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VERMICOMPOSTING OF COAL FLY ASH USING *EISENIA FOETIDA*: PHYSICO -CHEMICAL ANALYSIS

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ABSTRACT

Fly ash, a by-product of coal combustion in thermal power plants creates several environmental pollution problems and it needs large storage area to keep it out of the environment. Fly ash management remains a major concern in the developing countries. On contrary the material has great potential for beneficial use in agriculture. Vermicomposting is an exceptional technique for reducing the toxic heavy metals in fly ash through the action of earthworms. In this study we assessed the nutrient enrichment in fly ash during vermicomposting. Fly ash was mixed with Cow dung in 1:1, 2:1, 1:2, 3:1 and 1:3 ratios and incubated with *Eisenia foetida* for 60 days. The concentrations of nutrients were found to be increased in the earthworm-treated series of fly ash cow dung combinations compared with the compost and fly ash alone. This may be due to the biotransformation of considerable amounts of total nitrogen, total phosphorus, total potassium from fly ash into more soluble forms and thus resulted in increased nutrient contents in the vermicomposted series. Among different combinations of fly ash and cow dung, nutrient content was significantly higher in the 1:3 fly ash to cow dung treatment compared with the other treatments.

Keywords: Pollution, Biotransformation, nutrient, fly ash, vermicomposting, cow dung

INTRODUCTION

Major source of electricity in India is the coal based thermal power plants leading to excessive use of coal as the chief energy source**.** Fly ash is the end residue from combustion of pulverized bituminous or sub-bituminous coal (lignite) in the furnace of thermal power plants and consists of mineral constituents of coal which is not fully burnt. Fine minute particles of ash are carried away with flue gases in electrostatic precipitators and are collected by wet (slurry form) or dry scrubbing method, which requires large volumes of land, water and energy. Use of fly ash containing (30–50%) bituminous or sub-bituminous coal in thermal power stations, in addition to several captive power plants, contributes to indiscriminate disposal of this industrial waste every year (Garg *et al*., 2005). In India, the highest level of fly ash utilization of about 62.6% was achieved in the year 2009-2010 and it was estimated to be 58.48 % in the year 2011-2012, about 61.37 % in the year 2012-2013, 57.63 % in the year 2013-2014 and 55.69 % in 2014-2015. During the current period i.e. first half of the year 2015-2016, utilization of fly ash is 56.04 % which is behind the stipulated target. (LGBR Report 2015-16, Ministry of power) The utilization of fly ash is in the range of 10-12 % in making fly ash based building products and mine filling each, whereas it is less than 5% in the construction of roads and embankments. Other areas having larger potential of fly ash utilization needs to be explored for increasing the overall utilization of fly ash in the country. It has been proved through various studies across the globe, that the use of fly ash in agriculture has no significant ill effects. Mineralogically, fly ash is similar to soil but rich in macro and micro nutrients. The major attribute, which makes fly ash suitable for agriculture is its texture and the fact that it contains almost all the essential plant nutrients except organic carbon and nitrogen (Kumar, *et al.*, 2000). The main constraint in using fly ash as a soil supplement is its low availability although it is present in bound form (Bhattacharya and Chattopadhyay, 2002). Incorporation of organic matter with fly ash increases the nutrient availability, which was confirmed by several workers. Recycling of wastes using earthworms has become an important component of sustainable agriculture, which has a multidirectional impact in terms of safe disposal of wastes preventing environmental pollution besides providing nutrient rich material (Daniel and Anderson, 1992, Cox, 1993). Keeping all the benefits in view, the present study was carried out to assess the potential of the earthworm *Eisenia foetida* to convert fly ash into manure.

MATERIALS AND METHODS

Feed stock materials

Fly ash and cow dung were used as raw materials in this study. The earthworm *Eisenia foetida* was obtained from the Agriculture College, Madurai. Fly ash was obtained from Ramco Cement Factory, Soolakarai, Virudhunagar, which was actually collected from the TTPS (Tuticorin Thermal Power Station).Vermin bed was then prepared with the dried cow dung and fly ash.

Preparation of different feed mixtures (cow dung and fly ash) and inoculation of worms:

Experimental set ups were such that the fly ash and cow dung treated in various ratios like T_0 (fly ash only), T_1(1 FA:1 CD), T_2(2 FA : 1 CD), T_3 (1 FA : 2 CD), T_4(3 FA : 1 CD), T_5(1 FA : 3 CD) . The trials were carried out in earthen pots. A set of control was also maintained without earthworms. (Bhattacharya and Chattopadhyay, 2004). The moisture content was maintained between 60-80% throughout the study period by sprinkling sufficient quantity of distilled water. After 10 days, nonclitellated hatchlings of *Eisenia fetida* Savigny (10 nos. per kg of feed mixture) were introduced into each container. There were three replicates for each feed mixture. The pots were covered with a net to protect the earthworms from birds and insects. Water was sprinkled on the vermibeds daily so as to keep them moist. The experiments were terminated after all the materials had been ingested well by the earthworms. The prepared vermicomposts and composts were used for analysis. Student’s’t’ test was applied for the statistical analysis.

Physico-chemical analysis of fly ash

The porosity of the fly ash was observed by following the method of Chandrabose *et al* (1988). The water holding capacity of the fly ash sample under study were determined by the method of Inbar *et al* (1993). The analysis of chemical composition of fly ash was done at Ramco cement factory.

The sample extract was prepared by suspending 20 g of the sample in 100 ml of distilled water and stirred for one hour constantly. It was then filtered and the pH was measured using a glass electrode pH meter. (Elico).Total organic carbon content was estimated as per the modified method of Walkley and Black (1984). The total nitrogen of the sample was estimated by Kjeldahl method. Total phosphorus content was determined colorimetrically (Jackson, 1973). Total potassium content was determined using flame photometer (Jackson, 1973).

RESULTS AND DISCUSSION

The physico-chemical characteristics of fly ash were analyzed. The pH of the fly ash was found to be 7.9; the porosity of the fly ash was estimated as 48%. Water holding capacity of the fly ash was found to be 52%

The major composition of fly ash was found to be SiO_2 (59.48%) followed by 31.59% of Al_2O_3 and 9.1% of Fe_2O_3 and meagre quantities of MgO, CaO, K_2O and Na_2O. Physico-chemical parameters were analyzed in both the compost and vermicompost treatments.

Figure 1: Chemical Composition of fly ash

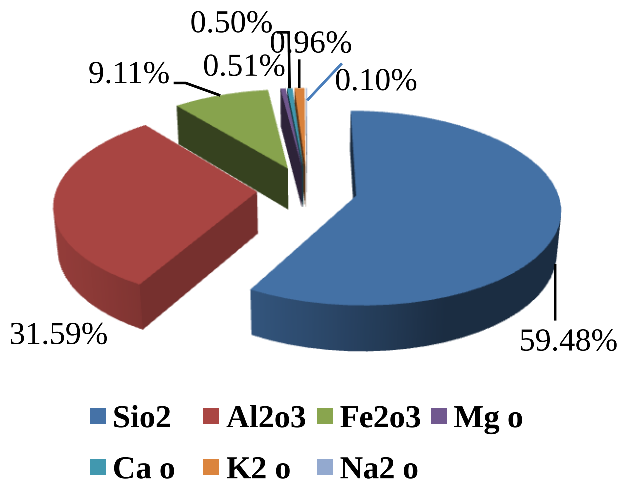

Table: 1 Physical Properties of fly ash

Parameters	Values
pH	7.9
Porosity (%)	48
Water holding capacity (%)	52
EC (ds/m)	0.8

The pH was found to be decreasing (Table.2) in all the vermicompost treatments than the compost which may be due to the accumulation of organic acids from microbial metabolism or from the production of fulvic and humic acids during decomposition (Albanell *et al.*, 1988; Chan and Griffiths, 1988); this is also in accordance with Atiyeh *et al* (2000). A significant decrease in EC was observed in the entire earthworm treated series. Initially up to 30 days the EC was found to be increasing and gradually it declined. The EC in the vermicompost after 60 days were 0.7 ds/m, 0.37,ds/m,0.31 ds/m, 0.38 ds/m, 0.29 ds/m, 0.35 ds/m, in the T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. (Table.3) The EC in the compost (control) in 60 days were 0.74 ds/m, 0.47 ds/m, 0.45 ds/m, 0.56 ds/m, 0.32 ds/m, 0.37 ds/m, in the T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. Similar results were obtained from the study of Wong *et al.*, (1995). Total organic carbon was found to be reduced with time in all the vermicompost treatments. (Table.4). The organic carbon may be lost as carbon dioxide. The reduction was higher in T_5 vermicompost(1:3) treatment (28.16%) which is higher than in control T_5 (9.1%). Lesser percentage of organic carbon reduction was found in T_4 treatment. The reduction of organic carbon was more in the vermicompost due to the assimilating capacity of earthworms. Maximum reduction (77.5%) was reported in T_5 (3:1) treatment, followed by T_3 (1:2) and T_4 (3:1) treatments. Total organic carbon decreased with time in all the treatments. The reduction was greater in vermicomposting compared to the ordinary composting. The organic carbon is lost as carbon dioxide and total nitrogen increased as a result of carbon loss (Crawford, 1983). The macronutrients NPK were estimated during different phases of vermicomposting. The change in total nitrogen content during composting of fly ash was presented in the Table-5. Total nitrogen was found to be increased in all the treatments of compost (0.13%, 0.51%, 0.54%, 0.4%, 0.37%, 1.12%) in the T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively during 60 days whereas in the vermicompost treatments (0.43%, 0.73%, 0.63%, 0.53%, 0.48%, 1.36%) of nitrogen was observed in T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively which is higher than that of compost. Total nitrogen content was found to be increasing rapidly with time in all the earthworm treated series. This shows that earthworms have greater impact on nitrogen transformation. Minimum increase in total nitrogen was found in T_4 treatment. Total nitrogen in the T_5 vermicompost treatment was estimated to be 1.36%, whereas in T_5 control treatment it was about 1.1%. The Nitrogen availability was more in the combination of higher quantity of cow dung. (Table.5). This finding is supported by the observations of Bhattacharya and Chattopathyay, (2004). Total potassium was also found to be increasing in all the treatments. The phosphorus content was observed to be increased in all the treatments of control (compost) for 60 days. There was no change in the phosphorus content of control T_0 (fly ash only) treatment. Among the control maximum content (1.1%) of phosphorus was observed in the T_5 treatment (1:3). The phosphorus content (Table-6) was found to be increasing rapidly with time in all the treatments in earthworm treated series. This shows that earthworms and their gut associated microbes have the ability to solubilise the phosphates in the feed stock mixtures. Total phosphorus in the T_5 vermicompost treatment was estimated to be 1.3% (Table.6) whereas in T_5 control treatment it was about 1.1%. These findings agree with the earlier work done by Rajesh banu *et al*., (2008). Potassium content in the initial feedstock material were 0.03%, 0.23%, 0.08%, 0.07%, 0.13%, 0.9% in T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. In the control treatments the potassium content was found to be increased up to 30 days period and slightly decreased during 45days and 60 days. There was a steady increase in the potassium content of control T_1 (1:3) treatment and a maximum content of phosphorus was observed in the vermicompost treatment (1:3) after 60 days. Potassium content in the control were 0.06 %, 0.28%, 0.12%, 0.12%, 0.13%, 1.13% in T_0, T_1, T_2, T_3, T_4 and T_5 treatments respectively. (Table.7). Kaviraj and Sharma (2003) reported 10% increase of total potassium by *Eisenia foetida* and 5% by *Lampito mauritii* during the vermicomposting of municipal solid waste and it was due to the influence of micro flora. Vadiraj *et al*., 1992 and Ushakumari *et al*., 1996 have reported the increase in potassium content in vermicompost prepared from different organic sources. From the above results nutrient availability was found to be lowest in fly ash treatment whereas it was observed to be highest in fly ash cow dung mixture treatments.

Table 2: Comparison of change in pH during Composting and Vermicomposting

Treatment		**Composting**				**Vermicomposting**			
	Initial	**15th day**	**30th day**	**45th day**	**60 th day**	**15th day**	**30th day**	**45 th day**	**60th day**
T_0	8.06±0.07	8.06±0.08	8.04±0.03	8.03±0.03	7.90±0.14	8.06±0.08	8.04±0.03	8.05±0.01	8.00±0.01
T_1	6.54±0.04	6.52±0.05	6.51±0.01	6.46±0.03	6.45±0.01	6.49±0.05	6.46±0.06	6.33±0.01	6.30±0.01
T	7.64±0.04	7.65±0.04	7.66±0.01	7.63±0.03	7.56±0.04	7.64±0.02	7.64±0.04	7.54±0.03	7.51±0.05
T_3	8.04±0.04	8.06±0.03	8.05±0.01	8.07±0.03	8.04±0.02	8.12±0.01	8.09±0.01	8.08±0.01	8.00±0.01
T_4	8.51±0.02	8.51±0.01	8.49±0.02	8.50±0.04	8.47±0.02	8.52±0.04	8.53±0.01	8.45±0.02	8.45±0.01
T_5	7.00±0.02	6.96±0.01	6.94±0.05	6.85±0.05	6.90±0.04	6.96±0.04	6.85±0.04	6.83±0.01	6.80±0.01

Table 3: Comparison of change in Electrical conductivity (ds/m) during Composting and Vermicomposting

Treatment		Composting				Vermicomposting			
	Initial	15th day	30th day	45th day	60th day	15th day	30th day	45th day	60th day
T_0	0.82±0.01	0.81±0.01	0.79±0.01	0.78±0.03	0.74±0.03	0.81±0.01	0.79±0.01	0.73±0.01	0.70±0.03
T_1	0.49±0.01	0.49±0.02	0.51±0.02	0.52±0.01	0.48±0.02	0.49±0.01	0.54±0.03	0.41±0.02	0.37±0.04
T_2	0.45±0.03	0.48±0.01	0.50±0.01	0.47±0.01	0.46±0.01	0.51±0.02	0.44±0.03	0.38±0.01	0.31±0.02
T_3	0.65±0.04	0.70±0.01	0.66±0.04	0.60±0.03	0.56±0.07	0.58±0.09	0.54±0.02	0.40±0.02	0.38±0.03
T_4	0.39±0.02	0.36±0.07	0.43±0.02	0.40±0.01	0.32±0.01	0.30±0.01	0.35±0.02	0.32±0.01	0.30±0.02
T_5	0.40±0.01	0.44±0.00	0.39±0.02	0.38±0.03	0.37±0.03	0.42±0.03	0.44±0.04	0.39±0.04	0.35±0.06

Table 4: Comparison of change in total organic carbon (%) during Composting and Vermicomposting

Treatment		Composting				Vermicomposting			
	Initial	15^{th} day	30^{th} day	45^{th} day	60^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0	16.90±1.01	17.10±1.02	16.30±0.79	16.07±1.00	15.60±0.50	16.43±0.68	15.86±0.50	15.37±0.47	14.43±0.60
T_1	16.60±0.42	15.90±0.12	15.60±0.91	15.50±0.50	15.00±0.20	16.27± 0.55	15.13±0.15	14.80±0.20	14.00±0.17
T_2	20.55±0.80	19.65±0.59	18.90±0.76	19.25±0.32	18.10±0.20	20.00±0.92	19.20±0.27	18.53±0.35	16.97±0.20
T_3	31.30±1.50	32.10±1.10	31.90±0.70	30.85±0.68	28.60±0.92	29.10±0.20	27.97±0.15	27.30±0.27	26.90±0.30
T_4	33.95±1.45	34.90±0.25	34.40±1.85	32.10±1.55	31.90±1.10	34.67± 0.31	33.63±0.45	32.03±0.15	31.20±0.26
T_5	41.40±1.05	41.50±1.53	39.60±2.12	38.55±0.55	37.60±0.61	39.17± 0.74	37.00±0.17	34.17±1.11	32.10±1.10

Table 5: Comparison of change in Total Nitrogen Content during Composting and Vermicomposting

Treatment		Composting				Vermicomposting			
	Initial	15^{th} day	30^{th} day	45^{th} day	60^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0	0.12±0.02	0.12±0.03	0.14±0.02	0.12±0.05	0.13±0.02	0.33±0.09	0.37±0.01	0.40+0.20	0.43±0.02
T_1	0.43±0.02	0.44±0.03	0.41±0.04	0.44±0.04	0.51±0.03	0.53±0.02	0.60±0.02	0.69±0.03	0.73±0.02
T_2	0.50±0.01	0.49±0.05	0.52±0.03	0.53±0.02	0.54±0.06	0.53±0.02	0.57±0.02	0.61±0.02	0.63±0.02
T_3	0.32±0.02	0.33±0.02	0.37±0.02	0.35±0.05	0.40±0.02	0.41±0.03	0.49±0.02	0.53±0.02	0.53±0.02
T_4	0.32±0.01	0.37±0.04	0.35±0.03	0.38±0.03	0.37±0.05	0.37±0.02	0.40±0.01	0.43±0.02	0.48±0.02
T_5	1.04±0.05	1.01±0.04	1.10±0.01	1.11±0.04	1.12±0.03	1.10±0.01	1.21±0.02	1.25±0.03	1.36±0.03

Table 6: Comparison of changes in total Phosphorus Content (%) during Composting and Vermicomposting

Treatments		Composting				Vermicomposting			
	Initial	15th day	30th day	45th day	60th day	15th day	30th day	45th day	60th day
T_0	0.03±0.00	0.02±0.01	0.02±0.01	0.02±0.01	0.03±0.02	0.02±0.01	0.03±0.01	0.05±0.006	0.06±0.01
T_1	0.18±0.01	0.17±0.01	0.21±0.06	0.22±0.03	0.33±0.11	0.22±0.01	0.42±0.02	0.64±0.02	0.72±0.03
T_2	0.09±0.01	0.08±0.02	0.17±0.04	0.32±0.08	0.53±0.11	0.10±0.02	0.27±0.15	0.53±0.021	0.63±0.03
T_3	0.52±0.03	0.52±0.02	0.68±0.04	0.72±0.07	0.72±0.04	0.62±0.03	0.82±0.03	0.82±0.015	0.91±0.01
T_4	0.20±0.02	0.20±0.04	0.20±0.02	0.24±0.05	0.27±0.06	0.32±0.01	0.33±0.03	0.41±0.02	0.52±0.02
T_5	0.91±0.02	0.93±0.03	0.95±0.04	1.04±0.07	1.11±0.07	0.93±0.03	1.14±0.05	1.23±0.02	1.32±0.02

Table 7: Comparison of change in total Potassium content (%) during Composting and vermicomposting

Treatment		Composting				Vermicomposting			
	Initial	15 days	30 days	45 days	60 days	15 days	30 days	45 days	60 days
T_0	0.04±0.01	0.04±0.01	0.04±0.01	0.04±0.02	0.06±0.01	0.07±0.01	0.10±0.01	0.09±0.02	0.08±0.02
T_1	0.23±0.03	0.23±0.03	0.24±0.03	0.27±0.20	0.28±0.03	0.11±0.01	0.14±0.02	0.12±0.01	0.11±0.01
T_2	0.08±0.05	0.10±0.03	0.10±0.01	0.11±0.12	0.12±0.03	0.21±0.02	0.24±0.02	0.28±0.02	0.32±0.01
T_3	0.08±0.03	0.06±0.04	0.07±0.06	0.12±0.01	0.12±0.12	0.08±0.03	0.09±0.02	0.12±0.01	0.13±0.02
T_4	0.14±0.02	0.13±0.04	0.14±0.04	0.12±0.02	0.12±0.02	0.12±0.02	0.12±0.02	0.13±0.01	0.15±0.02
T_5	0.92±0.06	0.93±0.04	1.04±0.06	1.12±0.02	1.13±0.02	0.96±0.04	1.09±0.02	1.15±0.06	1.13±0.04

Table 8: Summary of‘t’ test results for comparison of changes in physico-chemical characteristics of final compost with vermicompost

Parameters	‘t’ Value
pH	0.2955**
Electrical conductivity	0.0269*
Organic carbon	0.0702*
Nitrogen	0.0030*
Phosphorus	0.0075*
Potassium	0.1254**

*****Represents statistically significant

The table.8 shows the significance of different parameters between compost and vermicompost. EC, Organic carbon, Nitrogen, Phosphorus shows significance.

CONCLUSION

The present study suggests that through vermitechnology fly ash can be efficiently recycled into manure by *Eisenia foetida.* besides it enhances the nutrient availability of fly ash. Among the various treatments under study 1:3 (FA+CD) appeared to be the most efficient. This may probably as a result of the existence of the maximum microbial population due to sufficient availability of organic material.

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