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Examination Of Nutrient Status In Vermi-Digested Green Waste Over Windrow Composted Green Waste

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Abstract
The nutrient status of digested organic solid waste (Vegetable market waste) plays a significant role in plant growth. The present study analyses the nutrient status in vermi-digested (VC) and windrow composted (WC) vegetable market waste. Proximate and Ultimate analyses are carried out to determine the percentage composition of nutrients. Initially, the experiments were carried out for 120 days in parallel (Composting and Vermicomposting). Vital environmental parameters like pH, Temperature, EC, and moisture content were monitored at regular intervals and kept as per the requirements. Further, Geo-physical analysis was also carried out to determine the Water holding capacity (WHC) and cation exchange capacity (CEC), which play a vital role in root development and nutrient distribution in plants.
Keywords: *Vermicomposting (VC), Windrow Composting (WC), Eisenia fetida, Nutrient status.*

1. INTRODUCTION

Organic digestion of solid wastes holds secondary benefits in waste management. Many waste management practices prevail in the world, but composting and vermicomposting hold a significant place among them. The operation process in digesting waste differs from one another. Windrow composting is a recognised method to deal with vegetable wastes, where the material is heaped in stretched out rows and ventilated through either rotating the windrows or through air enforced through the material. This may take place in an enclosed area or an exposed environment. In this process, the waste is collected and loaded as long windrows 2 to 3 m wide and 1 to 1.5 m high. The side grades would vary, subject to the volume of waste to be digested per day. The windrows can be digested with a slurry substrate of bio-catalytic agents or engineered microorganisms for disintegration and for achieving accelerated bio-digestion of organic matter in the waste. Due to bio-reactions, the heat in the windrow rises to 55º to 65º within two days and kills the harmful microorganism.

The percentage of moisture content should be between 50% and 60% during the composting process. After a week's interval, the waste mass of the compost pile is turned manually or with suitable machines to aerate the waste mass and, in parallel, reduce the high flow of temperature flow in the waste pile. As the advancement of fermentation, the waste heap changes colour to dark brown humus-like substances, and in parallel, the volume of the waste mass is reduced to about 50%, representing the end stage of digestion. The digestion of waste is completed within a month and a half. The digested organic waste is processed in either manually or mechanically. Vermicomposting is the advanced form of composting that requires the integrated action of worms and microorganisms for digesting the organic waste fractions. The active participants in this process are worms and aerobic microorganisms. Since vermicomposting is an exothermic process, the organic constituents in the waste will be converted into plant nutrients, namely vermicast. In vermicomposting, the organic fractions in the waste are converted into manure in 3 phases: 1. The bigger size waste particles break down into small fractions by the bacterial population. 2. The broken small fractions ingested by worms were natural pulverizations of waste that happen. 3. The pulverization helps in increasing the surface contact area between waste mass and other microbial communities like fungi, and acetonomicez for further degradation (SenthilKumar and Kavimani, 2012). The other advantage in vermicomposting is that the digestion system of the worm acts like a bio-filter, eliminating the unwanted organic fraction and microbes in the solid wastes (Rahul and Swetha 2011). Senthilkumar et.al (2016) report that vermi composting will enhance the nutrient status in the process, and the level of macro and micro plant supplements in the vermicast will get greater enhancement than other organic biodegradations like com-posting.

The outcome of the above-discussed processes is nutrient-rich organic manure; still, the percentage composition and soil dissimilation properties of nutrients have to be studied to determine the effective-ness of the nutrients obtained from the processes. The present study deals with the analysis of physical (pH, Temperature, Moisture content), Bio-chemical (Organic Carbon, Nitrogen, Phosphorus, Potassium), and Geo-physical (Water Holding Capacity - WHC, Cation Exchange Capacity - CEC) properties of the digested vegetable waste.

2. MATERIAL AND METHODS

The duration of the study is divided into three phases

1. Vegetable waste collection
2. Waste processing (Composting and vermicomposting in parallel)
3. Sample analysis

2.1 Vegetable Waste Collection

Approximately 20 kg (vegetable and fruit wastes) were collected from the local vegetable market. The waste chunk holds a heterogeneous mixture of organic wastes that includes carrot, beans, tomato, cabbage, radish, lady finger, onion, beetroot, cluster beans, brinjal, garlic, ginger, peas, pumpkin, cauli-flower, plantain flower, mushroom, plantain, ivy gourd, and fruits like watermelon, banana, apple, orange, pineapple, peach, papaya, guava, dates, chikku, cucumber, and blackberry. It took four numbers of gunny bags to collect the vegetable waste, and further transferred to the processing area for conversion. The collected wastes are manually screened to remove the inert and other inorganic materials like plastic cups, bags, etc. And chopped for easing the digestion process (Figure 1).

Figure. 1: Manual screening of Vegetable marker waste

2.2 Lab-scale Windrow Composting (WC) Process

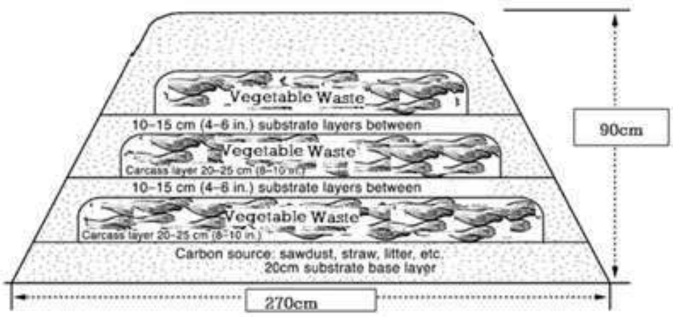

Figure. 2: Sectional view of the Windrow Composting Pile

Figure 2, shows the sectional view of the Windrow composting pile. Initially, the ground surface was cleaned and levelled for the composting process. Initially, the waste mass was heaped into a trapezoidal shape, and then the layering was started. On the bottom of the waste heap, carbon-rich sources of matter like sawdust, straw, and papers were layered for a depth of 20cm. This was followed by a layer of chopped vegetable waste for about 20-25cm (Figure. 2). Subsequently, 2 layers of waste with substrate layers were made to achieve a maximum height of about 90cm, which includes a covering layer to preserve the internal environmental parameters as per the condition. After the formation of waste heap, a thin moist cloth was covered to avoid the bird menace. At the end of every week the pile rotated manually to regulate the digesting environment and ensuring the aerobic digestion of the waste mass.

2.3 Lab scale Vermicomposting (VC) Process

The experiment was conducted with the aid of fabricated plastic tubes. Initially, a full length (1 m long) of 15 mm diameter, 4 mm thick PVC pipe was cut into 40 cm length tubes (Figure 3). One end of the tube was coupled with an end cap, the other end was kept free. In the vermi bin, the top 5 cm was kept as free board and the bottom 5 cm was filled with 15 mm to 20 mm pebbles, which would act as a filter media to drain excess moisture in the vermi bed. At the bottom of each vermi bin, a 3 mm diameter hole was drilled and coupled with a plastic tube to collect the vermin wash. For making the workbench, a rectangular sheet of plywood was drilled with a circular hole to the desired diameter to hold the vermi bins. After reviewing many research articles, it was concluded that Eisenia fetida is the most suitable species for conducting the experiments. The common names of Eisenia fetida are red worm, brandling worm, tiger worm, and red wiggler worm due to the reddish body marked with horizontal stripes. This worm holds about 80-110 segments and has a length between 23-130 mm. Eisenia fetida is also a hermaphrodite, possessing both male and female traits. It reproduces by mating upside down with another for fertilizing eggs. In addition, this worm possesses quicker organic waste degradation capability and obtains sexual maturity in advance. Further, it can withstand a wide range of temperatures (18℃ to 32℃). Earthworms were collected from the Periyar Maniammai University, Thanjavur, India (10.72˚N and 79.08˚E). The collected worms were cultured further by feeding on partly digested cow dung under optimum environmental conditions. Approximately 100-150 g of worms were collected for the study. About 100 grams of E. fetida were inoculated in the vermi bin for experimentation.

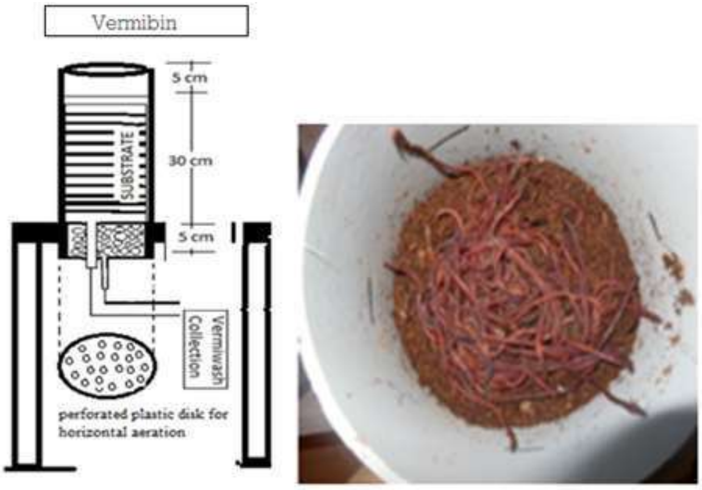

Figure. 3: Vermicomposting bin

2.4 Characterization of the vegetable waste

Analysis of Vegetable waste will provide necessary information about its physical and chemical characteristics (Figure.4). Analysis is essential in determining the efficiency of any waste treatment processes. The analyses are divided into two divisions: 1. Proximate analysis, and 2. Ultimate analysis. All the analyses were carried out as per the procedures given in "Soil testing in India, Methods and Manual, 2011 and APHA, 2005. The results of the analysis are furnished in Tables 1 and 2.

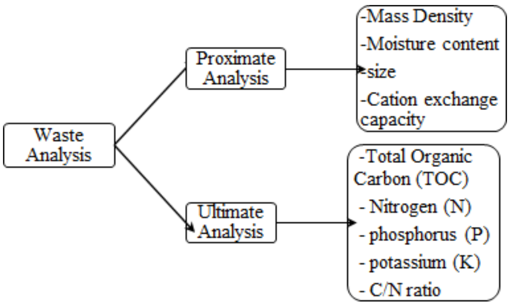

Figure. 4: Characterization of the vegetable waste

Table 1: Proximate analysis results

Processing of Vegetable Waste	Bulk Density (kg/m^3)	Moisture Content (%)	Size (mm)	CEC (cmolc/kg)	Percentage of volume reduction '%'
Raw waste	91.00	61	100-300	87.56	00
Chopped	109.20	63	20-30	112	20
Vermicast	558	10	0.1-0.07	357	87
Compost	627	04	<0.002	424	92

Table 2: Ultimate analysis results

Stages of processing vegetable Waste	Total Organic Carbon (TOC' (%)	Nitrogen 'N' (%)	Phosphorus (mg/g)	Potassium 'K' (mg/g)	C:N ratio
Raw waste	38.62	1.12	4.85	3.96	34.48
Chopped	40.12	1.36	4.98	3.32	29.50
Vermicast	23.89	1.9	6.89	4.56	13.33
Compost	20.25	1.28	8.24	5.89	15.82

3. RESULTS AND DISCUSSIONS

During experimentation, vital parameters like temperature (T°C), Moisture Content (MC), Electrical Conductivity (EC), and substrate depth are monitored periodically and kept under permissible limits. Temperature, Moisture content, and Electrical Conductivity (EC) are measured using the WET sensor kit (WET-2-K1). Samples are collected every 10th day during determining the pH, Total Organic Carbon (TOC), Nitrogen (N), C: N ratio, Phosphorous (P), and Potassium (K) as per the procedure given in Methods manual of Soil testing in India (2011) and APHA (2005).

3.1 pH

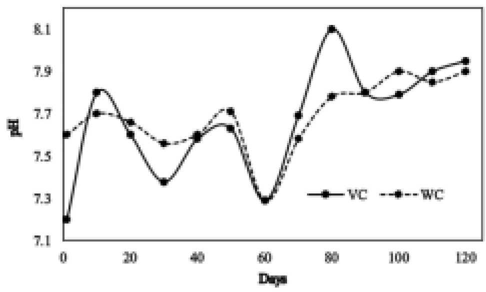

Figure. 5: pH variations recorded during the waste digestion process

pH plays a significant role in both vermicomposting and windrow composting waste digestion processes. Since worms do not have a separate respiratory organ, they do the respiration process through their skin (Ranganathan 2006). Therefore, pH in the substrate mass should be well within the range. pH below 6.5 and above 8.5 will hinder the respiration process of worms (Ranganathan 2006). In addition, pH is one of the most important parameters used to characterize the quality of digested waste. Senthilkumar and Sivaguru (2021) found that a pH range from slightly acidic (6.5) to neutral (8.0) is optimum for composting and vermicomposting. Ndegwa et.al (2000) reported that the pH shift in vermicomposting is dynamic and substrate dependent. In the present study, the rise in pH may be attributed to the breakdown of organic portions to simpler units and discharge as CO2. This rise in pH (Figure 5) may be endorsed due to the breakdown of organic elements into simpler units and release as CO2. The pH value stood between 6 and 8 for both types of waste digestion processes. A slight rise in the pH was observed during the later period of the digestion process, which may be due to the release of organic acids by the microbial communities present in the waste mass.

3.2 Temperature

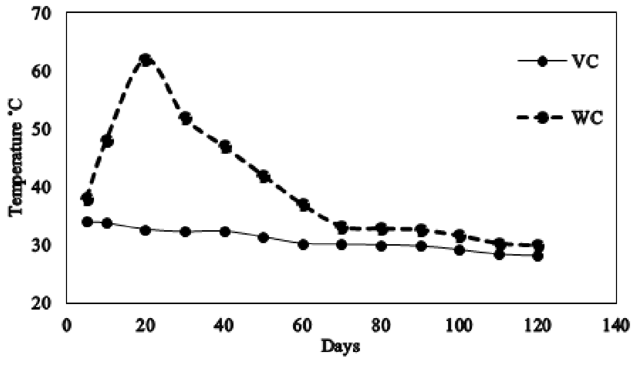

Figure. 6: Temperature variations recorded during the waste digestion

Temperature is a significant factor in major the zoological status of worms. High heat affects the existence conditions of the worms in the vermi bins. Figure 6 shows that a higher variation in temperature was recorded in the composting process than in vermicomposting. Temperature is a significant factor in major the zoological status of worms. High heat affects the existence conditions of the worms in the vermi bins. Figure 6 shows that a higher variation in temperature was recorded in the composting process than in vermicomposting. Senthilkumar et.al (2016) reported that in the composting process, the temperature will rise to a maximum of 80°C due effective involvement of the microbial community in breaking down the cellulose and lignin components in the waste mass during the first few weeks. The same was witnessed in the present study. Further, the temperature differences affect the development and sexual reproduction rate of earthworms. The optimal temperature for cocoon making of E. Fetida ranges between 20 to 27 °C. Further, Ranganathan (2006) reported that the best temperature for the vermicomposting process is 25 °C to 28 °C. During winter, to keep the system active, the temperature should be maintained above 10 °C, and in summer, the temperature should be maintained below 35 °C. This suggests that the worm's activities are highly sensitive to temperature. In the present study, the temperature in the vermin bin was maintained within 30 °C by moistening the substrate bed daily, and due to that, he vermin bin temperature was less than 33 °C. It can be considered that the temperature difference during the composting process is directly dependent on the degradation process and active microbial action on the feed materials (Figure 6). Hence, the rise in temperature due to the suitable addition of waste materials has been supported by Singh and Kalamdhad (2012).

3.3 Moisture Content

Substrate moisture content is one of the noticeable parameters that directly affects the vermicomposting process. The moisture content during vermicomposting depends on the type and size of the substrate mass. High size of waste mass allows the moisture to leave the process easily. Table 1, shows the raw waste possess high size of substrate and hence in composting the moisten was done three times more than in vermicomposting process, which lead to the flow of high moister in composting process (Figureure.7). Earthworms breathe through their skin, therefore, the vermi beds must have ideal moisture content. Optimum moisture content for the vermicomposting process is between 55 % and 65 % (Karthikeyan et.al. 2009). The improper moisture level will directly influence the life cycle of earthworms. High moisture content decelerates the process in vermicomposting, and a low moisture level will be lethal to worms by suppressing their respiratory activity.

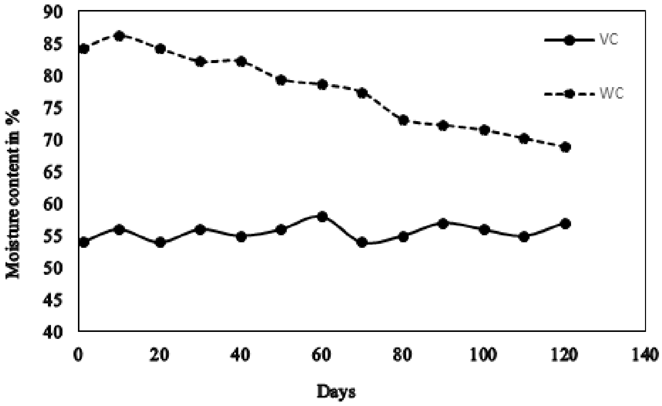

Figure. 7: Moisture Content variations recorded during the waste digestion

Tenzin (2002) reported that if the substrate mass is too wet, water will occupy the voids and inhibit the waste digestion process; if it is too dry, it suffocates the worms. Further, Senthilkumar and Sivaguru (2021) reported that the respiratory activity of worms completely differs from that of humans. In Vermicompoting, often moistening of the substrate bed was carried out and in parallel the excess moisture in the substrate bed was drained due to gravity, hence, the moisture content in the vermicomposting process stood between 50 and 55 percent (Figure. 7). In the composting process, the moisture and water vapours produced as a result of degradation were absorbed by dry waste mass and stuck in the system. During rotation of the windrow, the vapours were effectively released into the atmosphere, thereby drying out the compost, which results in the fall of moisture in the compost pile.

3.3 Electrical Conductivity (Ec)

Electrical conductivity is a gauge to measure the amount of soluble salts present in the media. Electrical conductivity (EC) determines the Cation Exchange Capacity (Table 1) of a medium through the presence of ions in it. In vermicomposting, like pH, Electrical conductivity also plays an effective role in the sustainability of worms and other associated microbes. The Cation Exchange Capacity (CEC) in vermicomposting is a predominant factor to determine the quality of vermicast (Kurian and Velmourougane 2010).

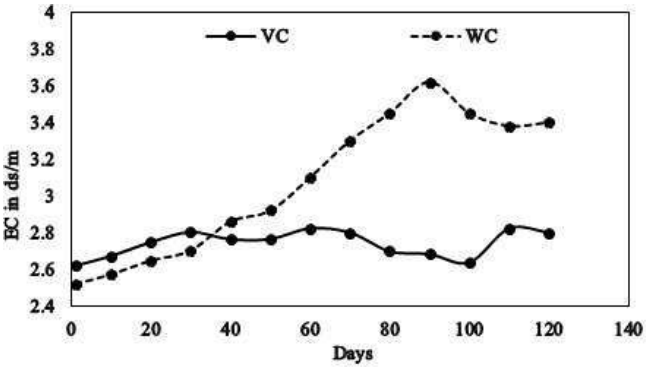

Figure. 8: Electrical conductivity variations recorded during the waste digestion

The Cation Exchange Capacity (CEC) will determine the capacity of the vermicast to hold the exchangeable cations. Vermi manure with good CEC will enhance the ability of the soil to hold the essential nutrients. The current conductivity of the waste mass during vermicomposting will depend on the following factors: 1. Characterisation of the waste to be digested. 2. Enzymes released by worms during waste digestion 3. The activity of microorganisms in converting organic fractions into CO2 and humic substance (Ranganathan 2006; Mariraj 2014). In the present study, the digested waste from composting is finer in size (Table 1) than that from vermicomposting, which results in the wide variation in EC (Figure 8) in the substrate mass.

3.4 Total Organic Carbon (TOC)

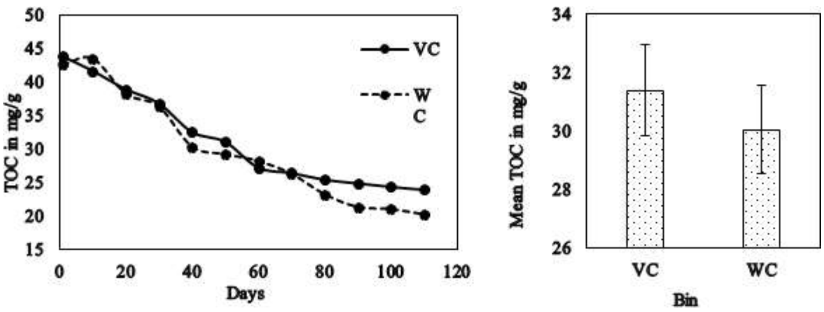

Figure. 9: TOC variations recorded during the waste digestion

Organic Carbon is the prime source for any living cell on the planet. Worms and microorganisms require a carbon source for their growth and sustainability. The external and internal organ growth of the worms depends on the humic and non-humic compounds present in organic waste. Humic substances are dark in colour and heterogeneous in mass with higher molecular weight (Senthilkumar and Sivaguru, 2021). Non-humic matters composed of polysaccharides, sucrose, fructose, proteins, and other amino acids. Both the humic and non-humic compounds play a vital role in the growth and reproductive cycle of worms. In the presents study the TOC reduction percentage is almost same in both the waste digestion process. This is because of the utilization of carbon in the substrate mass by both worms and microorganisms (Figure. 9). But in the composting process the TOC utilization is in the upper side due the heterogenic population of microorganism.

3.5 Nitrogen (N)

Similar to carbon, Nitrogen also plays a key role in the growth of living organisms. The major part of nitrogen contains amino acids, is an essential element for the construction of DNA (made of proteins and nucleic acids). Nitrogen alone contributes 78 percent of the atmosphere, but humans, plants, and animals cannot consume nitrogen directly from the atmosphere.

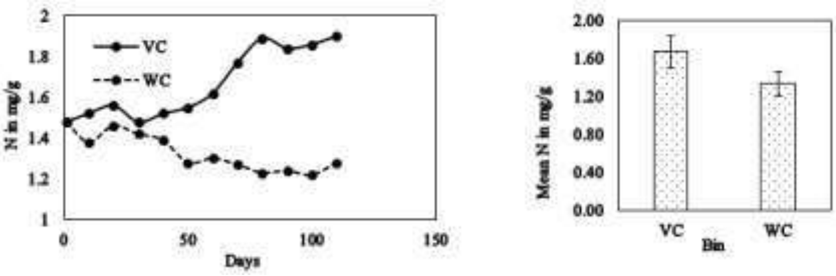

Figure. 10: Organic Nitrogen variations recorded during the waste digestion

The transformation of nitrogen in the soil is done by the nitrogen fixation cycle. Earthworms play a significant role in fixing nitrogen in the soil. The nitrogen fixation by worms is done in two ways: 1. Integrating organic constituents into the soil, and 2. Unravelling the nutrients held within partly degraded organic matter. In addition, scientists have determined that the percentage of nitrogen content in vermicast holds a fivefold increase compared to undigested organic matter.

3.6 Carbon: Nitrogen (C: N) Ratio

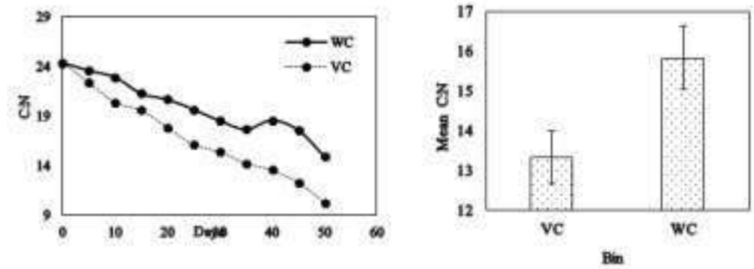

Figure. 11: C: N variations recorded during the waste digestion

The Carbon to Nitrogen ratio (C:N) is an important factor to determine the optimum ratio of carbon and nitrogen in the solid waste. The energy and nutrient balance of any organic matter is indicated by the carbon to nitrogen ratio (Sartaj et.al. 2015). It is a known fact that earthworm needs organic waste or animal residue with appropriate C:N ratio for their growth and reproduction (Sartaj et.al. 2015; Singh et.al. 2010). Improper C:N ratio will decelerate the worm's digestion rate, hence, vermicomposting the raw waste should be strictly avoided. If the C:N ratio is too narrow, there will not be sufficient carbon for the worms, further, it will increase the volatile nitrogen content. If the C:N ratio is too wide there will not be enough nitrogen for the microorganism to develop its cell wall in the waste mass. Pre-composting the raw waste with microbial inoculum will generate an optimum C: N ratio of waste mass, which can further be vermicomposted. Previous studies reported that for biological treatments of solid waste, the optimum C:N ratio should be between 18:1 and 35:1(Chefetz et.al, 1996). The ideal ratio of C:N for vermicomposting should be between 25:1 and 35:1 (Manual of MSW 2000). The present research clearly defines that the reduction of C: N ratio in the composing process was 18-20% higher than in vermicomposting (Figure 11). This may be due to the presence of a heterogeneous mass of microbial community, which extensively digests he carbon source in the substrate.

3.7 Phosphorus (P) And Potassium (K)

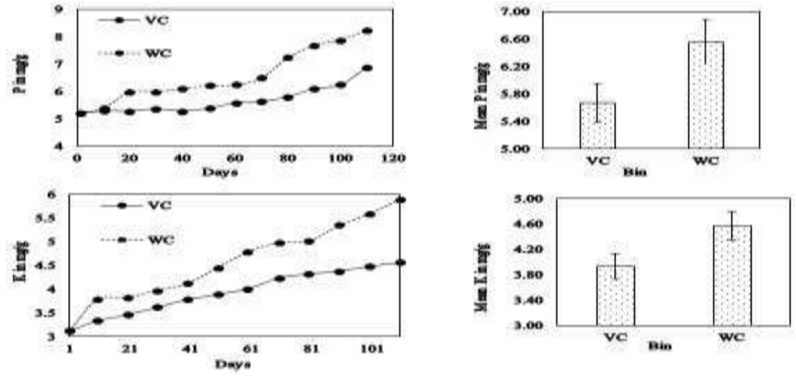

Figure. 12: Phosphorus and Potassium variations recorded during the waste digestion

The role of Phosphorus (P) in soil enrichment is distinctive. The percentage of P presence in the soil is affected by strong absorption of Al and Fe ions present in the soil (Ranganthan 2006). Hence, the availability of P in soil mainly depends on the bio-digestion of organic waste fractions. Vermicomposting is a non-thermophilic biodegradation. During the digestion of organic waste, the available nutrients like N, P, and K are enriched by worms and microbial digestion activity. Knowingly, worms enhance the available P percentage in the vermicast, and this is done by promoting high microbial diversity in the waste mass during vermicomposting (Haynes and Zhou, 2016). Potassium is one of the essential micronutrients and an intracellular ion for all living organisms, and it is the most required nutrient to balance the fluid and electrolytes in the cells. The potassium concentration in any matter will vary according to its nature; for instance, fruits hold a high percentage of potassium when compared with vegetables and red meat. Figurer. 12 clearly shows a rising trend in the Potassium level in both processes. Significantly, the potassium level was 19.59% higher in the composed substrate mass, which might be because of the presence of fungi and protozoa in the substrate mass. This organism breaks comply the organic fraction in the waste heap and produces amino acids, which are a vital component for cell growth of microbial community, and as a by-product, the microorganism enhances the P and K (Figure. 12) in the digested waste

4. CONCLUSIONS

The present study reveals that both waste digestion processes effectively disintegrate and digest green waste. The core outcome of this study is to examine the characteristics of the digested waste and determine the nutrient status, which is effective for plant growth. The salient nutrients like C: N, N, P, and K are found better in the composting process than in the vermicomposting. This may be due to the absorption of nutrients by the adult worms for their reproduction. Further, in the composting process, microbial communities produce many by-products like amino acids and monosaccharides during the waste digestion process. This results in an increase in the N, P, and K concentrations in the digested waste. As the prime outcome of the study, it was found that both waste digestion processes are cost-effective and easy to adopt. But, the nutrient states comparison, composting produces more effective nutrients than vermicomposting.

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