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Vermiconversion of wastewater sludge from textile mill mixed with anaerobically digested biogas plant slurry employing *Eisenia foetida*

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Abstract

Vermicomposting is commonly used for the management of organic wastes. We have investigated the potential of an epigeic earthworm, *Eisenia foetida*, to transform solid textile mill sludge (STMS) spiked with anaerobically digested biogas plant slurry (BPS) into vermicompost to evaluate the feasibility of vermicomposting in industries for waste management. The growth and reproduction of *E. foetida* was monitored in a range of different feed mixtures for 15 weeks in laboratory under controlled experimental conditions. *E. foetida* did not survive in fresh STMS. But worms grew and reproduced in STMS spiked with BPS feed mixtures. A greater percentage of STMS in feed mixture affected biomass gain and cocoon production by earthworms. The maximum growth was recorded in 100% BPS. The net weight gain by *E. foetida* in 100% BPS was two–four-fold higher than STMS-containing feed mixtures. After 15 weeks, maximum cocoons (78) were counted in 100% BPS and minimum (26) in 60% BPS + 40% STMS feed. Vermicomposting resulted in pH shift toward acidic, significant reduction in C:N ratio, and increase in nitrogen, phosphorus, and potassium contents. Microbial activity measured as dehydrogenase activity increased with time up to day 75 but decreased on day 90, indicating the exhaustion of feed and decrease in microbial activity. These experiments demonstrate that vermicomposting can be an alternate technology for the recycling and environmentally safe disposal/management of textile mill sludge using an epigeic earthworm, *E. foetida*, if mixed with anaerobically digested BPS in appropriate ratios.

Keywords: *Eisenia foetida*; Vermicomposting; Solid textile mill sludge; Anaerobically digested biogas plant slurry; Biomass growth; Cocoon production; C:N ratio; Dehydrogenase activity

1. Introduction

The commercially and ecologically sustainable management of industrial sludges is a great challenge worldwide. Industrial sludge disposal technologies adopted around the world include land filling, land spreading, incineration, thermal drying, lime stabilization, and composting. The authors have observed that, due to the prohibitive cost of sludge management, most of the textile mills in India dispose wastewater sludge in agricultural fields, open dumps, fellow land, and poorly managed sanitary landfills, and along railway tracks which can pollute surface or subsurface water, causing public health hazards. Meanwhile limited landfill space, more stringent national waste disposal regulations, and public consciousness have made land filling and land spreading increasingly expensive and impractical. Therefore, industries and municipalities are in search of sustainable sludge management technologies. The situation of sludge management in other developing countries is no different and may perhaps exist elsewhere also (Abbasi and Ramasamy, 2001).

Use of earthworms for waste management, organic matter stabilization, soil detoxification, and vermicompost production has been reported. The transformation of industrial sludge into vermicompost is of double interest: on one hand, waste is converted into a

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value-added product and, on the other; it controls waste that is a consequence of increasing industrialization. Considerable work has been carried out on the use of earthworms in composting various organic wastes such as cattle dung (Gunadi et al., 2002); plant litter (Frederickson et al., 1997); municipal sludge (Dominguez et al., 2000); sericulture waste (Gunathilagraj and Ravignanam, 1996); paper waste (Gajalakshmi et al., 2002); horse waste (Edwards et al., 1998; Hartenstein et al., 1979); weeds (Gajalakshmi et al., 2001); pig waste (Chan and Griffiths, 1988; Reeh, 1992); agricultural residues (Bansal and Kapoor, 2000); domestic kitchen waste (Sinha et al., 2002), etc.

In the past decade, many large-scale vermicomposting facilities have been developed all over the world with varying success. The largest vermicomposting facility in the United States is operated by American Resource Recovery in Westley, California. Currently 250,000 kg of earthworms process 75,000 t of waste annually. The wastes include paper–pulp waste generated from recycled cardboard, tomato residues, and green waste (Sherman-Huntoon, 2000). The Sydney Waters in New South Wales set up a vermicomposting plant of 40 million worms to degrade up to 200 t of urban waste per week (Sinha et al., 2002). Kale (1991) reported that Japan had imported 3000 t of earthworms from the United States in 1985–1987 for cellulose waste vermicomposting. But there are only a few studies on the vermicomposting of industrial sludges. Kaushik et al. (2003) and Garg et al. (2005) reported that textile mill sludge can be potentially useful as a raw substrate in vermicomposting if mixed up to 30% with cow dung (CD) or poultry droppings. Butt (1993) showed that paper-mill sludge was a suitable feed for *Lumbricus terrestris* under laboratory conditions. By the addition of spent yeast from the brewing industry, the C:N ratio of this sludge could be adjusted according to the requirements. Elvira et al. (1996) studied the efficiency of *Eisenia andrei* (Bouche) in bioconverting paper–pulp mill sludge mixed with primary sewage sludge. The presence of earthworms accelerated mineralization of organic matter, favored breakdown of structural polysaccharides, and increased humification rate. Solid paper-mill sludge mixed with sewage sludge in a 3:2 ratio resulted in the highest growth rate and the lowest mortality of *E. andrei*, whereas paper-mill sludge mixed with pig slurry exhibited a high mortality (Elvira et al., 1996). High mortality was attributed to changes in the environmental characteristics.

Eisenia foetida is an epigeic earthworm species which lives in organic wastes and requires high moisture content, adequate amounts of suitable organic material, and dark conditions for proper growth and development (Chaudhari and Bhattacharjee, 2002; Gunadi and Edwards, 2003; Gunadi et al., 2002). In order to utilize this species successfully in vermicomposting, its survival, growth, and fecundity in different wastes should be known.

In our laboratory, work is in progress to demonstrate that the raw material base for vermicomposting can be enlarged and some solid waste disposal problems can be solved (Garg et al., 2005; Kaushik et al., 2003, 2004). The laboratory-based experiments described in this paper aim to investigate the effects of solid textile mill sludge (STMS) spiked with biogas plant slurry (BPS) on growth and fecundity of an epigeic earthworm, *E. foetida*, as well to assess the physicochemical changes affected in different feed mixtures. It was hypothesized that different percentages of STMS in feed mixtures would affect the vermicompost quality and growth and reproduction of *E. foetida.*

2. Materials and methods

2.1. Cow dung

Fresh CD was procured from the Devi Bhawan cow farm, Hisar, India. The main characteristics of CD were pH (1:10 ratio) 7.90, total organic carbon (TOC) 497 g kg^{-1}, total Kjeldhal nitrogen (TKN) 7.1 g kg^{-1}, total available phosphorus (TAP) 5.30 g kg^{-1}, and C:N ratio 69.2.

2.2. Biogas plant slurry

Anaerobically digested BPS was procured from post-methanation storage tank of an on-farm biogas plant. The raw material used in the biogas plant was the CD collected from an intensively livestocked cow farm at the village Agroha, Hisar, India. The main characteristics of BPS were pH (1:10 ratio) 8.30, TOC 416 g kg^{-1}, TKN 5.2 g kg^{-1}, TAP 5.3 g kg^{-1}, and C:N ratio 80.0.

2.3. Solid textile mill sludge

Fresh STMS was obtained from the wastewater treatment plant of a textile factory (H.P. Cotton Mill Ltd.) located near Hisar, India. The main characteristics of STMS were total solids 197 g kg^{-1}, pH (1:10 ratio) 8.3, TOC 142 g kg^{-1}, TKN 0.74 g kg^{-1}, and C:N ratio 199. The sludge was dried in shade prior to use for vermicomposting.

2.4. Eisenia foetida

Nonclitellated hatchlings of the earthworm *E. foetida* were randomly picked for use in the experiments from several stock cultures containing 500–2000 earthworms in each, maintained in the laboratory with CD as culturing material. Each hatchling weighed between 0.100 and 0.250 g.

2.5. Stoichiometry

All the waste quantities were used on a dry weight basis that was obtained by oven drying known quantities of material at 110 °C in a hot air oven to constant mass.