3.55-4.06 ppm with an average of 3.76 ppm, while the range for CB was 1.07-1.51 ppm with an average of 1.32 ppm (Figure 7). Both averages for Iron fell below the critical limit and iron was the only nutrient that measured low or below the critical limit. VB had twice as high an average as CB for iron. For copper, the value range for VB was 8-14.27 ppm with an average of 11.01ppm, while the range for CB was 3.28-3.46 ppm with an average of 3.39 ppm. The copper average value for VB was more than twice as high as that for CB, but both however were well above the critical limit of 0.2 ppm.

A p-value of <0.05 indicates a significant difference exists and thus since the nutrient content for most of the vermicompost was less then we rejected the null hypothesis that there's no difference between the compost bin and vermicompost in term of efficiency for residential waste management (Table 2). The difference

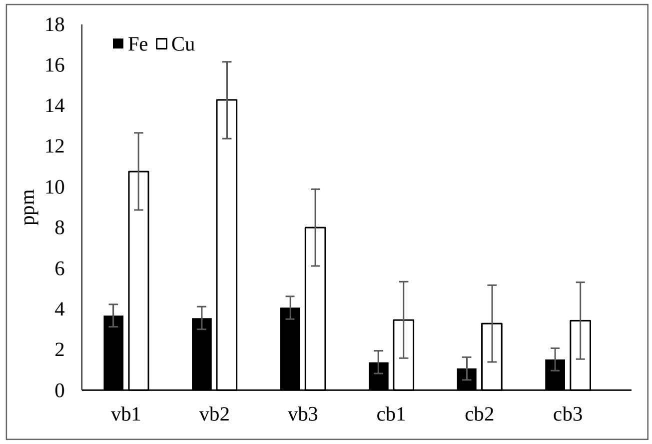

Figure 7: Average Fe and Cu content in vermicomposting and compost bins

Table 2: t-test sample showing p-value and level of significance for each nutrient content

Parameters	*p*-value	Level of Significance	
	Two tail	Yes (<0.05)	No (<0.05)
Temperature	0.0119341	Yes	
pH	0.0285926	Yes	
Nitrogen	0.0008368	Yes	
Phosphorous	0.7489944		No
Potassium	0.1712241		No
Calcium	0.0076327	Yes	
Magnesium	0.0030405	Yes	
Iron	0.0002684	Yes	
Copper	0.0136969	Yes	

in the secondary nutrient between vermicompost and compost is attributed to enhanced microbial activity contributed by the microbiota of earthworms (Ansari *et al.*, 2020).

Practical guidelines for successful composting

Composting methods may include worm bins, enclosed bins, compost tumblers and compost heaps among others; and the most suitable option will depend on your location, available space, available time and type of waste (Ansari et al., 2016; Ansari et al., 2020; Domínguez & Gómez-Brandón, 2012). For this experiment, vermicomposting method and a compost bin were set up (Ansari et al., 2020;Cheng et al., 2013;Inckel et al., 2005). Both methods successfully produced usable compost and as such can be used as the basis for guidelines for persons desirous of utilizing those methods.

Tchobanoglous (2009), concluded that approximately 62.64% of household waste is compostable and as such residential composting is a pertinent solution to mitigate the issue of solid waste management sustainably. Earthworms have a limited temperature range and such vermicomposting units should always be set up in the shade to ensure moisture (Borah et al., 2007).

CONCLUSION

Soil forms an integral network of the necessity for plant growth and productivity. Compost was successfully produced utilizing both vermicomposting and composting methods. The analyses have shown that samples have adequate nutrient composition to enhance plant growth. Moreover, they can be used to reduce the ecological impacts of wanton disposal of organic wastes in the environment. The evidence has shown a higher nutrient value and as such the vermicompost process was determined to be more efficient. System utilized in this experiment for vermicompost and compost could easily be set up for conducting residential composting.

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