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Evaluation of thermophilic fungal consortium for organic municipal solid waste composting

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HIGHLIGHTS

- Composting of OFMSW employing fungal inoculum is a rapid and low cost technology.
- Inoculation of fungal consortium significantly improved compost humification.
- *T. viride*, *A. niger* and *A. flavus* are effective at a wide range of temperature.
- Weekly turning frequency is effective for OFMSW windrow composting.

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ABSTRACT

Influence of fungal consortium and different turning frequency on composting of organic fraction of municipal solid waste (OFMSW) was investigated to produce compost with higher agronomic value. Four piles of OFMSW were prepared: three piles were inoculated with fungal consortium containing 5 l each spore suspensions of *Trichoderma viride*, *Aspergillus niger* and *Aspergillus flavus* and with a turning frequency of weekly (Pile 1), twice a week (Pile 2) and daily (Pile 3), while Pile 4 with weekly turning and without fungal inoculation served as control. The fungal consortium with weekly (Pile 1) turning frequency significantly affected temperature, pH, TOC, TKN, C/N ratio and germination index. High degradation of organic matter and early maturity was observed in Pile 1. Results indicate that fungal consortium with weekly turning frequency of open windrows were more cost-effective in comparison with other technologies for efficient composting and yield safe end products.

1. Introduction

Large quantities of municipal solid waste (MSW) are produced in modern society and its disposal poses serious environmental, social and economic problems. India nearly generates about 700 million tons of organic waste annually from cities alone (Pan et al., 2012). Rapid expansion of the cities/towns with massive migration of population from rural to urban centers caused considerable increases in per capita of MSW generation. The increasing rate of solid waste generation, limited landfill space and more stringent environmental regulations for new landfill sites and incinerators have increased the waste disposal fees especially in developing countries.

Therefore, municipalities and local governments are under heavy pressure to find sustainable and cost-effective solid waste management practices (Saha et al., 2010; Sharholy et al., 2008). In Jabalpur, Madhya Pradesh, India, about 450 tons of MSW consisting of household, market waste and yard wastes are generated; and ~65% are disposed in the landfills while the remaining is disposal off in the open environments (Gautam et al., 2010). Biological treatment such as composting of the organic fraction of MSW (OFMSW) is an environmentally and economically viable solution (Tosun et al., 2008).

Windrow composting is widely used for sanitary disposal of OFMSW. Several earlier researchers performed small-scale composting of OFMSW by windrow method, where it took between three and

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four months to produce compost; but the quality and maturity were uncertain (Adam and Frostick, 2009). During composting, decomposition of organic matter (OM) was very high under thermophilic conditions as high rate of biooxidation of organic materials begins at 40 °C (Huang et al., 2006). The increase in temperature facilitates the destruction of the large number of pathogenic microbes and weed seeds (Chang et al., 2006; Said-Pullicino et al., 2007).

Natural composting process takes long duration for degradation; however, the shortage of lands and large volume of OFMSW require these wastes to be treated more quickly. The inoculation with lignocellulolytic fungi could potentially enhance the organic degradation. Fungal species such as *Trichoderma viride*, *Aspergillus niger* and white-rot fungi are able to degrade the cellulolytic and lignolytic waste (Huang et al., 2006; Vargas-Gracia et al., 2010; Yu et al., 2007). These microorganisms considerably reduced the composting time of OFMSW (Crecchio et al., 2004; Zeng et al., 2010). Chemical and microbiological changes have been studied during OFMSW composting under field conditions in windrows and heaps (Adam and Frostick, 2009), and in a laboratory scale composting keeping temperature constant artificially (Zeng et al., 2010).

Aeration and microbial inoculums are important factors of influencing composting because composting is basically an aerobic process, where O_2 is consumed, and gaseous H_2O and CO_2 are produced. A few researches have demonstrated that single component cellulase or cellulase from pure cultures could not convert highly ordered polymer into monomer efficiently (Lin et al., 2011). Mixing of several types of enzymes like cellulase, protease, amylase and lipase acting synergistically has been proven to be an effective strategy for improving OFMSW composting (Echeverria et al., 2012). Since no single microorganism could produce all the necessary enzymes for complete decomposition of OFMSW, use of microbial consortia which act synergistically for rapid bioconversion of OFMSW biomass is attractive (Elango et al., 2009; Liu et al., 2011).

Previously, many researchers reported the use of microbial consortium for organic waste composting; but they all were performed under laboratory conditions and not exactly applicable to windrow composting; thus optimizing the turning frequency was not a criterion (Raut et al., 2008; Lin et al., 2011; Echeverria et al., 2012). Nowadays, commercial interest is emerging for effective microbial starter cultures for efficient windrow composting. However, available literature indicates that no data have been published on the windrow composting of OFMSW inoculated with fungal consortium under different turning frequency. If these deficiencies are addressed in a windrow of reasonable size then the results will be of potential commercial value. Therefore, the objectives of this study were to evaluate the effectiveness of fungal consortium to reduce composting time and compare with different turning frequencies required for OFMSW windrow composting to achieve rapid, cost effective treatment and obtain products of high nutritional value.

2. Methods

2.1. Organic municipal solid waste collection and processing

Different putrescible components of the MSW including vegetables waste, food waste, garden waste and office waste were separately collected from eight different zones of Jabalpur city; wastes were chopped into 10–20 mm length using a mechanical chopper before used as substrate. Selected physicochemical properties of the raw materials prior to composting are presented in Table 1.

2.2. Composting pile establishment

Four piles of 5 ton shredded OFMSW each were prepared by mixing of food, vegetable, garden and office wastes at 1:1:1:1 ratio (w/w wet weight basis), and mixed with 250 kg of wood shaving to achieve the initial C/N ratio of 25 to 30 and bulk density of ~0.5 kg/L. Windrow composting piles approximately 5 m × 1 m × 1.5 m (length × width × height) each were formed using a front end loader, and were composted for 35 days (Fig. 1). All windrows were mechanically turned using a loading shovel, with different turning frequencies; Pile 1 once a week, Pile 2 twice a week and Pile 3 every day while the Pile 4 was turned weekly. Piles 1–3 were supplemented with fungal inoculum while the Pile 4 without fungal inoculation served as control for Pile 1. The moisture content was adjusted to about 60% at the beginning of composting and then periodically water was added during the turning of composting when necessary to increase the moisture content. During the composting, temperatures were measured at different locations (Fig. 1), including the top (125 cm from the base of the pile), the middle (85 cm from the base of the pile) using a Raytek infrared digital thermometer (range: 20–100 °C, measurement accuracy: ±0.5 °C). Triplicate composite samples were collected periodically on days 0, 5, 10, 15, 20, 25, 30 and 35. For each pile, samples were randomly collected from ten different places of the piles and mixed to obtain composite samples. The sampling locations are indicated in Fig. 1.

2.3. Chemical analyses

The moisture content of samples was determined based on weight loss at 105 °C, while pH and electrical conductivity (EC) of the aqueous extract of fresh samples were (1:5, w/v, sample/water ratio) measured using a pH electrode (PB-10, Sartorius) and conductivity electrode (LF91, Wiss. Techn. Werkstatten). Total organic carbon (TOC), total Kjeldhal nitrogen (TKN), total phosphorous (TP), total sodium (TNa), total potassium (TK)and heavy metals (Cd, Pb, Cu, Cr, Zn and Ni) were determined following the methods (04.01–04.06) of TMECC (2002). The C/N ratio was calculated as the ratio of TOC to TKN. E_4/E_6 ratio of humic and fulvic acids was determined in aqueous extract using spectrometry determination at 460 and 660 nm, respectively (Page et al., 1982).

2.4. Microbial source and inoculums preparation

About 35 different fungal species were isolated and/or procured from the IMTECH, Chandigarh, India for screening. Selection of the strains for this study was made on the basis of enzymatic activity (cellualses, protease, amylase and lipases) at a wide range of temperature and pH, and substrate specific organic waste degradation at flask scale experiment (data not shown). Based on the performance of synergistic enzymatic activity the following species were selected for the inoculation in this study: *Trichoderma viride* MTCC 793, *Aspergillus niger* MTCC 1344 and *Aspergillus flavus* MTCC 1425. The selected strains were cultivated on potato dextrose agar, spores were collected from the agar surface plates with phosphate-buffered saline (PBS), quantified using microscope and suspended in 5 l autoclaved distilled water with PBS and 0.05% Tween 80. After that spore suspensions each of *T. viride* (6.8×10^6 spore/mL^{-1}), *A. niger* (4.5×10^4 spore/mL^{-1}) and *A. flavus* (4.5×10^4 spore/mL^{-1}) were mixed with 14 kg of air dried OFMSW with a particle size of <2 cm^3 and inoculated into the piles after 3 days of composting as described by Echeverria et al. (2012).

2.5. Microbiological analysis

Culturalble aerobic microorganisms, including bacteria, filamentous eumycetes and actinomycetes, were enumerated by traditional viable cell count method by inoculating in appropriate media with 0.1 mL of serially diluted sample as described by Vargas-Gracia et al. (2010). Media and incubation times for