Use of Earthworms for Composting of Sugar Industry Waste

*ZAHIDA UMAR & FAIZA SHARIF

Sustainable Development Study Centre, Government College University, Lahore

ABSTRACT

Transformation of industrial sludges into vermicomposts can convert these wastes into valuable products. This study explores the potential of converting the sugar industrial waste into value added fertilizer and vermicompost. A total of six treatments of sugar sludge with different percentages of sludge and cow dung (CD) were prepared with three replicates. The experiment was conducted in plastic pots at 27 ± 3°C and moisture contents were maintained at 70-80%. The treatments were monitored for the nutrient increments, heavy metals reduction (Fe, Mn, Cu, Ni) and growth of earthworms for 90 days. Earthworms survived only in S3 (300 g sugar mill waste + 200 g CD) and S4 (400 g sugar mill waste + 100 g CD). Earthworms caused a significant change in the chemical composition of these treatments. Increase in number and bodyweights of earthworms, pH, EC, N, P and K and heavy metals reduction were significantly (p < 0.05) better in S3 vermicompost as compared to S4. There was a significant (p < 0.05) reduction in heavy metal and total organic carbon and increase in pH, EC, N, P and K contents of final vermicomposts of S3 ans S4 than their initial mixtures. Results revealed that chemical properties (pH, EC, N, P & K) and heavy metals contents of sugar vermicomposts were in compliance with the standard end use compost limits and were suitable to be used as effective organic fertilizers and soil conditioners for agriculture purposes.

Key words: Agro-industrial sludge, sugar waste, vermicompost, earthworms, cow dung

INTRODUCTION

Vermicomposting is an eco-biotechnological process that converts complex and energy rich organic wastes into more stabilized vermicompost by exploiting earthworms (Benitez et al., 2000). Through this process, the essential nutrients of plants such as nitrogen, phosphorus, potassium and calcium present in the mixture are transformed into plant soluble and available forms through microbial action (Ndewga and Thompson 2001). In vermicomposting, several earthworm species are employed to accelerate waste conversion process to generate useful final product. Earthworms are capable of transforming garbage into ‘gold’ through a type of biological alchemy (Vermi Co 2001).

Industrial sludges should be mixed with nitrogen-rich organic waste to provide nutrients as micro-organisms inoculum and to obtain stabilized vermicomposts adequate for agricultural use (Hartenstein 1978). Studies indicated that certain epigeic species demonstrate outstanding result in bedding mixed with cow and sheep manures (Nogales et al. 1999).

Some agro-industrial sludge such as sugar industrial sludge has significant quantity of plant nutrients, which may be reutilized for restoration of land and food production. Sugar sludges are either stored in premises of sugar
mill or discarded along roadsides due to high sludge disposal cost where it causes harmful impacts on the ambient environment (Parthasarathi & Ranganathan 2008). These sludges can be valuable raw materials for vermicomposting at commercial level.

Current study is designed to see the potential of sugar industrial sludge to be converted into vermicompost by employing spring species (Darwida nepalensis and Remiella bishambari) of earthworms collected from GCU Botanical Garden, Lahore.

Use of sugar industrial sludge in vermicomposting are expected to provide sound management practices for this sludge in order to solve the widespread environmental and economic problems related with the disposal of this wastes and can also help farmers in income generation.

The objectives of the current study were to
1. Determine the appropriate ratio of sugar industrial sludge and cow dung required for suitable growth of earthworms.
2. Effectiveness of selected earthworm species in increasing concentration of nutrients and reducing heavy metals.

MATERIALS AND METHODS

Sample Collection
Sugar mill sludge was collected from Shakarganj sugar mill, Jhang. Spring species of Earthworms (Darwida nepalensis and Remiella bishambari) were collected from the Botanical Garden, GC University Lahore. The complete identification of species of earthworms was carried out with the help of monographic work of Gates (1972) and Julka (1988).

Experimental setup
Sugar sludge and fresh cow dung (CD) were air dried for 48 hours and were oven dried at 60°C for 24 hours. The experiment was conducted in plastic pots of 18 cm height and 17 cm diameter, each of 2 kg capacity. Total duration of experiment was 90 days. The composting mixture consisted of sugar sludge mixed individually with cow dung (CD) in different ratios (on dry weight basis). Total 500 g of composting mixture was taken in each experimental pot. Sugar sludge treatments were designated as S1 (100g sludge +400g CD), S2 (200g ss +300g CD), S3 (300g ss +200g CD), S4 (400g ss +100g CD) and S5 (500g ss). Three replicates for each treatment were run. Each mixture was turned over manually every 24 h for 15 days in order to eliminate volatile toxic substances. In each replicate pot, 10 healthy earthworms were inoculated after 15 days of predecomposition of organic wastes. This was done to avoid exposure of worms to high temperature during the initial thermophilic stage of composting. The moisture content of each replicate was maintained at 70-80% by periodic sprinkling of an adequate quantity of water. The experimental pots were kept under shade and covered with the muslin cloth to avoid direct sunlight and excessive evaporation. Earthworm survival and body weight in each treatment were noted after 15 days of inoculation of earthworms, 45 and 90 days of composting.
Analysis of vermicompost samples

Chemical parameters pH, EC$_{1:1}$, organic matter (OM), Total organic carbon (TOC), Na, K, P, Ca and Mg were analysed as described by Ryan et al. (2001). Copper (Cu), Manganese (Mn), Nickel (Ni) and Iron (Fe) were estimated by FAAS, shimadzuAA-7000F Atomic Absorption Spectroscopy (Kamitani & Kaneko 2007).

Statistical Analyses

The data were analyzed statistically and all values were presented as Mean ± SE (Standard Error). t-test was performed to determine the significant differences among different treatments for the studied parameters using SPSS version 16. The probability levels used for statistical significance were $p < 0.05$ for the tests.

RESULTS

Earthworms could not survive in pure sugar sludge treatment (S5) and increased cowdung concentrations more than 200g/500g of initial sugar-cowdung mixture (S1 & S2). At the end of one week, no earthworm survived in S1, S2 and S5, so these treatments were terminated. Earthworms only survived in S3 (300g sugar mill sludge + 200g Cow dung) and S4 treatments (400g sugar mill sludge + 100g CD).

Earthworm survival and body weight

Earthworm survival rate slightly declined during composting from 0 to 90 days in both S3 and S4 treatments (Table 1). In initial mixture, 10 earthworms were inoculated in both sugar mill sludge treatments that decreased to 9 in both S3 and S4 treatments. After 90 days the body weight of earthworms was increased to 7.58 g and 7.42 g in S3 and S4 treatments, respectively (Table 1). Difference of both treatments for earthworms survival and increase in body weight was statistically non-significant (Fig., 1).

Chemical Properties

After 90 days pH, EC$_{1:1}$, nitrogen (%), phosphorous (mg/kg), sodium (mg/kg) and potassium (mg/kg) significantly increased in both S3 and S4 treatments in final products as compared to 0 day (Table 1). While total organic carbon (%), organic matter (%), calcium (mg/kg), magnesium (mg/kg) and heavy metals i.e. Cu, Ni, Mn, Fe (mg/kg) significantly decreased in final product of both S3 and S4 treatments (Table 1).

In the final product, values of EC$_{1:1}$ (mS/cm), sodium and magnesium were significantly lower in S4 than S3. While total organic carbon (%), Phosphorous and heavy metals (mg/kg) were significantly less and Nitrogen, calcium and potassium were significantly higher in S3. Reduction in pH and organic matter (%) were non-significant in both S3 & S4 treatments (Fig., 1-5).
Table 1: Chemical changes in both sugar sludge treatments (S3 & S4) from 0 - 90 days

<table>
<thead>
<tr>
<th>Treatments</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>pH</td>
<td>6.9 ± 0.006</td>
<td>7.8 ± 0.017</td>
</tr>
<tr>
<td>EC (ms/cm)</td>
<td>1.36 ± 2.08</td>
<td>1.68 ± 0.88</td>
</tr>
<tr>
<td>TOC (%)</td>
<td>29.6 ± 0.09</td>
<td>24.3 ± 0.24</td>
</tr>
<tr>
<td>OM (%)</td>
<td>47.1 ± 0.21</td>
<td>40.4 ± 0.884</td>
</tr>
<tr>
<td>P (mg/kg)</td>
<td>56.5 ± 0.20</td>
<td>137 ± 0.88</td>
</tr>
<tr>
<td>N (%)</td>
<td>1.92 ± 0.01</td>
<td>21.5 ± 0.06</td>
</tr>
<tr>
<td>K (mg/kg)</td>
<td>958 ± 0.33</td>
<td>1858 ± 1.45</td>
</tr>
<tr>
<td>Na (mg/kg)</td>
<td>305 ± 1.20</td>
<td>821 ± 1.764</td>
</tr>
<tr>
<td>Mg (mg/kg)</td>
<td>807 ± 1.45</td>
<td>547 ± 4.63</td>
</tr>
<tr>
<td>Ca (mg/kg)</td>
<td>426 ± 2.33</td>
<td>137 ± 1.155</td>
</tr>
<tr>
<td>Cu (mg/kg)</td>
<td>0.33 ± 0.00</td>
<td>BDL</td>
</tr>
<tr>
<td>Ni (mg/kg)</td>
<td>0.07 ± 0.00</td>
<td>BDL</td>
</tr>
<tr>
<td>Mn (mg/kg)</td>
<td>2.43 ± 0.00</td>
<td>0.36 ± 0.00</td>
</tr>
<tr>
<td>Fe (mg/kg)</td>
<td>42.97 ± 0.002</td>
<td>18.46 ± 0.002</td>
</tr>
</tbody>
</table>

BDL = Below detection limit
Detection limits for Heavy Metals: Ni= 0.05 mg/kg Cu, Mn & Fe= 0.1 mg/kg

Table 2: Chemical and Heavy metals standards for compost (Wiemer and Kern 1994; Daniel et. al. 1997)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Compost Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6 – 7.5</td>
</tr>
<tr>
<td>EC</td>
<td>&lt;2 mmhos/cm</td>
</tr>
<tr>
<td>OM</td>
<td>&gt;30 %</td>
</tr>
<tr>
<td>P</td>
<td>800 – 2500 mg/l</td>
</tr>
<tr>
<td>N</td>
<td>100 – 300 mg/l</td>
</tr>
<tr>
<td>K</td>
<td>500 – 2000 mg/l</td>
</tr>
<tr>
<td>Cu</td>
<td>80 mg/kg</td>
</tr>
<tr>
<td>Ni</td>
<td>50 mg/kg</td>
</tr>
</tbody>
</table>

Comparison of sugar mill sludge treatments with standard compost limits
The chemical parameters of both S3 and S4 final products were in accordance with permissible limits of compost (Wiemer & Kern 1994; Daniel et al.)
1997). Resulted vermicomposts of both S3 and S4 were rich in nitrogen and organic matter and low in heavy metals from given standard limits (Table 2).

**Fig. 1:** Mean values of number of earthworms and gain in body weight (g) of S3 and S4 Treatments at 90 days

**Fig. 2:** Mean values of pH, EC and nitrogen of S3 and S4 Treatments at 90 days

*Significant difference at (\( p < 0.05 \)) according to independent sample t-test
Fig. 3: Mean values of TOC, OM, P and Fe of S3 and S4 Treatments at 90 days
*Significant difference at \( p < 0.05 \) according to independent sample \( t \)-test

Fig. 4: Mean values of Na, K, Ca and Mg of S3 and S4 Treatments at 90 days
*Significant difference at \( p < 0.05 \) according to independent sample \( t \)-test

Fig. 5: Mean values of Cu, Ni and Mn of S3 and S4 Treatments at 90 days
*Significant difference at \( p < 0.05 \) according to independent sample \( t \)-test.
DISCUSSION

Results of the current study indicated that earthworms remarkably modified the chemical properties of sugar sludge during vermicomposting in 90 days. Results revealed that both S3 and S4 sugar mill sludge end products were suitable to be used as a vermicompost for agriculture purposes and were in compliance with compost standard limits for nutrients and heavy metals (Wiemer & Kern 1994; Dainel et al. 1997). Sugar mill sludge treatment S3 was better than S4 with respect to total organic carbon (TOC), organic matter (OM), nitrogen (N %), phosphorous (P), sodium (Na), magnesium (Mg) and heavy metal reduction.

The results suggested that earthworm survival and body weights were directly related to the proportion of industrial sugar sludge mixed with cowdung used for vermicomposting. Earthworms were unable to survive in higher concentrations of sugar sludges and higher concentration of cowdung mixed with sugar sludge. The earthworm survival in waste generally depends on initial physio-chemical profile of the waste (Suthar 2008). The greater earthworm mortality in replicates with higher concentration of sugar sludge and higher concentration of cow dung indicated the non-suitability of such combinations of sludge with organic fertilizers. The toxic gases production i.e. carbon dioxide, nitrogen oxide, ammonia etc. could also affect the survival of earthworms (Edwards and Fletcher 1988). Earthworms are also sensitive to hydrogen ion concentration; they mostly prefer pH levels of 6.5 - 7.5. So, pH is a significant factor that limits the distribution and number of earthworms and could be one of the factors for their high mortality in sugar sludge with 5.08 pH.

The results showed that pH of sugar treatments shifted from acidic to neutral. Increase in pH in S3 sugar compost was 1.13 folds from its initial values. This pH shift during the composting process might have been due to microbial decomposition of waste, nitrogen and phosphorus mineralization into nitrates/nitrites & orthophosphates and biotransformation of organic materials into intermediate species of organic acids during vermicomposting process (Ndegwa et al. 2000).

In the sugar composts, EC$_{1:1}$ was increased to 1.24 folds from its initial mixtures. Electrical conductivity (EC) reflects the salinity content of an organic fertilizer. High concentration of salt can cause phytotoxicity. So, EC is a good indicator for the safety and suitability of vermicompost for agricultural uses. Increase in EC$_{1:1}$ of sugar sludge treatments during vermicomposting could be due to organic matter loss and to the release of soluble salts such as potassium, phosphate and ammonium, after the degradation of the most labile compounds (Villar et al. 1993).

Reduction in organic matter in S3 was 0.86 folds from initial mixture during vermicomposting. TOC was reduced to 0.82 folds from initial mixture in sugar sludge treatment. Loss of TOC from different industrial sludge may be due to mineralization of organic matter and microbial respiration in the form of CO$_2$ (Kaushik & Garg, 2003).

In sugar sludge end product of S3, increase in nitrogen was 11.2 folds. Organic carbon loss could be responsible for this nitrogen enrichment. Earthworms also have a great influence on nitrogen transformations in manure,
by accelerating mineralization of nitrogen, so that mineral nitrogen may be maintained in the nitrates form (Atiyeh et al. 2000).

Phosphorous content was increased to 2.42 folds in S3 sugar sludge treatment during vermicomposting. Increase in phosphorous could be due to mobilization and mineralization of phosphorus as a result of bacterial and faecal phosphatase activity of earthworms during vermicomposting. This could be due to direct action of worm gut enzymes and indirectly by stimulation of the microflora (Satchell & Martein 1984).

Result showed that K content was increased to 2.69 folds in S4 sugar treatment from initial mixture. Higher amount of exchangeable potassium (K) may be due to increased microbial activity and rapid mineralization rate (Suthar 2007). There was 0.3 folds reduction in Ca contents of S4 sugar sludge treatment during the process of vermicomposting. This reduction in Ca might be due to leaching of these cations by the excess water that drained out during the treatments.

Concentrations of Cu and Ni were decreased to BDL in S3 sugar vermicompost. Metal loss is associated with earthworms’ activity in the waste decomposition system. Earthworms are reported to accumulate heavy metals in their tissues if reared in contaminated waste for long period (Hartensein & Hartenstein 1981; Suthar 2008).

Conclusion

Results of current study indicate that sugar sludge composts have high nutrients values (i.e. nitrogen, potassium and phosphorous) with heavy metals reduction and are in accordance with compost standards (Wiemer and Kern 1994; Daniel et al 1997). These characteristics make vermicomposts useful as effective organic fertilizers and efficient soil conditioners for sustainable land practices. Use of sugar sludges as raw materials for vermicomposting can potentially help to convert these wastes into valuable products.

REFERENCES


