Ecological Engineering 47 (2012) 115–119

Contents lists available at SciVerse ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Vermistabilization of wastewater sludge from milk processing industry

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ARTICLE INFO

Article history:
Received 7 December 2011
Received in revised form 26 April 2012
Accepted 16 June 2012
Available online 20 July 2012

Keywords:
Vermistabilization
Industrial sludge
C:N ratio
Earthworm
Soil nutrients

ABSTRACT

This work illustrates the vermistabilization of milk processing industry wastewater sludge (MPIS) spiked with cow dung (CD) using earthworm *Eisenia fetida*. A total of four 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, exchangeable cations (K^+ and Ca^{2+}) and extractable trace elements (Fe, Mn and Zn). The waste mixture containing MPIS (60%) + CD (40%) showed the better mineralization rate as compared to others. The growth and cocoon production in *E. fetida* was also monitored in all experimental vermibeds. Also, *E. fetida* showed better growth and reproduction pattern in vermibeds with 40–60% MPIS. At high concentration MPIS caused significant mortality in worms. Results, thus suggested the suitability of vermicomposting for stabilization of noxious milk processing industry sludge.

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1. Introduction

India has emerged as the largest milk producing country in the world with 94.5 million tonnes annual milk production which is expected to be increased up to 135 million tonnes by the year 2015. In India, the milk-based product processing industry is included as one of the major food processing industry in the country. The wastewater and solids generated from milk processing industry pose problem like safe management and disposal of treated and/or untreated wastewater solids. The milk processing industry is considered to be the largest source of industrial wastewater in many countries. Although the dairy industry is not commonly associated with sever environmental problems but it must be watched continually for few environmental impacts – particularly organic pollutant loads (protein, carbohydrate, lipids, suspended oils and/or grease), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and nitrate contents (Britz et al., 2006). The open dumping of wastewater sludges not only pollutes surrounding natural resources but also provide shelter to several disease causing agents and disease-vectors. The stabilization of industrial sludge prior to use of disposal could reduce the environmental problems associated with its management (Gomez-Brandon et al., 2011). In general, stabilization involves the decomposition of an organic waste in to the extent of eliminating the hazards and is normally reflected by decreases in microbial activity and concentration of labile compounds (Benito et al., 2003).

Vermistabilization is stabilization of organic material, such as sludge, involving the joint action of earthworms and microorganisms. According to Loehr et al. (1985), in vermicomposting system earthworms maintain aerobic conditions in the organic wastes, ingest solids, convert a portion of the organics into worm biomass and respiration products, and expel the remaining partially stabilized product, i.e. vermicompost. They suggested that the process is a function of (a) the portion of waste that is biodegradable, (b) maintenance of aerobic conditions and (c) the avoidance of toxic conditions. Vermistabilization represents a technology that is environmentally sound and economically viable (Sinha et al., 2010). As compared to thermal composting, vermicomposting often produces a product with a lower mass, lower processing time, humus content, phytotoxicity is less likely, more N is released and fertilizer value is usually greater. The sludge can be stabilized effectively through vermistabilization process because of many beneficial impacts of inoculated earthworms upon aerobic decomposition process.

The objective of the present investigation was to stabilize the milk processing industrial sludge spiked with cow dung using composting earthworm *Eisenia fetida*. In majority of previous studies *E. fetida* was used as candidate species for vermicomposting operation because it can tolerate wide pH range, temperature, moisture and a wide range of putrescible substances and biotoxic compounds. Therefore, for this study *E. fetida* was selected as candidate earthworm species for experimentation.

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http://dx.doi.org/10.1016/j.ecoleng.2012.06.005

Table 1
Characteristics of milk processing wastewater sludge (MPIS) and cow dung (CD) used for experimentations.

Parameters	MPIS	CD
pH	7.05 ± 0.11	8.52 ± 0.13
C_{org} (g kg^{-1})	287.5 ± 5.23	285.99 ± 6.18
OM (g kg^{-1})	497.94 ± 8.93	495.31 ± 10.4
N_{tot} (g kg^{-1})	56.8 ± 2.34	16.84 ± 1.01
P_{avail} (g kg^{-1})	32.9 ± 2.01	5.57 ± 0.45
K_{exch} (g kg^{-1})	18.4 ± 0.34	4.87 ± 0.19
Ca_{exch} (g kg^{-1})	104.6 ± 4.56	12.53 ± 0.36
Zn (mg kg^{-1})	201.29 ± 17.44	287.40 ± 1.57
Fe (mg kg^{-1})	1698.12 ± 42.57	289.91 ± 2.23
Mn (mg kg^{-1})	279.60 ± 15.7	198.49 ± 3.69
C:N ratio	5.06 ± 0.07	16.98 ± 3.73
C:P ratio	8.74 ± 0.08	51.34 ± 4.29

2. Materials and methods

For vermicomposting experiments the composting earthworm (*E. fetida*) specimens were procured from a stock culture reared in our laboratory.

Freshly deposited wet-sludge (containing 70–81% moisture) was collected from wastewater treatment unit of a local milk processing industry. The wet-sludge was collected in large-sized plastic containers (20 L) and then brought to the laboratory for further processing. The sludge was shade dried in lab to remove the excess water form it. Also, regular turns were made to remove the characteristics smell of putrescible substances and biotoxic compounds, formed under anaerobic conditions. Partially dried sludge cake solids were homogenized and shredded prior to use in experimental vermibeds. Fresh urine-free cow dung was procured from a local cowshed. The cow dung was partially dried in shade and homogenized manually. The main chemical characteristics of milk processing industrial sludge (MPIS) and cow dung (CD) are given in Table 1.

MPIS and CD was mixed in different ratios to produce four vermibeds for vermicomposting experiments: T_1 – MPIS (20%) + CD (80%), T_2 – MPIS (40%) + CD (60%), T_3 – MPIS (60%) + CD (40%) and T_4 – MPIS (80%) + CD (20%). The physico-chemical properties of was mixture was in the ranges of: 7.20–7.86 (pH), 287.27–286.73 g kg^{-1} (total organic carbon), 24.57–48.93 g kg^{-1} (total Kjeldahl nitrogen), 10.99–27.51 g kg^{-1} (available phosphorous), 7.49–15.58 g kg^{-1} (exchangeable potassium), 30.89–86.72 g kg^{-1} (exchangeable calcium), 565.39–1506.70 mg kg^{-1} (extractable Fe), 213.75–263.33 mg kg^{-1} (extractable Mn) and 218.85–270.40 mg kg^{-1} (extractable Zn) (Table 2). The material in experimental pots acts as feed and bedding substrate for inoculated earthworms. For experimentation, 500 g experimental waste mixture (dry weight basis) was filled in plastic circular containers of 2 L capacity (one for each mixture). The waste mixtures moistened with tap water to maintain appropriate moisture level for initial decomposition of waste mixtures. These bedding were kept for 2 wk for initiation of microbial degradation, softening of waste mixture and thermal stabilization. After that, 25 earthworms (4–5-wk old) having individual live weight: ≈271–274 mg were released into each experimental container. The experimental containers were kept in triplicate for each experimental waste mixture. Appropriate moisture content was maintained in vermibeds throughout the study period by periodic sprinkling of water. The containers were placed in a humid and shady place at an ambient temperature 26.8 °C (SD = 0.25). The earthworm mortality was observed for initial critical periods (initial 15 days of experimental starting) and data of mortality were recorded for different experimental vermibeds. Homogenized samples of waste mixtures were drawn at 0, 15, 30, 45, 60, 75 and 90 days from each experimental container. The samples were oven dried (48 h at 60 °C), ground in stainless steel blender and stored in sterilized plastic airtight containers for further physico-chemical analysis.

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).

The pH was measured using a digital pH meter (Systronics made) in 1:10 (w/v) aqueous solution (deionized water). Total organic carbon 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 (1975). Available phosphorous was measured using the method described by Anderson and Ingram (Olsen et al., 1954). Exchangeable cations (K^+, and Ca^{2+}) were determined after extracting the sample using ammonium acetate (Simard, 1993). Extractable trace element (Mn, Fe and Zn) were determined by following diethylene-triaminepentaacetic acid (DTPA) extraction method; analyzed by atom absorption spectrophotometer (APHA–AWWA–WPCF, 1994).

One-way ANOVA was used to analyze the differences between treatments. A Tukey's *t*-test was also performed to identify the homogeneous type of the data sets. SPSS® statistical package (Window Version 13.0) was used for data analysis. All statements reported in this study are at the $p < 0.05$ levels.

3. Results and discussions

3.1. Physico-chemical changes in waste mixture during vermicomposting

The vermicomposted material was significantly different than initial waste mixtures in terms of physico-chemical contents (Table 3).

Table 2
Chemical characteristics of initial substrate material used in different treatments (mean ± SEM, $n = 3$).

Treatment[a]	pH	C_{org} (g kg^{-1})	N_{tot} (g kg^{-1})	P_{avail} (g kg^{-1})	K_{exch} (g kg^{-1})	Ca_{exch} (g kg^{-1})	$C:N_{ratio}$	$C:P_{ratio}$
T_1	7.86 ± 0.005	287.27 ± 1.60	24.57 ± 0.06	10.99 ± 0.06	7.49 ± 0.29	30.89 ± 0.56	11.69 ± 0.12	37.96 ± 0.39
T_2	7.58 ± 0.001	280.03 ± 0.53	32.95 ± 0.08	16.48 ± 0.05	10.50 ± 0.24	49.66 ± 0.64	8.49 ± 0.22	26.25 ± 0.28
T_3	7.36 ± 0.029	287.33 ± 0.34	41.98 ± 0.63	21.95 ± 0.09	13.03 ± 0.23	68.44 ± 0.38	6.85 ± 0.10	13.09 ± 0.72
T_4	7.20 ± 0.008	286.73 ± 0.42	48.93 ± 0.47	27.51 ± 0.34	15.58 ± 0.18	86.72 ± 0.63	5.86 ± 0.06	10.42 ± 0.14

Treatment[a]	Fe_{ext} (mg kg^{-1})	Mn_{ext} (mg kg^{-1})	Zn_{ext} (mg kg^{-1})
T_1	565.39 ± 19.7	213.75 ± 1.44	270.40 ± 2.67
T_2	851.62 ± 14.5	232.59 ± 1.00	254.76 ± 3.32
T_3	1152.48 ± 26.5	245.22 ± 2.21	235.90 ± 2.52
T_4	1506.70 ± 52.42	263.23 ± 2.01	218.85 ± 0.67

[a] For treatment compositions see Table 2.

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