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Vermicomposting of milk processing industry sludge spiked with plant wastes

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ABSTRACT

This work illustrates the vermistabilization of wastewater sludge from a milk processing industry (MPIS) unit spiked with cow dung (CD), sugarcane trash (ST) and wheat straw (WS) employing earthworms *Eisenia fetida*. A total of nine experimental vermibeds were established and changes in chemical parameters of waste material have been observed for 90 days. Vermistabilization caused significant reduction in pH, organic carbon and C:N ratio and substantial increase in total N, available P and exchangeable K. The waste mixture containing MPIS (60%) + CD (10%) + ST (30%) and MPIS (60%) + CD (10%) + WS (30%) had better waste mineralization rate among waste mixtures studied. The earthworm showed better biomass and cocoon numbers in all vermibeds during vermicomposting operation. Results, thus suggest the suitability of *E. fetida* for conversion of noxious industrial waste into value-added product for land restoration programme.

1. Introduction

Agriculture, food processing, pulp and paper, or any agriculture-based industry produces massive quantity of liquid, gaseous or solid wastes. Such agro-industrial sludge/wastes not only spoil aesthetics sense of local habitats but at the same time also create issues of all types of environmental pollution, if proper disposal and management policy is not adopted. The dairy processing industry is the major component of food processing industry in the India. It is considered to be the largest source of food processing wastewater in many countries. Although the dairy industry is not commonly associated with sever environmental problem, it must continually consider its environmental impact – particularly as dairy pollutants are mostly of organic origin (protein, carbohydrate, lipids, suspended oils and/or grease) with high concentration of suspended solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and nitrate contents (Britz et al., 2006). The wastewater and solids generated from dairy processing industry pose issues of safe management and disposal of treated and/or untreated wastewater solids. The traditional disposal methods such as open dumping and/or land filling practices of these materials are not only increasingly expensive, but impractical as open space becomes limited (Slater and Frederickson, 2001). Contamination of ground water, soils, as well as, food resources are some of the problems which have resulted from land filling practices of dumped waste materials (Ilgen et al., 2008). The emission of GHGs from waste dumping site is an issue of prime concern (IPCC, 2006; Lou and Nair, 2009). However, the stabilization of such sludge prior to use of disposal should reduce the environmental problems associated with its open dumping (Gomez-Brandon et al., 2011). In general, stabilization involves the decomposition of an organic waste into the extent of eliminating the hazards and is normally reflected by decreases in microbial activity and concentration of labile compounds (Benito et al., 2003).

Composting has been appeared as important tool to stabilize the organic waste generated from different sector of the society. Composting is the most sustainable option for onsite organic waste management as it is easy to operate and can be conducted in contained space provided (Lou and Nair, 2009; Hong et al., 2010). In recent years vermicomposting has been explored extensively to recycle the nutrient stuff from organic wastes from different community sources (Suthar, 2009). Vermicomposting, utilizing earthworms, is an ecobiotechnological process that transforms energy-rich and complex organic substances into a stabilized humus-like product vermicompost (Sinha et al., 2010). According to Dominguez (2004) it is a complex process involving the joint action of earthworms and microorganisms. Although microbes are responsible for biochemical degradation of organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering the biological activity.

Vermistabilization is stabilization of organic material, such as sludge, involving the joint action of earthworms and microorganisms. The sludge can be stabilized effectively through vermistabilization process because of many beneficial impacts of inoculated earthworms upon aerobic decomposition process. Loehr et al. (1985) concluded that in vermicomposting system the earthworms

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maintain aerobic condition in wastes, ingest solids, convert a portion of the organics to worm biomass and respiration products and expel partially stabilized matter as discrete particles (vermicompost).

The utilization of earthworm in waste stabilization practices is well documented in recently published work. There is evidence of successful utilization of earthworms for stabilizations of anthropogenic wastes generated from different industries: vinasse (Pramanik and Chung, 2011), grape mark (Gomez-Brandon et al., 2011), sago industry waste (Subramanian et al., 2010), paper mill sludge (Elvira et al., 1998), sugar factory waste (Khwairakpam and Bhargava, 2009; Suthar, 2010) and olive oil mill sludge (Moreno et al. (2000) distillery and winery industry sludge (Suthar and Singh, 2008; Gomez-Brandon et al., 2011), leather processing industry sludge (Ravindran et al., 2008) etc. After reviewing literature it is realized that dairy industry sludge can also be a candidate for vermistabilization operation. Epigeic earthworms could stabilize the sludge potentially and can accelerate the rates of destruction of sludge volatile solids in aerobic sludge greatly, which probably decreases the putrefaction; occurring because of anaerobic conditions. So, the main cause of increased rates of degradation of sludge is probably the increased aeration and turnover of wastes by the earthworms (Loehr et al., 1985).

The aim of the present investigation is to stabilize the diary industry wastewater sludge spiked with plant wastes in different ratios using earthworm *Eisenia fetida*. The different combinations of industrial sludge and bulky materials were tested under vermistabilization operation in order to find out suitable waste mixture for optimize earthworm activity.

2. Methods

2.1. E. fetida, dairy industrial sludge and bulky agent collection

To carry out the experiment specimens of earthworm species *E. fetida* (Savigny) were obtained from a stock culture reared in our laboratory and fed with decomposed cow dung spiked with plant litters.

Freshly deposited sludge (MPIS) was collected form wastewater treatment unit of a local milk processing industry. The wet-sludge (containing 70–81% moisture) was collected in large-sized plastic containers and then brought to the laboratory for further processing. The sludge was shade dried in lab to evaporate the excess water from it. Also, regular turns were made in order to reduce the characteristics smell of putrescible substances and biotoxic compounds present in sludge; generally formed under anaerobic conditions. Partially dried sludge cake solids were then homogenized and shredded prior to use in experimental vermibeds. Three bulky materials, i.e. cow dung (CD), sugarcane trash (ST) and wheat straw (WS) were used to prepare different substrate mixture for earthworms. The substrate acts as bedding and feeding materials for inoculated earthworms. The chopped straw of wheat (WS) and fresh sugarcane trash were procured from a local agriculture farm. Fresh urine-free cow dung was procured from a local cowshed. The cow dung was partially dried in shade and homogenised manually. The main chemical characteristics of dairy processing industrial sludge cake (MPIS) and bulky agents are given in Table 1.

2.2. Experimental design

The chemical characteristics especially nitrogen content and C:N ratio of waste stuff plays an important role in earthworm palatability and vermicomposting rate. The MPIS was mixed with bulky materials (CD, ST and WS) in appropriate ratio in order to balance the nutrient contents as well as bedding material size fractions. Following nine feed mixtures were used for vermicomposting experimentations.

T_1	MPIS (20%) + CD (80%)
T_2	MPIS (40%) + CD (60%)
T_3	MPIS (40%) + WS (60%)
T_4	MPIS (60%) + WS (40%)
T_5	MPIS (40%) + ST (60%)
T_6	MPIS (60%) + ST (40%)
T_7	MPIS (60%) + CD (10%) + WS (30%)
T_8	MPIS (60%) + CD (10%) + ST (30%)
T_9	MPIS (100%)

MPIS (100%) acts as experimental control bedding in order to compare the results of chemical and biological changes during vermicomposting in the presence of bulky agents. The chemical characteristics of initial waste mixtures (Table 2) were: 7.35–8.5 (pH), 419.18–503.65 g kg^{-1} (TOC), 7.96–39.73 g kg^{-1} (TKN), 2.32–23.50 g kg^{-1} (AP), 5.67–14.46 g kg^{-1} (EK) and 10.60–60.52 (C:N ratio).

Prior to vermistabilization the waste mixtures were pre-composted for 3 weeks for initial thermal stabilization, initiation of microbial degradation and softening of waste mixture. During this sludge mixture was turned out periodically (after 3 days) for aeration and to remove odour from decomposing wastes. The proper moisture content in composting beds was maintained. After 3-wk composting, 500 g waste mixture (dry weight basis) was separated from composting beds and filled in plastic circular containers of 2 L capacity (one for each mixture) for vermicomposting trials. Twenty earthworms (4-wk old) having individual live weights of ≈264–281 mg were released into each experimental container. The experimental beddings were kept in triplicate for each treatment. The moisture content was maintained at 65–70%, throughout the study period by periodic sprinkling of adequate quantity of water. The containers were placed in a humid and shady place at an ambient temperature 27.2 °C (SD = 0.14). The earthworm mortality was observed for initial critical periods (initial 15 days of experimental starting) and data of mortality were recorded for different experimental containers. To estimate the physic-chemical changes during vermistabilization process, homogenized samples (10 g) of waste mixtures were drawn at 0, 15, 30, 45, 60, 75 and 90 days from each experimental container. The samples of substrate mixture were oven dried (48 h at 60 °C), ground in stainless steel blender and stored in sterilized plastic airtight containers.

The biological productivity (biomass change, cocoon production etc.) of *E. fetida* was also monitored during the same interval for whole experiment duration by following method as described by Suthar (2009).

2.3. Chemical analysis

The pH was measured using a digital pH meter (Systronics made) in 1:10 (w/v) aqueous solution (deionized water). Total organic carbon (TOC) was measured after igniting the sample in a Muffle furnace at 550 °C for 60 min by the method of Nelson and Sommers (1996). Total Kjeldahl nitrogen (TKN) was measured using the method described by Jackson et al. (1975). Available phosphorous (AP) was measured using the method described by Anderson and Ingram (Olsen et al., 1954). Exchangeable potassium (EK) was determined after extracting the sample using ammonium acetate (Simard, 1993).

2.4. Statistical analysis

One-way ANOVA was used to analyze the differences between treatments. A Tukey's *t*-test was also performed to identify the