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Disposal of Municipal Solid Waste (MSW) of the Millennium City (Cuttack): Bioconversion to Nutrient-Rich Vermicompost

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ABSTRACT

Vermicomposting is one of the effective ways of disposal and management of municipal organic solid waste (MOSW), and is a process of composting of organic waste by using either or both exotic and indigenous species of earthworms. These worms devour organic wastes rapidly and produce a good quality end-product called vermicompost that becomes enriched with various plant nutrients (available nitrogen, potassium, phosphorus, calcium and magnesium), has more organic matter, and is more porous than soil. This paper deals with the disposal of MOSW of millennium city, Cuttack through vermicomposting using the exotic species *Eisenia fetida.* However, MOSW vermicompost possessed reduced concentrations of organic carbon, but a higher concentration of P, and K. Moreover, a comparative analysis was made between the major nutrients of the MOSW vermicompost and agricultural waste (AW). Vermicompost from AW was shown to be better than vermicompost from MOSW.

Keywords: agricultural waste, earthworm species, *Eisenia fetida*, municipal solid waste, vermicompost

INTRODUCTION

With booming modernization and population growth, the amount of municipal solid waste (MSW) generated has increased in enormous quantities. An increase in the amount of MSW has created a number of environmental problems. The open burning of the municipal solid wastes in India has caused air pollution and released toxic gases containing dioxins, furans in to the atmosphere. Moreover, the heavy metal leachates from the municipal solid waste dumping sites can percolate downwards and cause ground water pollution to a significant level. The organic fraction of the urban waste constituted > 50% of the total waste and can be a breeding ground for flies and mosquitoes, rodents and other vectors of pathogens (Pattnaik and Reddy 2010). However, it can be recycled and reused as a potential resource of plant nutrients as it can result in the formation of a good quality compost and vermicompost. Vermicomposting is a process in which earthworms devour organic waste excreting casts holding higher nutrients, and is an odour-free compost production.

Vermicomposting of MSW using the exotic species of earthworm *E. fetida* and the local species *Lampito mauritii* was reported by Kaviraj and Sharma (2003) and Pattnaik and Reddy (2010). During the process the nutrients locked up in the organic waste of MSW are transformed by earthworms to simple and absorbable forms of nutrients such as nitrate or ammonium nitrogen, exchangeable phosphorus, soluble potassium, calcium and magnesium in worm's gut (Lee 1985; Atiyeh *et al*. 2002; Pattnaik and Reddy 2010). Moreover, there is a significant reduction in the C/N ratio (Bansal and Kapoor 2000; Kaushik and Garg 2003).The end product of vermicomposting process is the vermicompost (VC) that possess higher level of nitrogen and phosphorus and more soluble potassium, magnesium compared to the substrate and normal compost (Singh and Sharma 2002; Gupta *et al*. 2007; Pattnaik and Reddy 2010). It is rich in plant nutrients and plant growth promoting like substances (Dash and Senapati 1985, 1986; Edwards 2004; Reddy and Okhura 2004; Arancon *et al*. 2005; Dash and Dash 2008). The VC, when applied to soil, improves the soil productivity favouring higher yield (Padmavathiamma *et al*. 2008). Its nutrient contents depend on that of the organic matter on which the earthworms feed (Kale 1995; Reddy and Okhura 2004; Pattnaik and Reddy 2010). The present paper deals with the management and disposal of MSW of the millennium city, Cuttack, Orissa (India) by its bioconversion to nutrient-rich VC using *Eisenia fetida*, and is first of its kind on vermicomposting disposal and management of MSW in this city.

MATERIALS AND METHODS

Study area and description

Cuttack city, known as the "millennium city", located at 20° 30′ North latitude and 85° 49′ 60″ East longitude and at an elevation of 36 m msl, is more than 1,000 years old. It is located at the apex of the delta formed by rivers Mahanadi and Kathajodi, the two important rivers flowing through the city. It experiences a tropical climate with a hot and humid weather between March and June. The maximum temperature of Cuttack during the summer is around 45°C while the minimum temperature during this period is about 25°C. During winter, the temperature of Cuttack ranges between 10 and 16°C. Furthermore, the city receives heavy rainfall between July and August, the monsoon season, with total rainfall amounting to about 144.39 cm.

Collection of municipal solid waste, vermicomposting, and analyses

The present experiment was conducted by taking samples of MSW of Cuttack from its main dumping site i.e. Chakradharpur located about 30 km away from the city. Wastes were first segregated and then categorized into biodegradable and non-biodegradable components and further into various sub-categories. Each of the samples of waste of sub-category was segregated and categorized manually into various waste types like paper and cartons, plastic materials and polythene bags, sand and pebbles, leather and rubber, cow dung, glass and metals. These waste materials were categoric-

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ally put into plastic sacks and weighed separately to determine its fraction in the total MSW sample (Kumar *et al*. 2009; Pattnaik and Reddy 2010). The weight of the container was subtracted to obtain the net component weight. The percentage of weight for each of the sub-category was calculated using the simple formula, which is as follows:

Percentage of the sub-category waste = [Net weight of the sub-category of waste/Total weight of the sample in kg] × 100

Then, the biodegradable component of the MSW was mixed with cow dung in a 3: 1 ratio and used to make the VC beds in tanks of suitable size and the earthworms (*E. fetida*) were inoculated in the ratio of 0.1:5 i.e., 0.1 kg of worms in 5 kg of the normal substrate (wet weight) following the methods of Pattnaik and Reddy (2009). The top surface of the beds was covered with jute sacs, and water was sprinkled on top of it to maintain moisture. Then the homogenized samples of the processed substrate material i.e., VC were collected at 15^{th}, 30^{th}, 45^{th} and 60^{th} day of vermicomposting from the bed and compound samples were made in each case, which were analyzed in three replicates for pH, electrical conductivity (EC), organic carbon (OC) and major nutrients like total nitrogen (N), exchangeable phosphorus (P) and potassium (K), following methods given in Jackson (1973). The pH of the samples was measured using a digital pH meter; the EC of the samples was measured by digital conductivity meter. The OC of the samples was measured by Walkley-Black method (Walkley and Black 1934); the N was estimated by the Kjeldahl method (Jackson 1973) and the P and K contents of the samples were analyzed by flame photometric method (Simrad 1993) and calorimetric method (Anderson and Ingram 1998), respectively.

The concentration of Ca, Mg, Fe, K, P, S, Cu, Mn and Zn in %, of the vermicomposts of MSW and AW harvested after 45^{th} day were analysed in three replicates using WDX-RAY Florescence Spectrophotometer. A comparative analysis was made between the vermicomposts of both the wastes.

Statistical analysis

One-way analysis of variance (ANOVA) was computed to test the level of significance (*P* value) in differences in physicochemical factors of the vermicompost samples of MSW collected at an interval of 15 days across 60 days. One-way ANOVA was also computed to test the level of significance (*P* value) in differences in nutritional factors of the VCs of AW and MSW harvested at the end of 45 days.

RESULTS AND DISCUSSION

The characterization of MSW of Cuttack indicated that it was comprised of 49% vegetable waste, 29% leather and rubber, 11% sand and pebbles, 7% plastic, glass and metals, 3% paper and cartons and 1% cow dung. There was more than 50% organic waste in the MSW, which corroborated the findings of Pattnaik and Reddy (2010). VC possesses higher concentrations of major nutrients than the organic substrate on which earthworms feed (Edwards 2004; Pattnaik and Reddy 2010). The pH of the substrate i.e., the organic fraction of MSW (MOSW) was 6.83 ± 0.11, and is slightly acidic in nature, which further decreased to 5.56 ± 0.11 on the 15^{th} day of vermicomposting. However, there was a marked increase in pH, which was 6.43 ± 0.05 on the 30^{th} day of vermicomposting probably due to the fact that there was degradation of short chained fatty acids and ammonification of organic N (Tognetti *et al*. 2005). Further, it was stabilized at pH = 6.53 ± 0.05 on the 45^{th} and 60^{th} days of vermicomposting. The EC of MOSW was 1.66 ± 0.1, but on the 15^{th} day of vermicomposting, it increased to 1.8 ± 0.10 and thereafter it remained more or less same i.e. 1.76 ± 0.11 during 30^{th} to 60^{th} days. This may be attributable to the fact that there might be greater mineralization.

The OC of the MOSW was 9.19 ± 0.03 g/kg, which increased to 15.23 ± 0.02 g/kg on the 15^{th} day and then, declined to 12.24 ± 0.03, 10.15 ± 0.03 and 9.84 ± 0.03 on the 30^{th}, 45^{th} and 60^{th} day, respectively (**Fig. 1**). The reduction of organic carbon later during the vermicomposting process has been reported by earlier studies (Kale *et al*. 1982; Garg and Kaushik 2005; Tognetti *et al*. 2005; Suthar 2007b; Pattnaik and Reddy 2009) which was probably due to digestion and utilization of MOSW by enzymatic action in the worm's gut. The earthworms utilized the organic matter as food and released carbon in the form of CO_2 during respiration, resulting in the significant reduction in organic C during 15^{th} to 60^{th} day of vermicomposting.

Table 1 ANOVA of different physico-chemical factors of vermicompost of the organic fraction of municipal solid waste 0, 15, 30, 45 and 60 days old.

Source of variation	SS	df	MS	F
pH				
Between groups	2.384	4	0.596	99.3333*
Within groups	0.06	10	0.006	
Total	2.444	14		
EC				
Between groups	0.03067	4	0.00767	0.60526
Within groups	0.12667	10	0.01267	
Total	0.15733	14		
OC				
Between groups	72.64678	4	18.162	20796.1*
Within groups	0.00873	10	0.00087	
Total	72.6566	14		
Nitrogen				
Between groups	0.00333	4	0.00083	94.4818*
Within groups	8.80E-05	10	8.80E-06	
Total	0.00341	14		
Phosphorus				
Between groups	0.00053	4	0.00013	10.0711*
Within groups	0.00013	10	1.30E-05	
Total	0.00066	14		
Potassium				
Between groups	0.00595	4	0.00149	4.20547*
Within groups	0.00354	10	0.00035	
Total	0.00949	14		

*$P < 0.05$

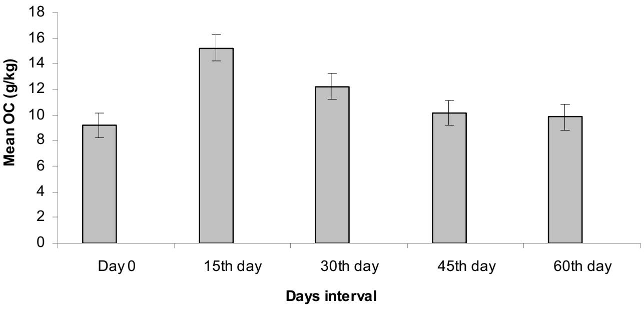

Fig. 1 Organic carbon content of the vermicomposts of MOSW obtained at an interval of 15 days until the 60^{th} day.

A relative increase in N during vermicomposting has been reported in earlier studies (Atiyeh *et al*. 2000; Suthar and Singh 2008; Pattnaik and Reddy 2009). However, in contrast, in the present study, there was gradual decline in the N content as vermicomposting progressed. The N content of MOSW was 0.15 ± 0.005 g/kg, which decreased to 0.147 ± 0.001 g/kg on the 15^{th} day; to 0.133 ± 0.001 g/Kg on the 30^{th} day; to 0.125 ± 0.001 g/kg on the 45^{th} day and to 0.114 ± 0.002 g/kg on the 60^{th} day (**Fig. 2**). This may be attributed to the fact that the earthworms utilized N from the waste for their growth and reproduction. The increase in the phosphorus (P_2O_5) level with progress of the vermicomposting process signifies the release of minerals such as exchangeable P due to the mineralization of organic matter. P_2O_5 was higher i.e. 0.024 ± 0.002 g/kg on the 60^{th} day, the end of the vermicomposting period, than in the initial substrate i.e.0.006 ± 0.002 g/kg (**Fig. 2**). This is consistent with earlier findings (Kaushik and Garg 2003; Manna *et al*. 2003; Suthar 2007a; Pattnaik and Reddy 2009). The magni-

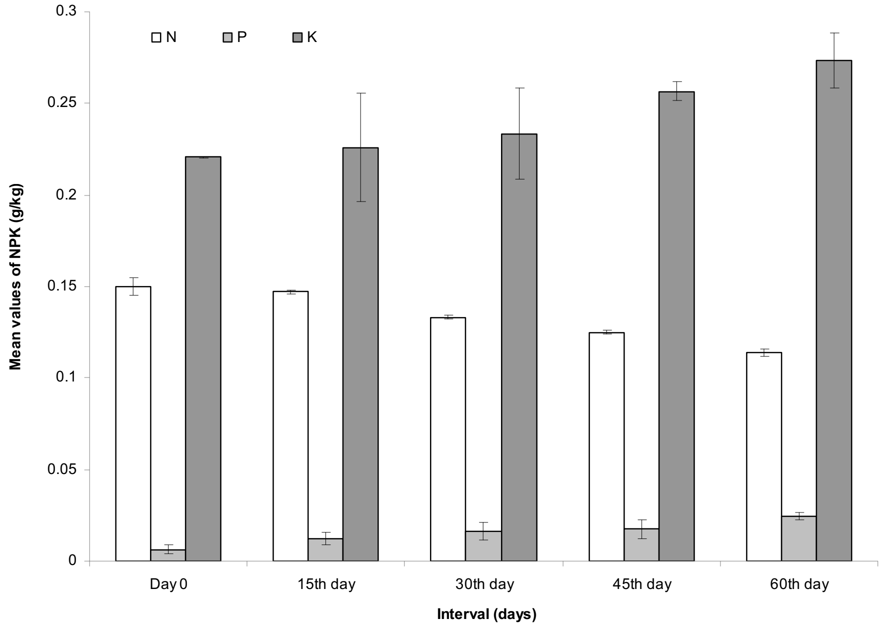

Fig. 2 Nutrients content (NPK) of the vermicomposts of MOSW obtained at an interval of 15 days until the 60th day.

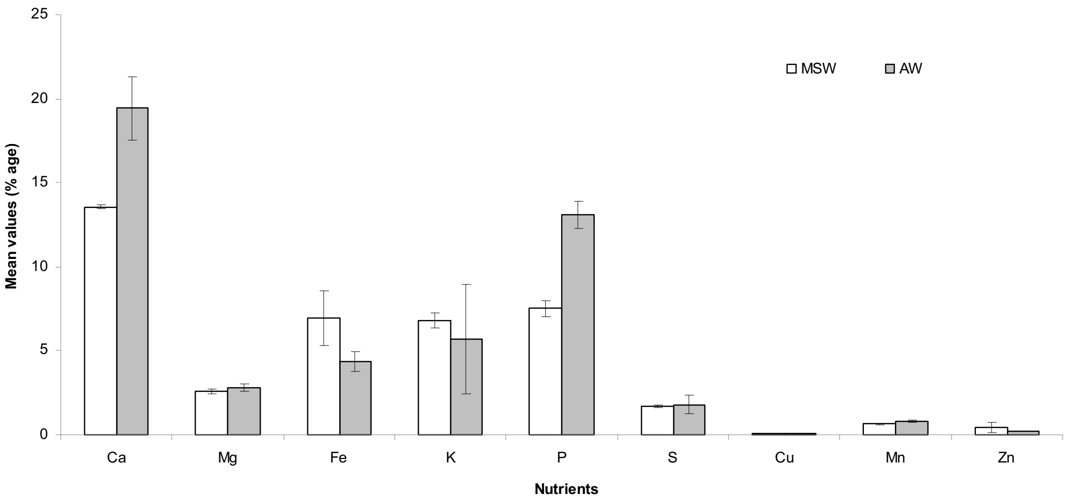

Fig. 3 Nutrients of the vermicomposts of MSW and AW obtained after 45 days of vermicomposting.

tude of transformation of P from the organic to the inorganic state implies that the action of microorganisms present in the worm's gut have helped to transform it into an available form of P (Padmavathiamma *et al*. 2008). The present study showed a significant increase of P content during the vermicomposting process ($P < 0.05$). There was also a significant increase in K during the vermicomposting process. The content of K in MOSW was 0.220 ± 0.0005 g/kg, which increased to 0.273 ± 0.015 g/kg on the 60th day, and is probably due to the influence of gut microorganisms by producing microbial metabolites solubilising the insoluble K (Kaviraj and Sharma 2003). This was also reported in earlier studies (Delgado *et al*. 1995; Suthar and Singh 2008; Pattnaik and Reddy 2009). The physico-chemical factors, except for the EC of vermicomposts of 15, 30, 45 and 60 days, were significantly different (**Table 1**).

A comparative analysis of the MOSW and AW VCs harvested after 45 days showed that that the concentration of Ca in AW was significantly higher than that of MOSW ($P < 0.05$). The amount of nutrients which resulted after the VC process depends on the amount of nutrients in the substrate used (Pattnaik and Reddy 2009). AW, when vermicomposted, acquired significantly higher Ca content than MOSW VC ($P < 0.05$) (**Fig. 3**). However, the concentrations of Mg and Fe of the wastes were not significantly different, although slightly higher in AW VC (**Fig. 3**). The concentration of K remained high in the vermicomposting of AW, as supported by earlier studies (Garg *et al*. 2006; Suthar 2007b). However, the present study showed that there is no significant difference in the concentration of K in AW and MOSW after vermicomposting (**Fig. 3**). The P content of AW was significantly higher than that of MOSW ($P < 0.05$) (**Fig. 3**). A similar trend was also observed for S content: 1.69 ± 0.05 in MOSW, which was significantly less than that of AW ($P < 0.05$) (**Fig. 3**).

On the other hand, the concentration of Zn and Cu was significantly higher in MOSW than AW ($P < 0.05$ in both cases) (**Fig. 3**). This may be because MOSW contains a large variety of materials made of heavy metals, and the initial concentration of the above elements must have been higher in the substrate, MOSW. The Mn content was significantly higher in the AW VC than in the MOSW VC ($P < 0.05$), probably because of its plant origin, since Mn is one of the principal elements found in plant pigments. Thus, AW VC has a better content of micronutrients such as Mn, indicating that it can be used as a better source of fertilizer than MOSW VC.

CONCLUSION

The present study indicates that since VC contains higher amounts various plant nutrients, it can be used widely for sustainable agricultural productivity. AW VC was a better source of fertilizer than MOSW VC. Thus, vermicomposting can rightly be called an alchemy, transforming base matter that is waste to nutrient-rich compost. Therefore, vermicomposting, no doubt, can be an alternative way of management of the biodegradable component of MSW.

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