CHAPTER – 4

PHYSICAL AND CHEMICAL PROPERTIES OF VERMICOMPOST

4.1. INTRODUCTION

Earthworms can be called as biological indicators of soil health, for soils with earthworms definitely support healthy populations of bacteria, fungi, actinomycetes, protozoans, insects, spiders, millipedes, and a host of other organisms that are essential for sustaining a healthy soil (Ismail, 1997c). Earthworm casts get converted into stable soil aggregates by the action of gums that result from microbial digestion of their organic compounds (Waksman and Martin, 1939), or by the binding effect of fungal hyphae (Parle, 1963 a,b). There are also reports that certain metabolites produced by earthworms may be responsible to stimulate plant growth (Gavrilov, 1962; Neilson, 1965).

In-situ management of earthworms for soil fertility is always beneficial (Borowski 1995). To maintain earthworms in the soil, moisture and organic matter requirements are essential. Many such traditional and ecofriendly technologies, which are innovative, must be implemented to produce food free from chemicals, toxic substances and residues. One among the many such technologies, which can be used in all spheres, is "VERMITECH" (Ismail, 1994a,1994b,1994c; 1995a, 1995b) using native or indigenous earthworms for converting organic waste into valuable vermicompost, and in soil management.

Growing concerns relating to land degradation, the inappropriate use of inorganic fertilizers, atmospheric pollution, soil health, overgrazing, soil biodiversity
and sanitation have rekindled global interest in organic recycling practices such as vermicomposting. The potential of vermicomposting to turn on-farm waste materials into a farm resource makes it an attractive proposition. Vermicomposting offers benefits such as enhanced soil fertility and soil health that engender increased agricultural productivity, improved soil biodiversity, reduce ecological risks and a better environment. However, many farmers, and especially those in developing countries find themselves at a disadvantage as they fail to make the best use of organic recycling opportunities using earthworm. Thus, vermicomposting could be one of the valuable options for Indian farmers to restore or enhance their agricultural soil physical, chemical and biological properties.

4.2. MATERIALS AND METHODS

4.3. PHYSICAL PARAMETERS

4.3.1. Determination of pH

The pH of the compost sample was determined as per the procedure described by Chandrabose et al., (1988). The pH is defined as the negative log to the base 10 of the H+ ion concentration. The pH of the bedding materials was determined Potentiometric method using a digital pH meter.

Thirty gm of air-dried sample passed through a 2mm sieve was transferred to a clean 100ml beaker to in which 60ml of distilled water was added. The contents were stirred intermittently and the sample suspension was again stirred just before taking the reading. The electrodes were immersed into the beaker containing sample water suspension and meter readings both in the supernatant solution and suspension were recorded.
4.3.2. Determination of Electrical Conductivity (EC)

The electrical conductivity of the test samples was determined as per the procedure outlined by Chandrabose et al., (1988). Electrical conductivity is the measurement of total amount of soluble salts present in the sample and is expressed as millimess/cm (mS/cm). To five gm of the experimental sample, 50 ml of distilled water was added, stirred well and the suspension was allowed to settle for eight hrs. The electrode of the conductivity cell was immersed into the sample solution and the EC was read and expressed in millimess/cm (mS/cm).

4.4. CHEMICAL PARAMETERS

4.4.1 Estimation of Organic Carbon by Empirical Method

The determination of organic carbon was carried out as per the procedure of Empirical Method. Exactly one g of finely ground oven dried sample (at 105°C) was placed in a constant mass silica crucible and heated in a muffle furnace at 550°C for 2 h. The crucible was allowed to cool down in a dessicator and again weighed.

\[
\text{Organic matter} \times \% = \left( \frac{\text{Initial mass} - \text{Final mass}}{\text{Initial mass}} \right) \times 100
\]

The ratio of carbon content to volatile substance content remains to some extent for a particular type of organic waste. The volatile substance in the sample was determined as for organic matter estimation.

\[
\text{Organic Carbon} \times \% = \frac{\text{VS}}{A} = \frac{\text{Organic matter} \times \%}{1.724}
\]

Where, \( A = \) a constant 1.724 (Walkley and Black, 1934)

\( \text{VS} = \) Volatile substance percent (organic matter percentage)
4.4.2. Estimation of Total Nitrogen (N)

The total nitrogen of the sample was estimated by Kjeldahl method. This method involved two steps (i) digestion of the sample to convert the N compound in the sample to the NH$_4^+$ form and (ii) distillation and determination of NH$_4^+$ in the digest.

(i) To a 100ml Kjeldahl flask 0.5gm of dried sample was transferred. Twenty ml of the sulphuric salicylic acid mixture was added and swirled gently so as to bring the dry sample in contact with the reagents. It was allowed to stand over night. About 5gm of sodium thiosulphate was added the next day and heated gently for about 5 min. Care was taken to avoid frothing. The contents were cooled to which 10gm of sulphate mixture was added and digested in the Kjeldahl apparatus for 1 hr. Bumping during the digestion can be avoided by adding glass beads. When the digestion was completed, the digest was cooled, diluted and distilled as follows.

(ii) To a vacuum jacket of micro- Kjeldahl distillation apparatus, 10ml of the digest was transferred. In a conical flask, 10ml of 4% boric acid solution was taken containing bromocresol green and methyl red indicators, to which the condenser outlet of the flask was dipped. After adding the aliquot digest, the funnel of the apparatus was washed with 2-3 ml of deionised water and 10ml of boric acid. After completion of distillation, boric acid was titrated against N/200 H$_2$SO$_4$. Blank was also carried out to the same end point as has been followed in the case of the sample.

- Weight of the sample = 0.5gm
- Normality of H$_2$SO$_4$ = N/200
- Volume of digestion = 100ml; Aliquot taken = 5ml
- Titrant Value (TV) = Sample TV-Blank TV

\[
N(\%) = \frac{TV \times 0.00007 \times 100 \times 100}{0.5 \times 0.5} (1 \text{ml of } N/10 \text{ H}_2\text{SO}_4 + = 0.000014 \text{gm } N)
\]
4.4.3 Estimation of Phosphrous

(i) Diacid digestion

Using a 9:4 mixture of HNO₃ carried out Diacid digestion: HClO₄. One gm of ground sample was placed in a 1000ml volumetric flask. To this, 10 ml of acid mixture was added and the contents of the flask were mixed by swirling. The flask was placed on a hot plate at low heat in a digestion chamber. The flask was subsequently heated at higher temperature until the production of red NO₂ fumes ceases. The contents were further evaporated until the volume was reduced to about 3-5 ml but not to dryness. The completion of digestion was confirmed when the liquid becomes colourless. After cooling the flask, 20ml of deionised or glass distilled water was added and the solution was made upto the mark with deionised water. Then it was through Whatman No.1 filter paper.

(ii) Determination of Phosphorus (P)

Total phosphorus content of the sample was estimated by colorimetric method. The aliquot from sample digestion was pipetted out to 50ml volumetric flask. Then 10ml of vanadomolybdate reagent was added to each flask. The volume was made up with deionised water and mixed thoroughly (by shaking). Yellow colour was developed in about 30 minutes (The colour is stable for 2-3 weeks). The absorbance / transmittance of the solution was read at 420nm with a spectrophotometer. The phosphorus concentration was determined using the prepared standard curve.

\[
P (\%) = \text{Sample concentration (ppm)} \times \frac{1}{\text{Weight of the sample}} \times \frac{\text{X}}{\text{Aliquot (ml)}} \times \frac{100}{1000} \times \frac{\text{Final volume(ml)}}{1000}
\]
Digestion of Sample by Dry Ashing Method

For the estimation of K, Ca, Mg, Na, Zn, Fe, Mn and Cu, digestion of manure sample by dry ashing method was followed as shown below. To carry out dry ashing, 1.0 gm of ground, sieved and oven dried (at 105°C) sample was taken in a silica crucible, placed in a muffle furnace and heated at 550°C for 5 hrs. The ash was then cooled and dissolved in 10ml of 6N HCl. The solution was filtered through an acid washed filter paper into a 100 ml volumetric standard flask. The filter paper was washed and the solution was made upto the mark with deionised water.

4.4.4. Estimation of Potassium

Total potassium content of the manure sample was determined as per Tandon (1993) by flame photometric method. The unknown sample was atomized in the flame photometric and the readings were recorded. The potassium concentration was determined using the prepared standard curve and multiplied with dilution factor.

4.4.5 Estimation of Calcium and Magnesium (Ca & Mg)

(A) Determination of Calcium

The calcium and Magnesium contents of the sample were determined as per procedure of Tandon (1993). An aliquot of the sample solution containing upto 3mg calcium was pipetted out into a china dish and diluted to 10ml. About 10 droops of each of potassium cyanide, hydroxylaminehydrochloride, potassium hexacyoferrate and triethanolamine solution were added. Also 2.5 ml NaOH solution and one ml of calcon solution were added. Then, the contents were titrated against 0.01N EDTA until the colour changed from wine red to blue using EBT indicator.
(B) Determination of Ca and Mg

An aliquot of sample solution containing up to 3.0mg of Ca and Mg was pipetted out into a China dish and diluted to 10ml. To this 15ml of ammonium chloride, ammonium hydroxide buffer solution, about 10 drops of each of potassium cyanide, hydroxylamine hydrochloride, potassium hexacyofarrate and triethanolamine solution were added. After adding all these reagents, the solution was warmed for 3 min., cooled and 10 drops of Erichrome Black-T (EBT) indicator solution was added. The contents were titrated with EDTA.

4.4.6 Determination of Magnesium

Magnesium content was calculated from the difference between the contents Ca + Mg and the calcium content.

\[
\text{Ca or (Ca + Mg) meq/gm} = \frac{(\text{ml of EDTA consumed} \times \text{Normality of EDTA})}{\text{Aliquot taken}} \times \text{X Volume made up}
\]

For calculation of percentage of calcium and magnesium, the milliequalants of Ca or Mg are to be multiplied by their respective equivalent weights (Meq X Eq. wt/mg). Then 10 to get Ca or Mg percent per gm of sample divided the value.

4.4.7. Estimation of Sulphur

Total sulphur content was normally estimated by wet ashing of plants tissue sample (manure) (as described under phosphorous Diacid digestion) and the sulphate turbidimetry method.

Ten ml aliquot from sample Diacid digestion (described as phosphorous) was pipetted out to volumetric flask to which 25ml of salt buffer solution was added. The volume was made up with deionised water up to 50ml and mixed thoroughly. Ten ml each of the above solutions was pipetted into a 50 ml conical flask. One ml of 6N HCl
and 1ml of 0.05% gum acacia solutions were added. Swirling and 0.5 gm of barium chloride crystals were dissolved mixed the content. The absorbance or transmission of the solution was read on a spectrophotometer at 420nm. Sulphur concentration was determined using the prepared standard curve.

\[
S(\%) = \frac{RX}{\text{Sample}} \times \frac{100}{1000000} \text{ or } \frac{R}{\text{Sample} \times 100}
\]

4.5. RESULTS OF PHYCO-CHEMICAL PROPERTIES OF VERMICOMPOST

PHYSICAL PARAMETERS

The physico-chemical status of the different compost used in the present study is given in Fig - 1 to 14. These Graphs shows the physico chemical characteristic of the composts produced by two different species of earthworms over 45 days.
4.5.1 pH

The pH of the both leaf litter was slightly acidic range from 6.96±0.30, 7.04±0.12, 7.26±0.40, 7.26±0.23, 7.01±0.44 in control, EU/CA, EU/TP, EF/CA and EF/TP (Figure-1) substrate respectively before composting and after composting the values changed towards alkali. The pH of the composts after composting was 7.00±0.41 and 6.96±0.73 in *Eudrilus* treated *C.auriculata* and *T.Purpurea* compost. But It was 7.65±0.17 and 7.50±0.26 in *Eisenia* treated compost on 45th day.

**Figure - 1 Mean pH in control and different types of Vermicompost over 45 days**

EE/CA - *Eudrilus* treated *C.auriculata* compost
EE/TP - *Eudrilus* treated *T.Purpurea* compost
EF/CA - *Eisenia* treated *C.auriculata* compost
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.2 ELECTRICAL CONDUCTIVITY

The mean electrical conductivity of the initial control was 0.79±0.03 mS/cm. The gradual increase of EC was observed in all experiments including control from its initial value (Figure-2). The final EC recorded was 0.52±0.04 in control, 0.56±0.04 in *C.auriculata* and 0.54±0.00 in *T.purpurea* on *Eudrilus* worked compost at 45th day. The final EC recorded was 0.56±0.02 in *C.auriculata*, and 0.56±0.03 mS/cm in *T.purpurea* on *Eisenia* treated compost at 45th day.

**Figure –2. Mean Ec (ms/cm) in control and different types of Vermicompost over 45 days**

EE/CA - *Eudrilus* treated *C.auriculata* compost
EE/TP - *Eudrilus* treated *T.Purpurea* compost
EF/CA - *Eisenia* treated *C.auriculata* compost
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.3 WATER HOLDING CAPACITY

The initial and final water holding capacity of the two different leaf litter before and after composting is presented in Figure-3. The water holding capacity of control is 62.0±1.33. After composting, the water holding capacity was found to increase in the two different leaf litter over initial and control.

Initially the water holding capacity of *Eudrilus* treated *C.auriculata*, *T.purpurea* was 56.85±6.70, 56.98±3.39 and *Eisenia* treated *C.auriculata*, *T.purpurea* was 55.06±6.16, 55.81±7.46 respectively. But it was 74.96±1.35, 86.00±1.44, 86.88±0.89 and 90.65±1.50 in the both *Eudrilus* and *Eisenia* treated leaf litter at the 23rd day. Finally it reached 95.02±4.38, 113.9±4.65, 101.4±8.39 and 111.5±1.17 for *Eudrilus* and *Eisenia* compost respectively at 45th day. In the present study, the compost which was prepared by using *Eudrilus* found maximum water holding capacity in the both worms.

*Figure - 3 Mean water holding capacity in control and different types of Vermicompost Over 45 days*

<table>
<thead>
<tr>
<th>Days</th>
<th>Control</th>
<th>EE/CA</th>
<th>EE/TP</th>
<th>EF/CA</th>
<th>EF/TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>62.0±1.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23rd</td>
<td>74.96±1.35</td>
<td>56.85±6.70</td>
<td>56.98±3.39</td>
<td>55.06±6.16</td>
<td>55.81±7.46</td>
</tr>
<tr>
<td>45th</td>
<td>95.02±4.38</td>
<td>86.00±1.44</td>
<td>86.88±0.89</td>
<td>90.65±1.50</td>
<td></td>
</tr>
</tbody>
</table>

- Control
- EE/CA - *Eudrilus* treated *C.auriculata* compost
- EE/TP - *Eudrilus* treated *T.Purpurea* compost
- EF/CA - *Eisenia* treated *C.auriculata* compost
- EF/TP - *Eisenia* treated *T.Purpurea* compost
CHEMICAL PARAMETERS

4.5.4 ORGANIC CARBON

The amount of organic carbon in the initial and final composted leaf litter mixed with cow dung and control is given Figure-4. Significant reduction over initial and control was observed in all the treatments. The maximum reduction in *T.purpurea* (27.9) was recorded in *Eisenia* worked compost. Followed by *Eudrilus* treated *T.purpurea* (29.2). The *Eudrilus* worked compost *C.auriculata* was (30.05) and *Eisenia* worked *C.auriculata* (31.2) had maximum reduction.

**Figure - 4** Amount of organic carbon in control and different types of Vermicompost Over 45 days

![Graph showing organic carbon over 45 days](image)

EE/CA - *Eudrilus* treated *C.auriculata* compost
EE/TP - *Eudrilus* treated *T.Purpurea* compost
EF/CA - *Eisenia* treated *C.auriculata* compost
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.5. NITROGEN

The Nitrogen content of two different leaf litter treated with both earthworms before and after composting is shown in Figure-5. In all the four different leaf litter compost, increase in the nitrogen content over the control was observed in Eudrilus treated compost. T.purpurea compost found to have maximum nitrogen content 1.99±0.27 followed by Eisenia T.purpurea compost (1.75±0.08), Eisenia C.auriculata (1.60±0.08) and Eudrilus worked C.auriculata compost (1.56±0.08). The Analysis of variance (ANOVA) shows significant difference between control and treatment (p < 0.05).

**Figure - 5 Amount of Nitrogen in control and different types of Vermicompost Over 45 days**

<table>
<thead>
<tr>
<th></th>
<th>1st</th>
<th>23rd</th>
<th>45th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE/CA</td>
<td></td>
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<tr>
<td>EE/TP</td>
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</tr>
<tr>
<td>EF/CA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EF/TP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EE/CA - Eudrilus treated C.auriculata compost  
EE/TP - Eudrilus treated T.Purpurea compost  
EF/CA - Eisenia treated C.auriculata compost  
EF/TP - Eisenia treated T.Purpurea compost
4.5.6. PHOSPHORUS

The phosphorus content was recorded maximum in all the four different compost under this study than the control. Increased phosphorus content was observed in the *Eisenia T.purpurea* compost (0.14±0.00, 0.72±0.08 and 1.32±0.63) during initial, 23rd and 45th day (Figure-6). This was found to be maximum when compared to all other compost. Followed by *Eudrilus T.purpurea* compost (1.18±0.05), *Eudrilus C.auriculata* (1.15±0.01) and *Eisenia C.auriculata* (1.05±0.16) respectively. The Analysis of variance (ANOVA) shows significant difference between control and treatment (p < 0.05).

**Figure - 6 Amount of Phosphorus in control and different types of Vermicompost Over 45 days**

![Phosphorus graph]

- Control
- EE/CA
- EE/TP
- EF/CA
- EF/TP

EE/CA - *Eudrilus* treated *C.auriculata* compost
EE/TP - *Eudrilus* treated *T.Purpurea* compost
EF/CA - *Eisenia* treated *C.auriculata* compost
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.7. POTASSIUM

Significant increase was noted in all the four different composts at the end of the experiment (Figure-7). Maximum increase was noted in *Eisneia T.purpurea* compost (1.55±0.02) and Maximum increase of potassium in *Eudrilus* worked composts was recorded in *C.auriculata* (1.51±0.07) and it was minimum in *Eisenia C.auriculata*.

The Analysis of variance (ANOVA) shows significant difference between control and treatment (p < 0.05).

**Figure - 7 Amount of Potassium in control and different types of Vermicompost Over 45 days**

EE/CA - *Eudrilus* treated *C.auriculata* compost  
EE/TP - *Eudrilus* treated *T.Purpurea* compost  
EF/CA - *Eisenia* treated *C.auriculata* compost  
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.8. CALCIUM

Figure-8 shows the mean values of calcium content in two different leaf litter worm worked compost. In general, significant increase in calcium content was observed in all the four different compost. The calcium content was recorded to be maximum in *Eisenia* worked *C.auriculata* (1.14±0.04) followed by *T.purpurea* compost (1.10±0.04), *Eudrilus C.auriculata* compost (1.09±0.03) and *Eisenia C.auriculata* compost (1.05±0.09) respectively.

**Figure - 8 Amount of Calcium in control and different types of Vermicompost Over 45 days**

EE/CA - *Eudrilus* treated *C.auriculata* compost  
EE/TP - *Eudrilus* treated *T.Purpurea* compost  
EF/CA - *Eisenia* treated *C.auriculata* compost  
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.9. MAGNESIUM

Significant increased magnesium level was observed in the present study for four different compost Figure-9. After composting the magnesium values increased in all the compost over initial and control. In the Eisenia worked C.auriculata compost the maximum percentage increase was recorded (0.47±0.01) and Eudrilus worked C.auriculata compost (0.43±0.02). In the worm worked T.purpurea both composts recorded same of magnesium (0.38) level over their respective controls.

The Analysis of varience (ANOVA) shows significant difference between control and treatment (p < 0.05).

Figure - 9 Amount of Magnesium in control and different types of Vermicompost Over 45 days

EE/CA - Eudrilus treated C.auriculata compost
EE/TP - Eudrilus treated T.Purpurea compost
EF/CA - Eisenia treated C.auriculata compost
EF/TP - Eisenia treated T.Purpurea compost
4.5.10. SULPHUR

Figure -10 shows significant increase in sulphur over initial and control was observed in all the four different leaf litter on final of composting. In the *Eisenia* worked composts the increased ppm observed was in *T.purpurea* compost (0.82±0.02), then *C.auriculata* compost (0.80±0.02). In the *Eudrilus* worked composts maximum increase was recorded in *T.purpurea* compost (0.81±0.03) and minimum was recorded in *C.auriculata* compost (0.78±0.02).

**Figure - 10 Amount of Sulphur in control and different types of compost Over 45 days**

![Graph showing sulphur levels over 45 days](image)

EE/CA - *Eudrilus* treated *C.auriculata* compost  
EE/TP - *Eudrilus* treated *T.Purpurea* compost  
EF/CA - *Eisenia* treated *C.auriculata* compost  
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.11. ZINC

Figure -11 shows significant increase over initial and control in all the treatments. Among treatments maximum ppm increase was observed in *Eisenia* and *Eudrilus* worked composts in *T.purpurea* compost (0.35±0.01), (0.33±0.01) respectively. Among the *C.auriculata* compost, both worm recorded same zinc content (0.31) on 45\textsuperscript{th} day.

**Figure - 11 Amount of Zinc in control and different types of Vermicompost Over 45 days**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>EE/CA</th>
<th>EE/TP</th>
<th>EF/CA</th>
<th>EF/TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc ppm</td>
<td>0.05</td>
<td>0.15</td>
<td>0.30</td>
<td>0.32</td>
<td>0.35</td>
</tr>
</tbody>
</table>

- EE/CA - *Eudrilus* treated *C.auriculata* compost
- EE/TP - *Eudrilus* treated *T.Purpurea* compost
- EF/CA - *Eisenia* treated *C.auriculata* compost
- EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.12. IRON

The range of iron in *Eudrilus* worked composts in *C.auriculata* and *T.purpurea* compost was 3.14±0.03 and 3.15±0.10 respectively. In *Eisenia* worked compost it found to be 3.21±0.05 and 3.47±0.17 in *C.auriculata* and *T.purpurea* compost. (Figure-12).

**Figure - 12 Amount of Iron in control and different types of Vermicompost Over 45 days**

EE/CA - *Eudrilus* treated *C.auriculata* compost
EE/TP - *Eudrilus* treated *T.Purpurea* compost
EF/CA - *Eisenia* treated *C.auriculata* compost
EF/TP - *Eisenia* treated *T.Purpurea* compost
4.5.13. COPPER

In the *Eudrilus* worked composts the increased copper content was observed in *C. auriculata* and *T. purpurea* compost, which was found to be 0.02±0.00. In the *Eisenia* worked composts it was 0.03±0.00 in *C. auriculata* and 0.02±0.00 in *T. purpurea* compost. (Figure- 13)

**Figure - 13 Amount of Copper in control and different types of Vermicompost Over 45 days**

EE/CA - *Eudrilus* treated *C. auriculata* compost
EE/TP - *Eudrilus* treated *T. purpurea* compost
EF/CA - *Eisenia* treated *C. auriculata* compost
EF/TP - *Eisenia* treated *T. purpurea* compost
4.6. DISCUSSION

4.6.1. pH

Earthworms are directly affected by low pH. Each species showed a specific tolerance to acidity that influenced the distribution of that species in soils (Laverack, 1963). The distribution of the earthworm species get determined by the native soil pH. (Piearce, 1972). Haimi and Huhta (1987) stated that the decrease of pH towards neutral is an important factor to be considered influencing retention of nitrogen. The lower pH recorded in the final products might have been due to the production of CO$_2$ and organic acids by microbial activity during the process of bioconversion of the different substrates in the beds (Haimi and Huhta, 1987).

High solubility of nutrients in earthworm casts increases the pH of cast (Barley, 1959). This could be another reason for the rise in pH of the substrates observed in the present study. Bhatnagar and Palta (1996) stated the preference of neutral soils by most earthworm species expecting \textit{Eisenia foetida} that tolerates slightly acidic soils. Several workers reported that earthworms’ casts are found to be more neutral than the soil in which the worms live (Ramalingam, 1997). One possible reason for this may be the neutralization of soils as it passes through the earthworm gut, through secretion of the calciferous glands. In contrary, Edwards and Lofy (1977) explained the neutralization of soil by secretions from the intestine and ammonia excretion. El Duweini and Ghabbour (1965) observed that the population can be adversely affected by high salt concentrations. Springett and Syers (1984) found that the production of cast increased with increasing pH and calcium level, but not with increasing calcium when pH was constant. Observance of increased collections of castings of \textit{Metaphire posthuma} and \textit{Eutychoeus waltoni} was found in soils having pH of 5-9 than 7.8 and 8.4.
The observed pH of 7.33 to 8.27 in the present study is on par with the above results, which was found to be favourable for the increasing biomass, fecundity and cast production of the earthworms. The increase in pH of the mycocompost may be due to the decomposition of nitrogenous substrates, which might have contributed to the production of NH$_4^+$ (Cuevas et al., 1988).

4.6.2. Electrical Conductivity

Electrical conductivity is an indicator of concentrations of soluble salts. The electrical conductivity of the vermi compost produced was more than the substrates and control. Bhatnagar and Palta (1996) suggested that the ionic conductivity below 3.0mS/cm as optimum for earthworms. Electrical conductivity of 1.5-3.0mS/cm supported the weight gain of earthworms (Kaplan et al., 1980). The increase of electrical conductivity in vermicompost when compared to the control might be due to the presence of exchangeable calcium, magnesium and potassium in worm cast than the soil (Bhatnagar and Palta, 1996). Balamurugan et al., (1999) have also obtained similar result with pressmud composted by *Eisenia fetida*, *Eudrilus eugeniae* and *Trichoderma harzianum*. The observed EC of the present study was in agreement with the reports of Bhatnagar and Palta (1996) Balamurugan et al., (1999) and Balamurugan (2002).

4.6.3. Water Holding Capacity

The values of water holding capacity in the final composts were found to be more than that in the control. *Eudrilus* worked compost recorded maximum water holding capacity in all the four different composting system under this study. Several reporters recorded similar increase in water holding capacity in the *Lampito* worked compost obtained from leaf litter. Similar results were obtained by Umamaheswari et
al., (2003) in the mango litter waste composted by *Perionyx sansibaricus*. These findings corroborate with the present research work.

4.6.4. Nitrogen

After composting the nitrogen values significantly over control in all the experiments. The increase trend in nitrogen in the vermicomposts was also reported by Dash and Patra (1977, 1979) Curry *et al.*, (1995) Ramalingam (1997) and Balamurugan (2002). Of the total nitrogen excreted by worms, about another half is secreted as mucoproteins by gland cells found in the epidermis, and half in the form of ammonia, urea and possibly uric acid as allantoin in a fluid excreted from the nephridiopores (Edwards and Lofty, 1977). Dash and Patra (1977, 1979) analyzed the nutrient status of the *Lampito mauritii* worked soils and observed that the cast contained 0.47%N, compared with 0.35% in the surrounding soil. They also estimated that the increase in nitrogen in casts was equivalent to 9.29 gm m⁻² y⁻¹ and some of them probably from excretion of urine.

Graff (1971) too reported that the excreta of earthworms had more nitrogen considerably in casts than the surrounding soil. The increase of nitrogen in the present study is suggested as due to the addition of muco-proteins secreted from the body wall of the earthworms. Muco-proteins secreted from the body surface in drososphere were found by Lee (1985). A net mineralization of nitrogen occurred due to earthworm activity, whereas a net loss of mineral nitrogen was observed on exclusion of earthworms (Opperman *et al.*, 1987). Blair *et al.*, (1997) have observed that the earthworm might increase nitrogen availability by reducing microbial immobilization. Therefore the variation in increased percentage of nitrogen over control in composites using each species of earthworms may be due to the varying number of
microorganisms present in the different concentration of the substrates and the palatability of the substrates by earthworms.

Curry et al., (1995) observed that the earthworms would contribute an addition of 3.4-4.1g of mineral nitrogen to the soil through excretion, mucus production and soil ingestion. Bhatnagar and Palta (1996) revealed that about 6% more nitrogen was made available to plants by worm excreta. These documents are in conformation with the present study. Selvakumar et al., (2003) have also observed similar results when they analysed the nitrogen content of the vegetable wastes composted by Eudrilus eugeniae.

4.6.5. Phosphorus

The initial and final phosphorus contents in the four different composting system show that composting has increased phosphorus concentration over control in all the experiments. The uptake of bacteria and fungi followed by grazing microorganisms by the earthworms, excretion and decomposition might result in release of phosphorus compounds that can be cycled through plants and back again to the soil biota as observed by Coleman et al., (1983). Similar results were reported by Mansell et al., (1981) with regard to the increase of short-term plant availability of phosphorus derived from plant litter by two or three fold by the earthworms. The uptake of proliferated fungal species was found to be more in the beds treated with Eudrilus, which might account for enhanced phosphorus content in the Eudrilus composts than the Lampito worked compost and Trichoderma harzianum inoculated composts. Phosphorus was found to be more in casts than the surrounding soil (Lunt and Jacobson, 1944; Graff, 1971). Bhatnagar and Palta (1996) reported that 15-30% more phosphorus was made available to plants by worm activity. Vermicompost

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obtained individually from cow dung, sugarcane trash, pig manure and horse manure had higher level of phosphorus compared to control (Jambhekar 1992). Gunjal and Nikam (1992) observed similar findings in grapevine under drip irrigation system, Ramalingam (1997) in press mud mixed with organic waste and Selvakumar et al., (2003) in vegetable waste vermicompost. The present study also lends support to the above results.

4.6.6. Potassium

The initial and final of potassium in different concentrations of leaf litter revealed that potassium increased progressively more than the control. Gunjal and Nikam (1992) also found that water-soluble potash of grapevine increased more than 8.4 times in vermicompost over control. Jambhekar (1992) observed considerable increase in available potassium than the initial and control treatments in different animal residues and agricultural wastes. Graff (1971), Nijhawan and Kanwar (1952), Watanabe (1975), Buchanan et al., (1988) and Ramalingam (1997) reported similar trends. The findings of the present studies are also in conformity with the above-mentioned results.

4.6.7. Calcium

The increase of calcium in the vermicomposts might be due to the excretion of calcium from the calciferous glands. The value of calcium at the end of compost formation was more than the control. The soil particles in the worm intestine are found to be cemented by calcium humate formed from the intestine organic matter and calcite excreted by the calciferous glands (Satchell, 1967). In the present study calcium was found to increase over the initial value. A report that the cast contained 1.3 times more calcium than the surrounding soil was provided by Kale and Krishna.
moorthy (1982). They also found that the excess of calcium gets excreted in concretions formed in the calciferous glands. Occurrence of enough calcium in available form in the calciferous glands with the primary role of secreting calcium and secondarily excreting wastes was reported by Jamieson (1981). Similar results were observed by Watanabe (1975), Dash and Patra (1979), Buchana et al., (1988), Bhatnagar and Palta (1996) and Ramalingam and Thilagar (2000) whose findings corroborates with the present one. Kavian and Ghatnekar (1991) observed increased calcium content in 25% soybean oil extraction sludge waste on subjection to treatment by *Lumbricus rebellus*.

**4.6.8. Micronutrients**

The initial and final values of the micronutrients such as magnesium, sulphur, copper, Iron and zinc revealed that the main reason for the increase in the micronutrients in the vermicomposts in the present might be due to the release of the excess amount of micronutrients and heavy metals from the earthworm body into the environment through the calciferous glands. Ireland (1975) suggested that the chemical changes that occur in the alimentary tract of earthworms might enable various metals more readily available to plants and mineralization of dead earthworms would release accumulated heavy metals into the environment. The chemical properties of earthworm cast, termite mould and ant gallery were compared by Reddy and Dutta (1984) who found that the earthworm casts had increased nutrients than the others.

The availability of metals such as Pb, Cu, Cd, Zn, Mn and Ca in the tissue of earthworm was reported by Ireland (1979). Ionic regulatory mechanism in earthworms involves uptake of Fe, Mn and Na from ingesta and its excretion via
calciferous glands (Bouche, 1983). Ash and Lee (1980) found Pb, Cd, Cu and Fe concentration in the tissue of L. terrestris, L. rubellus and A. chlorotica. The concept of increase in the rate of heavy metal accumulation with addition of compost was provided by Mba and Wei-Chun (1982) on examination of the body content for Cd, Pb, Cu, Ni, Mn, Fe and Cr in A. calizinosa. Kale et al., (1994) observed insignificant increase of Fe and Cu in Eudrilus eugeniae worked compost. Ramalingam (1997) recoded both increase and decrease in the level of Fe and uniform decrease in the level of Cu in the Eudrilus eugeniae and Lampito mauritii worked compost. These two metals are required for haemoglobin formation (Maynard et al., 1983).

Anderson and Laursen (1982) observed the excretion of Zinc, Manganese and Iron through the calciferous glands in L. terrestris, which coincided with the present study in Eudrilus eugeniae and Eisenia fetida in two different leaf litters. Ramalingam (1997) and Balamurugan (2002) observe similar results in different organic wastes. The difference of micronutrients and metals in the differences wastes may be due to the differential mineralization rates due to the combined effect of earthworms and microorganisms.

4.6.9. Organic Carbon

The level of organic carbon in the four different composting was found to decrease from its initial value in both control and treatments. Microorganisms have the capability of utilizing carbon as their energy source and nitrogen for growth during the process of decomposing materials in which carbon will be released as CO₂. During the respiration of earthworms combustion of carbon into CO₂ brings down the amount of carbon (Bhatnagar and Palta, 1996). A similar trend was suggested in the present study too. The respiration of earthworms and growth of microorganisms may
be responsible for the reduction of organic carbon Bhandari et al. (1967) found that the worm cast had considerably more organic carbon than the parental soils and that the casts were significantly richer in polysachharides than the soil. Hand et al. (1988) recorded a decrease in the organic carbon content of the peat and slurry mixture at the beginning of the experiment which got stabilized after 21 days and was observed to be lower than in the control at the end of the experiment. This finding strongly supports the present work in leaf litter compost.

In the present study, the amount of organic carbon reduced a little from its initial value and it was within the range of 27.12% to 34.05%. Satchell and Martin (1984) recorded similar results in culture containing earthworms, hence it could be concluded that the organic carbon in the vermicompost is the main source of energy for microorganisms, plants and soil aggregates.

Based on the discussion it could be concluded that these two different leaf waste available in enormous quantities could be used as an effective medium for Vermiculture supplemented with cattle dung not only served as it a suitable medium for the growth and reproduction of the earthworms but also yielded a valuable biomanure for agriculture practices. Data on the physico-chemical analysis of wastes before and after treatments indicated that though T.purpurea was ideal giving the highest microbial count and reproductive rate of the earthworms. The use of two different (C.auriculata and T.purpurea) as raw material in the vermi composting systems, can potentially help to convert these wastes into value added materials, and reduce the cost related to the exclusive use of different types of farm wastes as feeds for the earthworms.