Bioresource Technology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Bioresource Technology

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

Co-composting of gelatin industry sludge combined with organic fraction of municipal solid waste and poultry waste employing zeolite mixed with enriched nitrifying bacterial consortium

Mukesh Kumar Awasthi [a,b,c], Akhilesh Kumar Pandey [d], Pushpendra Singh Bundela [c], Jonathan W.C. Wong [f], Ronghua Li [e], Zengqiang Zhang [a,*]

[a] College of Natural Resources and Environment, Northwest A&F University, Yangling, Shaanxi Province 712100, PR China
[b] Department of Biotechnology, Amicable Knowledge Solution University, Satna, India
[c] Regional Office, Madhya Pradesh Pollution Control Board, Jabalpur, India
[d] Madhya Pradesh Private Universities Regulatory Commission, Bhopal, India
[e] Key Laboratory of Plant Nutrition and the Agri-environment in Northwest China, Ministry of Agriculture, Yangling 712100, PR China
[f] Sino-Forest Applied Research Centre for Pearl River Delta Environment, Department of Biology, Hong Kong Baptist University, Kowloon Tong, Hong Kong, PR China

HIGHLIGHTS

- 10% zeolite mixed with ENBC helps to reduce the nitrogen loss during GIS co-composting.
- GIS significantly buffered and provide optimum pH for composting.
- GIS 6% combined with OFMSW and PW improve the end product quality.
- ENBC is very effective at wide range of GIS concentration.

ARTICLE INFO

Article history:
Received 28 December 2015
Received in revised form 5 February 2016
Accepted 6 February 2016
Available online xxxx

Keywords:
Co-composting
Gelatin industry sludge
Poultry waste
Inoculation
Bacteria consortium

ABSTRACT

This work illustrates the co-composting of gelatin industry sludge (GIS) combined with organic fraction of municipal solid waste (OFMSW) and poultry waste (PW) employing 10% zeolite mixed with enriched nitrifying bacteria consortium (ENBC). Five piles of GIS were prepared mixed with OFMSW and PW at 2:1:0.5, 4:1:0.5, 6:1:0.5 and 8:1:0.5 and without GIS 0:1:0.5 (dry weight basis) served as control, while 10% zeolite mixed with ENBC was inoculated in all piles and composted for 42 days. The Pile-4 with GIS, OFMSW and PW ratio 6:1:0.5 and 10% zeolite + ENBC were drastically reduced the nitrogen loss and enhance the mineralization rate as compare to other piles. The co-amendment of 6% GIS effectively buffered the pH between ~7.5 to 8.0 and shortened the compost maturity period, while lower concentration of GIS was comparatively delayed the early decomposition. Therefore, our results suggested that suitability of 10% zeolite + ENBC with initial feedstock ratio 6:1:0.5 as the best formulation for the composting of GIS into value-added stable product.

1. Introduction

Gelatin industry are considered one of the most polluting industries in all over the word, because huge quantity of freshwater is utilized during different process of manufacturing resulting a large quantity of wastewater, sludge and other solids generate (Gautam et al., 2010a,b). The gelatin production generates about 40% of sludge, 30% ash, 15–20% bone residues, while 15–20% other solid waste like lime mud, lime slacker grits, boiler and furnace ash, scrubber sludge. The GIS from wastewater treatment units containing collagen fibers, bone residues, calcium carbonate, clay and other inorganic materials (Dalev et al., 2000; Abrusci et al., 2007; Gautam et al., 2010a). The majority of these types of industrial wastes is directly disposed in a landfill area without any treatment, which not only poses a health hazard of local habitats and also leads to create several health problems like water contamination; odor and greenhouse gas emission, because of anaerobic decomposition of high nitrogenous organic compounds (Hoyos et al., 2002; Suthar et al., 2012; Zhou et al., 2013; Wang et al., 2016).

* Corresponding author. Tel.: +86 13609254113; fax: +86 02987080055.
E-mail address: zhangzq58@126.com (Z. Zhang).

http://dx.doi.org/10.1016/j.biortech.2016.02.026
0960-8524/

The ecofriendly management of these types of industrial sludge and solid wastes are major challenging issue for the industries, scientist, and society (Gautam et al., 2010a; Suthar et al., 2012). Due to these region gelatin industries faces a serious solid waste disposal problem as environmental issue become increasingly stringent and landfill space grows scarcer. The physico-chemical analysis (high organic matter content, pH, buffer capacity, high nitrogen and phosphorous level, while low concentrations of heavy metals and other organic pollutants) have revealed that GIS contain valuable plant nutrients, which may improve the soil fertility and crop productivity (Morisaki et al., 1989; Hedström, 2001; Karak et al., 2014; Wang et al., 2016), but stabilization involving decomposition of an organic waste to the extent that biological and chemical hazards are eliminate is required (Suthar et al., 2012). Because Zucconi et al. (1981), Wong et al. (2009) have already reported that use of immature compost in agricultural fields inhibit plant growth due to the presence of pathogenic microorganism, toxic metabolites and heavy metals. While Wang et al. (2016) have reported that application of well mature organics promote the plant growth and increase soil fertility.

In recent years, windrow composting is providing a cost effective and eco-biotechnological process for organic waste recycling and converting a stable product from wastes that can be used as a soil conditioner or fertilizer (Echeverria et al., 2012; Awasthi et al., 2014). All those several previous researchers performed small-scale composting of OFMSW combined with different industrial waste by different methods (Hoyos et al., 2002; Wong et al., 2009; Suthar et al., 2012). But all of these methods take long duration to produce mature end product; the quality, because of its specific characteristics such as high moisture (Abrusci et al., 2007; Doublet et al., 2011), alkalinity, nitrogenous materials (Dalev et al., 2000; Zhou et al., 2013) and salinity (Sánchez-Monedero et al., 2001) may also reduce the decomposition process. For these respects, high alkalinity and odor emission have received much attention (Hoyos et al., 2002; Wong et al., 2009). Therefore, mixing with other organic waste can alleviate the initial high pH to achieve efficient organic matter degradation, but loss of nitrogen in form of ammonia is another problematic issue (Ogunwande et al., 2008; Wang et al., 2013; Chan et al., 2016). During composting involves the rapid biooxidation and stabilization of high quantities of easily available organic materials lead up to 65% of the total nitrogen loss, and also suddenly acidifies the composting mass, which are gradually inhibited the microbial activity and causes odor problems (Jeong and Kim, 2001; Ren et al., 2010; Wang et al., 2013; Wang et al., 2016).

Therefore, it is necessary to alleviate the low pH and help to accelerate the composting, but at the same time reduce the loss of nitrogen. Beside this, traditional natural composting of GIS also time taking process, because of high nitrogen and keratin waste content 90% dry matter (d.m.) (Hoyos et al., 2002) and GIS are classified as waste material resistant to degraded by common microbial species and its enzymes. The resistance of GIS to standard proteases results primarily from high content of disulphide bonds (Korniłłowicz-Kowalska, 1997), and only limited bacterial and fungal species has been reported (i.e. *Bacillus subtilis*, and *Bacillus licheniformis*, *Penaeus monodon* and *Macrobrachium rosenbergii*; Kumar et al., 2013), some actinomycetes (as *Streptomyces fradiae*; Williams et al., 1990), keratinolytic fungi (*Trichophyton* spp., *Microsporum* spp., *Chrysosporium* and *Myceliophtora*) and their teleomorphs (*Arthroderma* spp. and *Nannizia* spp., respectively), (Korniłłowicz-Kowalska, 1997) are capable of spontaneous saprotrophic utilization of native keratin as the sole source of C, N and energy.

However, these microbes reduce the composting mass and time, but some researches has been reported that single microbes could not convert highly ordered sulfur containing amino acid protein polymer into monomer (Hoyos et al., 2002; Gautam et al., 2010b). Therefore, inoculation of mixture of potential multi-enzymes secreting microbes combined with additives into composting mass to be an effective strategy for nitrogen conservation and improve composting efficiency (Villaseñor et al., 2011; Echeverria et al., 2012; Awasthi et al., 2015; Chan et al., 2016). Beside this, utilization of various forms of additives combined with microbial consortium for the decomposition of different kinds of solid waste/bio-waste has been also reported by some researchers (Kithome et al., 1999a, 1999b; Abrusci et al., 2007; Echeverria et al., 2012). Meanwhile, Villaseñor et al. (2011), Kumar et al. (2013) also observed that inoculation of additives such as zeolite can reduce the nitrogen loss and regulating nutrient cycling processes. Although zeolites are microporous, aluminosilicate minerals, which are commonly used by various researcher Villaseñor et al. (2011), Chan et al. (2016) for laboratory scale in vessel composting as commercial adsorbents and catalysts, because it has the ability to reduce the salinity, various gases emissions and immobilization of heavy metals during composting. Previous studies by Singh et al. (2013), Chan et al. (2016) shown that the addition of zeolite into solid materials was not a good buffering agent against the low pH during composting. Taking into advantages the above described potential use of zeolites and its applicability to enhance the rate of degradation, reduce ammonia loss and heavy metals during the composting process has investigated (Villaseñor et al., 2011; Singh et al., 2013; Chan et al., 2016). In addition, there are no studies have been found regarding windrow composting of GIS generated from a wastewater treatment unit of gelatin industries; meanwhile several effects of zeolites combined with ENBC have been hypothesized.

Therefore, the aim of this work was to examine the efficiency of inoculated ENBC combined with 10% zeolite in various combinations of GIS with OFMSW and PW, meanwhile also investigate their influence on nitrogen conservation, pH buffering during composting and end product quality.

2. Methods

2.1. Feed stock collection and processing

Fresh GIS was collected from wastewater treatment unit of the Narmada Gelatins Industry Pvt. Ltd. Jabalpur, in plastic bags and air dried in the shade on polythene bags to evaporate the excess water while turning daily to reduce the noxious smell of putrescible substances and toxic compound available in GIS. Partially dried GIS cake solids were homogenized and shredded. Fresh OFMSW was collected and processed as per our previous method Awasthi et al. (2014) and PW was obtained from a poultry farm located in Maharajpur, Jabalpur, India. The PW was also partially dried in a shade and stored for further experiment. All the components of the feed stock were properly homogenized and shredded into 1 cm^3 to obtain uniform particle size. Then, feed stock were mixed with wood shaving sawdust (WS) used as a bulking agent to adjust the optimum C/N ratio ~25 and bulk density of ~0.5 kg/L for 5 tone composting mass on dry weight basis, while the initial moisture content was maintain to 55% through the addition of deionized water. The physicochemical-characteristics of the each feedstock are presented in Table 1.

2.2. Composting pile establishment and physico-chemical analyses

GIS, OFMSW and PW were mixed in different ratios on dry weight basis to prepare five open windrows for composting experiments: Pile-1 (0:1:0.5), Pile-2 (2:1:0.5), Pile-3 (4:1:0.5), Pile-4 (6:1:0.5) and Pile-5 (8:1:0.5). The physicochemical properties of

Please cite this article in press as: Awasthi, M.K., et al. Co-composting of gelatin industry sludge combined with organic fraction of municipal solid waste and poultry waste employing zeolite mixed with enriched nitrifying bacterial consortium. Bioresour. Technol. (2016), http://dx.doi.org/10.1016/j.biortech.2016.02.026