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Vermiconversion of industrial sludge for recycling the nutrients

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ABSTRACT

The aim of the present study was to investigate the transformation of sugar mill sludge (PM) amended with biogas plant slurry (BPS) into vermicompost employing an epigeic earthworm *Eisenia fetida*. To achieve the objectives experiments were conducted for 13 weeks under controlled environmental conditions. In all the waste mixtures, a decrease in pH, TOC, TK and C:N ratio, but increase in TKN and TP was recorded. Maximum worm biomass and growth rate was attained in 20% PM containing waste mixture. It was inferred from the study that addition of 30–50% of PM with BPS had no adverse effect on the fertilizer value of the vermicompost as well as growth of *E. fetida*. The results indicated that vermicomposting can be an alternate technology for the management and nutrient recovery from press mud if mixed with bulking agent in appropriate quantities.

1. Introduction

The sugar industry occupies a vital place in Indian economy and contributes substantially to its exports earnings. Amongst the 83-cane sugar producing countries in the world, India is the second largest producer of sugarcane and sugar (Rao, 2005). The industry achieved a spectacular growth as it has 1062 sugar mills of large to medium capacities (Sangwan et al., 2008) as compared to 138 during 1950–1951. According to Department of Agriculture and Co-operation, sugarcane production in 2004–2005 was estimated at 232.3 MT. But it has been identified as one among the most polluting industries. Sugarcane mills mainly use activated sludge process for wastewater treatment, which generates huge quantity of sludge commonly known as press mud (PM). Murty et al. (2006) have reported pollution status for some factories in India. For about 134 million tonnes of sugarcane crushed, 4.0 million tonnes of press mud are generated (Yadav, 1995). According to Parthasarthi (2006) approximately 12 million tonnes press mud is produced in India annually. Due to the prohibitive cost of sludge disposal, it is either dumped in open or along roadsides or railway tracks or stored in the sugar mill premises where it causes adverse impacts on the ambient environment. Apart from this, such practices entail wastage of organic and inorganic nutrients present in the sludge that might be put to good use (Elvira et al., 1985).

Press mud has significant fertilizer value as it is a rich source of organic matter, organic carbon, sugar, protein, enzymes, micronutrients (N, P and K) and macronutrients (Zn, Fe, Cu, Mn, etc.) and microbes (Sangwan et al., 2008; Yaduvanshi and Yadav, 1990; Ranganathan and Parthasarathi, 1999). Farmers are reluctant to apply it directly due to its bad odor, transportation cost and fear that its application may lead to crust formation, pH variation and pollution problem. Wax content of press mud (8.15%) affects the soil property by direct application (Thopate et al., 1997) and its high rate of direct application (upto 100 tonnes/acre) leads to soil sickness and water pollution (Bhawalkar and Bhawalkar, 1993). Conventional composting of press mud takes about 6 months and also does not remove the foul odor completely (Sen and Chandra, 2006). The compost so obtained has less nutritive value and more compactness. Therefore, appropriate press mud management technology is desired which not only protect and conserve the environment and land resources but also to recover the nutrients present in it.

Earthworms have been used in the vermiconversion of urban, industrial and agro-industrial wastes to produce biofertilizers (Elvira et al., 1998; Gupta and Garg, 2008; Suthar, 2006). It is well established that a large number of organic wastes can be ingested by earthworms and egested as peat like material termed as vermicompost. It is much more fragmented, porous and microbially active than parent material (Edwards et al., 1998; Edwards and Bohlen, 1996) due to humification and increased decomposition. Kaushik and Garg (2003, 2004) have reported the vermicomposting of textile mill sludge using *Eisenia fetida*. Butt (1993) showed that solid paper mill sludge was a suitable feed for *Lumbricus terrestis* under laboratory conditions. Elvira et al. (1998) have reported vermicomposting of paper mill sludge using *Eisenia andrei* under laboratory as well as field conditions. Nogales et al. (2005) have reported the vermicomposting of winery waste using

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E. andrei under laboratory conditions. Gajalakshmi et al. (2002) studied the vermicomposting of paper waste using anecic earthworm *Lampito mauriti*. Suthar (2006) has reported the vermicomposting of guar gum industrial waste using *Perionyx excavatus*. Sugarcane processing mill wastewater treatment plant sludge contains a significant percentage of organic matter and is a rich source of nitrogen. In our laboratory, the work is in progress to explore the potential of earthworms in management of industrial sludges (Kaushik and Garg, 2003, 2004; Garg and Kaushik, 2005). The present contribution reports the results of laboratory-based experiments performed to investigate the ability of earthworms for the management of press mud. It was hypothesized that the viability of different vermicomposters would be affected by different percentages of press mud and BPS.

2. Methods

2.1. Eisenia fetida, cow dung (CD), biogas plant slurry (BPS) and press mud (PM)

Healthy clitellated specimen of *E. fetida* weighing 350–400 mg live biomass were randomly picked up for the experiment from stock culture maintained in the laboratory taking cow dung as culturing medium by authors.

Fresh CD was collected from an intensively live stocked farm situated at Hisar, India. Anaerobically digested BPS was collected from post-methanation storage tank of an on-farm biogas plant situated at *Agroha*, Hisar, India. Sugar mill sludge (PM) was procured from effluent treatment plant of a sugar mill (The Jind Cooperative Sugar Mill Ltd.) located at Jind, India. The main characteristics of CD, BPS and PM are given in Table 1.

2.2. Experimental set-up

Seven waste mixtures having different ratios of BPS and PM were prepared including one with cow dung and biogas plant slurry each. One hundred and fifty grams of each waste mixture were filled in 1-l circular plastic containers (diameter 16 cm, depth 10 cm), called vermicomposter, on dry weight basis. The composition of different waste mixtures is given in Table 2.

Table 1
Initial physico-chemical characteristics of different feed materials

Parameter	Cow dung	Biogas plant slurry	Press mud
pH	8.20 ± 0.3	8.10 ± 0.2	7.10 ± 0.2
TOC (g/kg)	499 ± 22	464 ± 21	440 ± 19
TKN (g/kg)	12.8 ± 0.5	15.8 ± 0.9	24 ± 0.7
TP (g/kg)	4.6 ± 0.3	5.50 ± 0.4	5.1 ± 0.6
TK (g/kg)	20.9 ± 1.6	17.4 ± 0.8	8.3 ± 0.9
C:N ratio	39.0 ± 4.5	29.4 ± 3.8	18.3 ± 0.7

Table 2
Initial content (percentage) of different wastes in different vermicomposters

Vermicomposter number	Biogas plant slurry (BPS) (g)	Press mud (PM) (g)	Cow dung (g)
1	0	0	150 (100)[a]
2	150 (100)[a]	0	0
3	135 (90)[a]	15 (10)[a]	0
4	120 (80)[a]	30 (20)[a]	0
5	105 (70)[a]	45 (30)[a]	0
6	90 (60)[a]	60 (40)[a]	0
7	75 (50)[a]	75 (50)[a]	0

[a] The figures in parentheses indicate the percentage content in initial feed mixtures.

All waste mixtures were turned over manually for 15 days in order to pre-compost it so it becomes palatable to earthworms. After 15 days of pre-composting, 5 adult clitellated earthworms of *E. fetida* species were inoculated in each vermicomposter. All the vermicomposter were operated in dark at a laboratory temperature of (25 ± 3 °C). The moisture content was maintained at 70 ± 10% by periodic sprinkling of distilled water. During the experimental period no extra waste mixture was added at any stage in any vermicomposter. The worms were separated from vermicomposter by hand sorting, counted, washed, dried by paper towels and weighed weekly and transferred back to the respective vermicomposters. No corrections for gut content were applied to any of the data. All the vermicomposters were maintained in triplicate with earthworm density of five in each container. Same set up for each vermicomposter was established without worms, which acted as a control.

At the end of experiment worms, cocoons and hatchlings were removed and so produced vermicompost was air dried at room temperature and packed in airtight plastic bottles for further physico-chemical and nutrient content analysis.

2.3. Physico-chemical analysis

All the vermicomposters were operated for 13 weeks and homogenized samples of all feed substrates were drawn at 0, 15, 30, 45, 60, 75 and 91 days. Here 0 day refer to the day of inoculation of earthworms after pre-composting. The physico-chemical analysis was done on dry weight basis. All the chemicals used were analytical reagent (AR) grade. Double distilled water was used for analytical work. All the samples were analyzed in triplicate and results were averaged.

The pH was determined using double distilled water suspension of each mixture in ratio of 1:10 (w/v). Total organic carbon (TOC) was measured using the method of Nelson and Sommers (1982), Total Kjeldhal nitrogen (TKN) was determined by digesting the samples with conc. H_2SO_4 and $HClO_4$ (9:1, v/v) by Bremner and Mulvaney (1982) procedure. Total phosphate was analyzed by using the spectrophotometric method with molybdenum in sulphuric acid. Total potassium (TK) was determined by flame photometer (Elico, CL 22 D, Hyderabad, India) after digesting the sample in diacid mixture (conc. HNO_3, conc. $HClO_4$; 4:1, v/v) (Kaushik and Garg, 2004; Bansal and Kapoor, 2000).

One-way ANOVA was used to analyze the significant differences among different vermicomposters for studied parameters. Tukey's test was performed to identify the homogeneous type of vermicomposters for the various parameters. The probability levels used for statistical significance of tests were $p < 0.05$.

3. Results and discussion

3.1. Nutrient quality of the waste mixtures in different vermicomposters

Table 3 shows the nutritional quality of different waste mixtures and their final products. A decrease in pH was observed in all the waste mixtures during vermicomposting (Table 3). Most of other reports on vermicomposting (Sangwan et al., 2008; Gunadi and Edwards, 2003; Garg and Kaushik, 2005) have also reported similar results. The decrease in pH may be due to mineralization of nitrogen and phosphorus into nitrites/nitrates and orthophosphates and bioconversion of the organic material into intermediate species of organic acids (Ndegwa and Thompson, 2000). Different waste mixtures could result in the production of different intermediate species and hence different waste mixtures show a different behavior in pH shift. Decrease in pH in vermicomposter no. 2, 4, 5,