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# Microbiological and Physico-Chemical Analysis of Vermicompost of Fruit Waste by *Eudrilus eugeniae*

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**ABSTRACT**

Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. During the process of composting the important plant nutrients in the materials (particularly nitrogen, potassium, phosphorus, and calcium) are released and converted through microbial action into forms that are more soluble and bioavailable to plants. The performance of the composting process and the quality of the end product is assessed by the combined application of independent methodologies like physical, chemical, microbiological and statistical methods for the determination of its stability. The earthworm species, *Eudrilus eugeniae* was used in the study. Two different types of fruit waste generated from Vegetable market Coimbatore were collected and segregated as banana peel waste and papaya peel waste. On the 30$^{th,}$ and 45$^{th}$ day of the experimental period, the samples of compost and vermicompost from all experimental units were collected and used for analysis. Vermicompost of Papaya waste was found to be rich in nitrogen, phosphorus and Total organic carbon with increased electrical conductivity and neutral pH. The vermicompost of Banana waste was found to be rich in nitrogen with a neutral pH. The total bacterial count decreased in both the vermicomposts. The vermicomposting process improves soil aeration and thereby promotes the survival and dispersal of the useful bacterium within such systems. Vermiculture provides the best answer for ecological agriculture, which is synonymous with "sustainable agriculture".

## INTRODUCTION

Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways (Gandhi *et al.*, 1997). It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and earthworm.

Waste management is considered as an integral part of a sustainable society, thereby necessitating diversion of biodegradable fractions of the societal waste from landfill into alternative management processes such as vermicomposting. Earthworms excreta (vermicast) is a nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycetes and growth hormones auxins, gibberellins and cytokinins. Both vermicompost and its body liquid (vermiwash) are proven as both growth promoters and protectors for crop plants.

During the process of composting the important plant nutrients in the materials particularly nitrogen, potassium, phosphorus, and calcium) are released and converted through microbial action into forms that are more soluble and bioavailable to plants.It has been found that earthworms necessarily have to feed on microbes, particularly on fungi for their protein /nitrogen requirement (Ranganathan and Parthasarathi, 2000). Kale *et al*., 1982; Elvira *et al*., 1998; Suthar, 2007 reported that body fluid and excreta secreted by earthworm e.g. mucus, the high concentration of organic matter, ammonium and urea promote microbial growth in vermin composting.

Hand *et al*., 1988 have reported that Eiseniafoetida in cow dung slurry increased the nitrate - nitrogen content. Losses of organic carbon might be responsible for nitrogen addition in the form of mucus nitrogenous excretory substances, growth stimulatory hormones and enzymes from the gut of earthworms (Tripathi and Bhardwaj, 2004). Suthar, (2008) reported that the C: N ratio of substrate material reflects the organic waste mineralization and stabilization during the process of decomposition. Kaviraj and Sharma, (2003) observed that level of Total potassium was increased to 10% by *Eisenia foetida* and 5% by *Lampito mauritii* during vermin composting.

Suthar, (2008) studied that the post-harvest crop residues and cattle shed manure were recycled through vermicomposting by using the epigeic earthworm *Eudrilus eugeniae*. It has been well established that epigeic forms of earthworms can hasten the composting process to a significant extent with the production of better availability of vermicomposts.

The present study primarily deals with the management of different types of fruit waste generated in vegetable markets, fruit shops and Juice outlets using the earthworm *Eudrilus eugeniae*. The performance of the composting process and the quality of the end product is assessed by the combined application of independent methodologies like physical, chemical, microbiological and statistical methods for the determination of its stability as manure.

## MATERIALS AND METHODS

The earthworm species, *Eudrilus eugeniae* was used in the study and collected from the vermicompost pit of Nirmala College for Women (Autonomous), Coimbatore. Two different types of fruit waste generated from Vegetable market Coimbatore were collected and segregated as banana peel waste and papaya peel waste. The fruit wastes were shredded manually.Cow dung was obtained from a local cowshed and was sun-dried and flaked.

The experiment was conducted in square plastic pots measuring 17 ×17 ×17 cm of length, breadth, and height respectively. Holes were drilled at the bottom of the pots so as to drain excess water. The pots were filled from the bottom up with successive layers of pebbles, coconut husk, cow dung flakes, and shredded fruit peels respectively. The fruit waste was mixed with cow dung flakes in the ratio of 1:1. All pots were maintained in triplicates. Water was sprinkled daily on all pots to maintain the moisture content and turned at regular intervals for proper mixing and aeration. The experimental pots were kept under shade and covered with gunny bags to prevent moisture loss. This setup was maintained for 15 days for partial degradation and stabilization. After 15 days, 20 non-clitellated earthworms were introduced into each treatment pots containing banana peel waste and papaya peel waste. The control pots of banana peel waste and papaya peel waste were devoid of earthworms. This setup was also sprinkled with water daily and was monitored for a period of 60 days.

On the $30^{th,}$ and $45^{th}$day of the experimental period, the samples of compost and vermicompost from all experimental units were collected and used for analysis.

**Physico-chemical parameters:**

**Electrical conductivity (is: 14767: 2000)**

**pH (sundberg*et al.*, 2004)**

**Total nitrogen (is 14684: 1999, reaffirmed 2005)**

$$N\% = V \times 0.00014 \times D \times 10 / W \times A$$

Where, V = volume of N / 50 HCL used, D = Dilution factor (Volume made in volumetric flask), W = Weight (g) of sample, A = volume of liquid taken.

**C/N ratio (Sonowal*et al.*, 2014)**

The C/N ratio (C: N) was calculated from the measured values of total organic carbon (TOC) and total nitrogen (N).

**Total phosphorus (p) (is 10158: 1982, reaffirmed 2003a)**

$$\text{Total P} = 0.059\ [V1\text{-}V2\text{-}(V3\text{-}V4)/5] \div M$$

Where V1 = volume in ml of 0.5 N sodium hydroxide solution used with the sample,

V2 = volume in ml of 0.5 hydrochloric acid used with the sample,

V3 = volume in ml of 0.1 N sodium hydroxide used in the blank,

V4 = volume in ml of 0.1 N hydrochloric acid used in the blank, and

M = mass in g of the material contained in the solution taken for precipitation.

**Total potassium (k) (is 10158: 1982, reaffirmed 2003b)**

$$\text{Total K} = K \times V / 1000 \times S$$

Where, K =amount of potassium in mg/1in sample,

V = total volume of sample extract prepared

S = weight of sample taken

**Total Organic Carbon (TOC) (Nelson and Sommers, 1982)**

Organic carbon was determined by dry combustion method. A sample of 500 mg of dried ground sample (< 2 mm) was put into a pre-weighed china crucible. The sample was ignited in a muffle furnace at 600º Celsius for 1 ½ hrs.The furnace was allowed to cool and the ash produced was weighed. Organic carbon was calculated from the following relationship:

Organic carbon (%) = (100 – ash %) /1.724

**Microbiological Estimation**

**Total Bacterial Content (Johnson *et al.,* 1959)**

The vermicompost samples were analyzed for their total bacterial count and were determined by serial dilution plate count method (Johnson *et al.,* 1959) on Nutrient Agar medium. The bacterial colonies appeared were purified by streak plate method and maintained on the nutrient agar slants by keeping them in the refrigerator. Isolates were identified by various biochemical tests and observing the colonies under the microscope.

**STATISTICAL ANALYSIS**

All results reported are the means of three replicates using SPSS 16.0 package. One way ANOVA was determined to analyze significant differences ($P<0.05$) between the composted and vermicomposted samples for parameters evaluated on $30^{th}$ and $45^{th}$ day.

**RESULTS AND DISCUSSION**

**PHYSICAL PARAMETER**

**Electrical Conductivity**

The Electrical conductivity for control 30 days of compost of banana waste is 880 ±3.87 ($p<0.05$) (Table1). The experimental value of Electrical Conductivity for the vermicompost has decreased to 440 ± 2.83. After 45 days the control Electrical Conductivity value increased to 980 ± 3.08. While the vermicompost for the $45^{th}$ day increased to 750 ± 4.47 significant at 5% level. The one way ANOVA for Electrical Conductivity on $30^{th}$ and $45^{th}$ day is significant at 1% level and the CV% is 0.41(Table 7).

The control Electrical Conductivity value for 30 days of compost produced from papaya waste is 610 ± 5.48 (Table 4).The experimental vermicompost has an increased Electrical Conductivity value of 760 ± 3.16 (P<0.05).After 45 days the Electrical Conductivity in the control has increased to 660 ± 4.85, while the vermicompost after 45 days decreased to 670 ± 4.47 significant at 5% level. The one-way ANOVA for Electrical Conductivity value on 30$^{th}$ and 45$^{th}$ is significant at 1% level and the CV% is 0.47(Table 8).

**BIOCHEMICAL ANALYSIS**

**pH**

The control pH for 30 days of compost from banana waste is 8.61 ± 0.02 (p<0.05) (Table 1). The experimental value of pH for the vermicompost has decreased to 8.04 ± 0.02. After 45 days the control pH value decreased to 7.85 ± 0.04. While the vermicompost for the 45$^{th}$ day decreased to 7.93 ± 0.03, significant at 5% level. The one way ANOVA for pH on 30$^{th}$ and 45$^{th}$ day is significant at 1% level and the CV% is 0.39 as shown in Table7.

The control pH for 30 days of compost produced from papaya waste is 8.06 ± 0.049 (Table 4).The experimental vermicompost has a pH value of 9.02 ± 0.05 (P<0.05).After 45 days the pH value in the control has decreased to 7.76 ± 0.09, While the vermicompost for 45 days decreased to 7.81 ± 0. 03, significant at 5% level. The one way ANOVA for pH on 30$^{th}$ and 45$^{th\ day}$ is significant at 1% level and the CV% is 0.39 (Table 8).

**Total Nitrogen**

The control nitrogen for 30 days of compost produced from banana waste is 0.28 ± 0.05 (p<0.05) (Table 2). The experimental value of nitrogen for the vermicompost has increased to 0.41 ± 0.08. After 45 days the control nitrogen increased to 0.48 ± 0.03. The vermicompost after 45 days remained the same at 0.41 ± 0.07 significant at 5% level. The one way ANOVA for nitrogen on 30$^{th}$ and 45$^{th}$ day is significant at 1% level and the CV% is 8.01(Table 7).

The control nitrogen value for 30 days of compost produced from papaya waste is 0.28 ± 0.04 (Table 5).The experimental vermicompost has an increased nitrogen value of 0.43 ± 0.03 (P<0.05). On the 45th day, the nitrogen value in the control has increased to 0.41 ± 0.07. While the vermicompost on 45$^{th}$ day increased to 0.47 ± 0. 05, significant at 5% level. The one way ANOVA for nitrogen on the30$^{th}$ and 45$^{th}$ is significant at 1% level and the CV% is 7.91(Table 8).

**C/N ratio**

The control C/N ratio value for 30 days of compost produced from banana waste is 47:1 (Table 2). The experimental value of C/N ratio for the vermicompost has decreased to 23:1. After 45 days the control C/N ratio value decreased to 33:1. While on the 45$^{th}$ day, the experimental value was also low 28:1 significant at 5% level.

The control C/N ratio value for 30 days of vermicompost produced from papaya waste by *Eudriluseugeniae* is 33:1(Table 5).The experimental vermicompost has a decreased C/N ratio value of 30:1. At 45 days the C/N ratio value in the control has decreased to 28:1. While the vermicompost after 45 days decreased to 24:1 significant at 5% level.

**Total Phosphorous**

The control phosphorous for 30 days of compost produced from banana waste was 990 ± 4.00 ($p<0.05$) (Table 2). The experimental value of phosphorous for the vermicompost has decreased to 686 ± 1.22. After 45 days the control phosphorous value increased to11705 ± 5.83. While the vermicompost for the 45$^{th}$ day increased to 840 ± 2.55 significant at 5% level. The one way ANOVA for phosphorous on the 30$^{th}$ and 45$^{th}$ day is significant at 1% level and the CV% is 0.34 (Table7.)

The control phosphorous for 30 days of compost produced from papaya waste by *Eudrilueugeniae* is 1175 ± 3.03 (Table 5). The experimental vermicompost has a decreased phosphorous value of 808 ± 2.92 ($P<0.05$). At 45 days the phosphorous value in the control has decreased to 787 ± 6.12. Vermicompost for 45 days showed an increased value of 971 ± 9.08 significant at 5% level. The one way ANOVA for Phosphorous on the 30$^{th}$ and 45$^{th}$ is significant at 1% level and the CV% is 0.34(Table 8).

**Total potassium**

The control potassium for 30 days of compost produced from banana waste is 41.10 ± 0.30 ($p<0.05$) (Table 2). The experimental value of potassium for the vermicompost has decreased to 38.80± 0.45. After 45 days the control potassium value decreased to 23.0 ± 0.37. While the vermicompost for the 45$^{th}$ day decreased to 17.1 ± 0.32 significant at 5% level. The one way ANOVA for potassium value on the 30$^{th}$ and 45$^{th}$ day is significant at 1% level and the CV% is 1.05(Table 7).

The control potassium value for 30 days of compost produced from papaya waste is 31.40 ± 0.24 (Table 5).The experimental vermicompost has a decreased potassium value of 20.50 ± 0.27 (P<0.05).On the 45 days, the potassium in the control decreased to 21 ± 0.32, while the vermicompost at 45 days decreased to 19.10± 0. 28 significant at 5% level. The one way ANOVA for potassium on 30$^{th}$ and 45$^{th}$ is significant at 1% level and the CV% is 1.37 (Table8).

**Total Organic Carbon**

The control TOC value for 30 days of compost from banana waste is 8.23 ± 0.07 (p<0.05) (Table 2). The experimental value of TOC for the vermicompost has decreased to 8.04 ± 0.02. After 45 days the control TOC value increased to 13.70 ± 0.32. While the vermicompost for the 45$^{th}$ day also increased to 9.70 ± 0.28 significant at 5% level. The one way ANOVA for TOC value on 30$^{th}$ and 45$^{th}$ day is significant at 1% level and the CV% is 2.10 as (Table 7).

The control TOC value for 30 days of compost from papaya waste is 7.16 ± 0.05 as shown in (Table 5). The experimental vermicompost has an increased TOC value of 12.15± 0.07 (P<0.05).At 45 days the TOC value in the control has increased to 7.76 ± 0.09. While the vermicompost for 45 days decreased to 11.30 ± 0. 40 significant at 5% level. The one-way ANOVA for TOC value on 30$^{th}$ and 45$^{th}$ is significant at 1% level and the CV% is 2.29

(Table 8).

**MICROBIOLOGICAL ESTIMATION**

**Total Bacterial Content**

The bacterial content for control banana waste is 60 ± 4.24 (p<0.05) (Table 3). The experimental value for 30 days of treatment has increased to 70 ± 6.23. After 45 days the control bacterial content value decreased to 50 ± 3.63. While the vermicompost for the 45$^{th}$day decreased to 48 ± 2.83, significant at 5% level.

The control bacterial content value for 30 days compost produced from papaya waste by is 80 ± 5.48 ( Table 6).The experimental vermicompost has a decreased bacterial content value of 60 ± 7.78(P<0.05). At 45 days the bacterial content in the control has decreased to 48 ± 3.15. While the vermicompost for the 45$^{th}$day decreased to 40 ± 3.16, significant at 5% level.

**Table 1: Physico-chemical analysis of vermicompost of Banana waste by *Eudrilus eugeniae***

| Sample | Physicochemical Parameters | |
|---|---|---|
| | pH | Electrical conductivity (µmhos/cm) |
| **C1 (30 days)** | 8.61 ± 0.06 | 880 ± 3.87 |
| **T1 (30 days)** | 8.04 ± 0.02* | 440 ± 2.83* |
| **C2 (45 days)** | 7.85 ± 0.04* | 980 ± 3.08* |
| **T2 (45 days)** | 7.93 ± 0.03* | 750 ± 4.47* |
| **SEd**<br>**CD (P<0.05)** | 0.0200<br>0.0424 | 2.0000<br>4.2399 |

Values are Mean ± Standard Deviation of three samples in each group; **SED** – Standard Error of the Difference; **CD** – Critical Difference; **NS** – Not Significant * - Significant at p < 0.05 level; **C1, C2** – Banana waste, **T1, T2** –Banana waste + Earthworm

**Table 2: Chemical analysis of vermicompost of Banana waste by *Eudrilus eugeniae***

| Sample | Chemical Parameters | | | | |
|---|---|---|---|---|---|
| | N (%) | P (mg/kg) | K (mg/kg) | TOC (%) | C/N % |
| **C1 (30 days)** | 0.28 ± 0.05 | 990 ± 4.00 | 41.40 ± 0.30 | 11.24 ± 0.04 | 47:1 |
| **T1 (30 days)** | 0.41 ±0.08* | 686 ± 1.22* | 38.80 ± 0.45* | 8.23 ± 0.07* | 23:1 |
| **C2 (45 days)** | 0.48 ±0.03* | 1170±5.83* | 23 ± 0.37* | 13.70 ± 0.32* | 33:1 |
| **T2 (45 days)** | 0.41 ±0.07* | 840 ± 2.55* | 17.1 ± 0.32* | 9.70 ± 0.28* | 28:1 |
| **SEd**<br>**CD (P<0.05}** | 2.0200<br>0.0424 | 2.0000<br>4.2399 | 0.2000<br>0.4240 | 0.1421<br>0.3013 | |

Values are Mean ± Standard Deviation of three samples in each group; **SED** – Standard Error of the Difference; **CD** – Critical Difference; **NS** – Not Significant * - Significant at p < 0.05 level; **C1, C2** – Banana waste, **T1, T2** –Banana waste + Earthworm

**Table 3: Microbiological analysis of vermicompost of Banana waste by *Eudrilus eugeniae***

| Sample | Microbiological Parameter |
|---|---|
| | **Total Bacterial Content (CFU/g)** |
| **C1 (30 days)** | 60 ± 4.24 |
| **T1** (30days) | 70 ± 6.23* |
| **C2 (45 days)** | 50 ± 3.63* |
| **T2 (45 days)** | 48 ± 2.83* |
| **SEd**<br>**CD (P<0.05)** | 2.0000<br>4.2399 |

Values are Mean ± Standard Deviation of three samples in each group; **SED** – Standard Error of the Difference; **CD** – Critical Difference; **NS** – Not Significant * - Significant at p < 0.05 level; **C1, C2** – Banana waste, **T1, T2** –Banana waste + Earthworm

**Table 4: Physicochemical analysis of vermicompost of papaya waste by *Eudrilus eugeniae***

| Sample | Physicochemical Parameters | |
|---|---|---|
| | **pH** | **Electrical Conductivity (µmhos/cm)** |
| **C1 (30 days)** | 8.06 ± 0.04 | 610 ± 5.48 |
| **T1 (30 days)** | 9.02±0.05* | 760 ± 3.16* |
| **C1 (45 days)** | 7.76 ± 0.09* | 660 ± 4.85* |
| **T1 (45 days)** | 7.81 ± 0.03* | 670 ± 4.47* |
| **SEd**<br>**CD (P<0.05)** | 0.0200<br>0.0424 | 2.0000<br>4.2399 |

Values are Mean ± Standard Deviation of three samples in each group; **SED** – Standard Error of the Difference; **CD** – Critical Difference; **NS** – Not Significant * - Significant at p < 0.05 level; **C1, C2** – Banana waste, **T1, T2** –Banana waste + Earthworm

**Table 5: Chemical analysis of vermicompost of papaya waste by *Eudrilus eugeniae***

| Sample | Chemical Parameters | | | | |
|---|---|---|---|---|---|
| | N (%) | P (mg/kg) | K (mg/kg) | TOC (%) | C/N % |
| **C1 (30 days)** | 0.28 ± 0.04 | 1175 ±3.03 | 31.40 ± 0.24 | 7.16 ± 0.05 | 33:1 |
| **T1 (30 days)** | 0.43 ± 0.03* | 808 ±2.92* | 20.50 ± 0.27* | 12.15 ± 0.07* | 30:1 |
| **C1 (45 days)** | 0.42 ± 0.06* | 787 ±6.12* | 21 ± 0.32* | 8.60 ± 0.30* | 28:1 |
| **T1 (45 days)** | 0.47 ± 0.05* | 974 ±9.08* | 19.10 ± 0.28* | 11.30 ± .0.40* | 24:1 |
| **SEd**<br>**CD (P<0.05)** | 0.0200<br>0.0424 | 2.0000<br>4.2399 | 0.2000<br>0.0424 | 0.1421<br>0.3013 | |

Values are Mean ± Standard Deviation of three samples in each group; SED – Standard Error of the Difference; **CD** – Critical Difference; **NS** – Not Significant * - Significant at p < 0.05 level; **C1, C2** – papaya waste, **T1, T2** –papaya waste + Earthworm

**Table 6: Microbiological analysis of vermicompost of papaya waste by *Eudrilus eugenia***

| Sample | Microbiological Parameters |
|---|---|
| | Total Bacterial Content (CFU/g) |
| **C1 (30 days)** | 80 ± 5.48 |
| **T1 (30 days)** | 60 ± 7.78* |
| **C1 (45 days)** | 48 ± 3.15* |
| **T1 (45 days)** | 40 ± 3.16* |
| **SEd**<br>**CD (P<0.05)** | 2.0000<br>4.2399 |

Values are Mean ± Standard Deviation of three samples in each group; **SED** – Standard Error of the Difference; **CD** – Critical Difference; **NS** – Not Significant * - Significant at p < 0.05 level; **C1, C2** – Banana waste, **T1, T2** –Banana waste + Earthworm

**Table 7: One Way ANOVA for the parameters analyzed on the 30th and 45th day of the experimental period of Banana waste**

| Parameter | df | SS | MS | F | P | CV% |
|---|---|---|---|---|---|---|
| **pH** | 3 | 1.757000 | 0.585667 | 585.6667 | 0.000** | 0.39 |
| **EC** | 3 | 826375.000000 | 275458.333333 | 27545.8333 | 0.000** | 0.41 |
| **N** | 3 | 0.104500 | 0.034833 | 34.8333 | 0.000** | 8.01 |
| **P** | 3 | 634073.750000 | 211357.916667 | 21135.7917 | 0.000** | 0.34 |
| **K** | 3 | 2113.937500 | 704.645833 | 7046.4583 | 0.000** | 1.05 |
| **TOC** | 3 | 81.956375 | 27.318792 | 540.9662 | 0.000** | 2.10 |

of - degrees of freedom; **SS** – Sum of Squares; **MS** – Mean Square; F – F –test; P – Probability; **CV** – Coefficient of Variation; ** - Significant at P < 0.01 level; * -Significant at P < 0.05 level; **NS** – Not Significant

**Table 8: One Way ANOVA for the Parameters analyzed on the 30th and 45th day of the experimental period of Papaya waste**

| Parameter | df | SS | MS | F | P | CV% |
|---|---|---|---|---|---|---|
| **pH** | 3 | 5.160375 | 1.720125 | 1720.1250 | 0.000** | 0.39 |
| **EC** | 3 | 58500.000000 | 19500.000000 | 1950.0000 | 0.000** | 0.47 |
| **N** | 3 | 0.103000 | 0.034333 | 34.3333 | 0.000** | 7.91 |
| **P** | 3 | 485750.000000 | 161916.666667 | 16191.6667 | 0.000** | 0.34 |
| **K** | 3 | 480.100000 | 160.033333 | 1600.3333 | 0.000** | 1.37 |
| **TOC** | 3 | 80.910375 | 26.970125 | 534.0619 | 0.000** | 2.29 |

df - degrees of freedom; **SS** – Sum of Squares; MS – Mean Square; F – F –test; P – Probability; **CV** – Coefficent of Variation; ** - Significant at P < 0.01 level; * -Significant at P < 0.05 level; **NS** – Not Significant

Results showed that electrical conductivity decreased due to the activity of earthworms and the decomposition of organic matter. This can be attributed to the biological accumulation of some minerals in the earthworms' bodies, and consequently, the reduced amount of minerals in the soil. EC measures the amount of salinity in an organic material and is a good indicator of vermicompost quality used in agriculture (Lim *et al.*, (2014). According to Shak *et. al.*, (2014), the decrease in EC during vermicomposting may be due to the precipitation or leaching of soluble salts and mineralization of organic acids.

The increased EC during the period of the composting and vermicomposting processes is inconsistency with that of earlier workers (Kaviraj and Sharma, 2003; Jadia and Fulekar, 2008) which is probably due to the degradation of organic matter releasing minerals such as exchangeable Ca, Mg, K, and P in the available forms, in the form of cations in the vermicompost and compost (Guoxue*et al.*, 2001; Tognetti *et al.*, 2005).

pH usually decreases from alkaline to neutral, during the process of vermicomposting.The change in pH towards acidic or neutrality may be due to the formation of organic acids and mineralization of organic waste which leads to the production of both the ammonium ions and humic acids (Komilis and Ham, 2006). According to Ndegwa and Thompson, (2000), the changes in pH of final vermicompost are due to decomposition of organic waste into organic acids.

The increasing trend of N in the vermicomposts produced by the earthworm species in the present study corroborated with the findings of earlier reports (Bouche *et al.*, 1997; Balamurugan *et. al.*, 1999).The enhancement of N in vermicompost is probably due to mineralization of the organic matter containing protein (Bansal and Kapoor, 2000; Kaushik and Garg, 2003) and conversion of ammonium-nitrogen into nitrate (Suthar and Singh,2008). Earthworms can boost the nitrogen levels of the substrate during digestion in their gut adding their nitrogenous excretory products, mucus, body fluid, enzymes, and through the decaying dead tissues of worms in the vermicomposting subsystem (Suthar, 2007).

The decrease in organic carbon during the vermicomposting process indicates complete degradation, maturity, mineralization and waste decomposition (Hait and Tare, 2011). Earthworms and microbes in the feed mixtures activate microbial respiration and degradation of organic wastes, thereby increases the loss of organic carbon during the vermicomposting process (Garg and Kaushik, 2005; Suthar, 2006). C: N ratio is an important parameter used for determining the vermicompost maturity and stability. According to Suthar and Singh,

(2008), the loss of carbon and addition of nitrogen during the vermicomposting process reduces the C/N ratio in the end product.

The total Phosphorus is higher in the vermicompost harvested at the end of the experiment compared to that of the initial substrate (Kaushik and Garg, 2003; Manna *et al.,* 2003). The enhanced Phosphorous level in vermicompost suggests phosphorous mineralization during the process. The worms during vermicomposting convert the insoluble Phosphorous into soluble forms with the help of Phosphorus-solubilizing microorganisms through phosphatases present in the gut, making it more available to plants (Suthar and Singh, 2008; Padmavathiamma *et al.,* 2008; Ghosh *et al.,* 1999).

Das et al., (2014) opined that the rate of nutrient loss was directly related to the initial level, decreasing the fastest for the nutrients with the highest initial concentrations. They also suggested that K concentrations steadily decreased over the length of the study in which they determined the optimum storage time for the vermicompost without significant loss of nutrients. The present finding was supported by Sangwan et al., (2008) who reported a decrease in potassium content in the vermicompost produced by *Eisenia foetida* compared to that of the control substrate, This may be due to the leaching of this soluble element (Tahir and Hamid, 2010). Potassium exhibited lower values in the vermicompost (Hashemimajd *et al.,* 2004).

Total organic carbon decreased with the passage of time during vermicomposting and composting processes in both the substrates. These findings are consistent with those of earlier authors (Garg and Kaushik, 2005; Tognetti *et al.,* 2005). The organic carbon is lost as carbon dioxide through microbial respiration and mineralization of organic matter causing the increase in total N (Crawford, 1983). Part of the carbon in the decomposing residues released as $CO_2$ and a part was assimilated by the microbial biomass (Cabrera *et al.,* 2005; Fang *et al.,* 2001; Elvira *et al.,* 1998). Microorganisms use the carbon as a source of energy decomposing the organic matter. The reduction is higher in vermicomposting compared to the ordinary composting process, which may be due to the fact that earthworms have the higher assimilating capacity.

It has been shown that the level of artificially inoculated potentially harmful microorganisms such as E.coli, Enterococcus species, Salmonella species is significantly reduced due to the activity of earthworms of vermicomposting bio-solids from municipal plants (Eastman *et al*., 2001). Selective reduction of pathogenic bacteria was observed during the vermicomposting

of cow manure: the level of fecal enterococci, fecal coliforms and E.coli was reduced, but the level of Clostridium; total coliforms and enterobacteria remained unchanged (Aira *et al.*, 2011).

## CONCLUSION

The present study concludes that the two types of fruit wastes utilized namely banana waste and papaya waste can be degraded efficiently through vermicomposting using *Eudrilus eugeniae* than normal composting process. It is also interesting to note that papaya waste was degraded more efficiently than banana waste with higher macronutrient content. The vermicompost thus obtained was rich black and homogenous in nature. Vermicomposting turns out to be an effective strategy to manage and degrade different fruit waste generated in vegetable markets. The vermicomposting process improves soil aeration and thereby promotes the survival and dispersal of the useful bacterium within such systems. Vermiculture provides the best answer for ecological agriculture, which is synonymous with "sustainable agriculture".

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