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Research Paper

Effective utilisation of trickling liquid discharged from a bio-trickling filter as a moisture conditioning agent for composting

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ARTICLE INFO

Article history:
Received 2 December 2013
Received in revised form
13 March 2014
Accepted 1 April 2014
Published online 5 December 2014

Keywords:
Composting
Moisture adjustment
Nitrogen evolution
Germination index
Bio-trickling filter
Trickling liquid

Primary fermentation experiments were carried out investigating the disposal and reuse of trickling liquid discharged from a bio-trickling filter as a moisture conditioning agent. The liquid was mixed with food waste and mushroom bran. Compared to the addition tap water (TW), the addition of trickling liquid (TL) was found to accelerate the decomposition/fermentation rate of organic waste, which is defined in terms of enhancement in heat generation and waste mass reduction. The acceleration effect may be due to the activity promotion of heterotrophic bacteria induced by the addition of TL containing high level of ammonium. The addition of TL also promoted compost maturity based on the evaluation indices. The carbon–nitrogen ratio, $Q_{2/6}$, and $Q_{4/6}$ of the TL treatment were 15.3, 10.7, and 7.6, respectively. These values were 8.9, 4.3, and 3.6 lower than those in the TW treatment after 15 d of primary fermentation. The germination index of the TW treatment was 22.3% lower than that of the TL treatment (79.4%), which met the criteria (80%) for matured composting product. Furthermore, a nitrogen mass calculation indicated that mass reduction of nitrogen of the TL and the TW treatments were −9.6% and 12.2%, respectively. Therefore, reusing TL as a moisture conditioning agent for organic waste composting could enable zero discharge of TL, promote maturity, and increase the nitrogen content of compost.

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http://dx.doi.org/10.1016/j.biosystemseng.2014.04.002

Nomenclature

TW	tap water
TL	trickling liquid
BOD_5	five-day biochemical oxygen demand (mg l^{-1})
COD_{cr}	chemical oxygen demand determined with potassium bichromate method (mg l^{-1})
UV–vis	ultraviolet–visible spectroscopy
A_{664}	absorbance of the supernatant at $\lambda = 664$ (–)
A_{280}	absorbance of the supernatant at $\lambda = 280$ (–)
A_{472}	absorbance of the supernatant at $\lambda = 472$ (–)
$Q_{2/6}$	relation between non–humified and strongly humified material, $Q_{2/6} = A_{280}/A_{664}$ (–)
$Q_{4/6}$	the humification index, $Q_{4/6} = A_{472}/A_{664}$ (–)
GR	germination rate (%)
GI	germination index (%)
C/N	carbon–nitrogen ratio (–)
T value	ratio of final C/N to original C/N (–)
TN	total nitrogen (–)
TKN	Total Kjeldahl nitrogen (mg g^{-1})

1. Introduction

Odour pollution associated with composting process is gaining increased public attention. Thus, numerous in-depth studies on deodorisation have been carried out in recent years. Previous studies have indicated that organic solid waste composting always leads to atmospheric pollution because of odorous emissions, mostly ammonia (NH_3) (Ko, Kim, Kim, Kim, & Umeda, 2008). Compared with biofilters, bio-trickling filters are more suitable for NH_3 removal for two reasons. Firstly, accumulated microbial metabolites ($NO_x^- - N$) and excess biomass in packing material can be removed by the recirculation and intermittent discharge of TL. Moreover, the optimum conditions for nitrifying bacteria in a bio-trickling filter system can be maintained by nutrient adjustment, which also promotes the utilisation rate of TL. Secondly, given that nitrifying bacterial activity is inhibited at >40 °C ambient temperature, the negative impact of this activity caused by the high temperature of exhausting compost odour can be reduced by the recirculation and intermittent discharge of TL (Wu et al., 2011). Therefore, studies on the treatment of NH_3 in air streams by bio-trickling filters have increased (Xue, Wang, Wu, Zhang, & Xie, 2010; Xue, Wang, Wu, Zhao, & Xie, 2011). However, the accumulation of nitrogen-containing metabolites and nitrogen species in the TL following long-term operation may result in negative effects on nitrifying bacteria and diminish the efficiency of a bioreactor (Baquerizo et al., 2005; Chen, Yin, & Wang, 2005; Smet, Van, & Maes, 2000;). Thus, to maintain high purification performance, further treatment of TL produced by bio-trickling filters is necessary. A number of experiments have been carried out to investigate the performance of a bio-trickling filter for NH_3 removal. However, an appropriate approach to the treatment of TL from a bio-trickling filter is rarely studied, which hinders the practical application of this technology.

More than 20 factors influence the decomposition of organic matter during composting. Temperature, moisture content, oxygen concentration in airspace, and carbon–nitrogen (C/N) ratio are considered the primary factors affecting composting (Ahn, Richard, & Glanville, 2008; Ekinci, Keener, & Elwell, 2002). Ahn et al. (2008) suggested that moisture content is critical to the optimisation of compost systems. This factor influences the physical structure and transports essential oxygen to the composting zone, thereby having a significant effect on the activity of microorganisms. Moisture content can even exert a compensating or an offsetting effect on temperature and pH.

Composting is faster if moisture content is maintained within the optimum range. Composting requires a high water supply (Fang, Wong, Li, & Wong, 1998; Manios & Stentiford, 2004). The optimisation and adjustment of initial moisture contents are usually the main approach to controlling moisture content in composting systems. However, several drawbacks are associated with this method. Several studies have been recently conducted on the effect of improving moisture adjustment on composting performance. Suehara, Ohta, Nakano, and Yang (1999) used fresh tofu refuse as raw material for compost. They found maximum compost fermentation rates of 23.8 and 27.9 g h^{-1} at around 50% and 70% controlled moisture contents, respectively, and a lower rate when moisture content is uncontrolled. This result was similar to that of Walker, Nock, Gossett, and Vandergheynst (1999) who found that adding water three times a week resulted in a cumulative uptake of O_2 at 622 g [O_2] kg^{-1} [total solid] for 496 h, which is 48% higher than the uptake when no water was added for an additional 96 h of decomposition. Nelson, Growe, Shah, and Watson (2006) found that windrows maintained at 50% moisture require the least amount of energy to turn and achieve the best temperature profile. Liang, Das, and Mcclendon (2003) showed that when the moisture content is maintained between 30% and 60%, higher moisture contents lead to higher microbial activities.

Rynk (2001) found that other water sources used by composting facilities apart from fresh water include runoff storage ponds, manure storage lagoons, treated wastewater, wet feedstocks, condensate traps, and other readily available sources such as leachate from biofilters. Thus, choosing an optimum moisture conditioning agent for a composting system should consider both economic and operational aspects.

Based on the aforementioned principle of selecting moisture resources, reusing discharged trickling liquid from a bio-trickling filter (TL) as a moisture conditioning agent for composting can be an alternative when a bio-trickling filter is used for composting exhaust gas treatment. However, studies on the effect of adding TL on the duration and extent of decomposition have not yet been reported. In this study, laboratory-scale composting reactors were used to identify the feasibility of using TL as moisture conditioning agent for organic waste composting. The evaluation indices included temperature, pH, waste reduction, spectroscopic properties, germination index (GI), carbon–nitrogen ratio (C/N), and nitrogen evolution. Results were compared with those obtained from the addition of tap water (TW). To evaluate further the effect of moisture content adjustment using TL on the quality of composting products, the nitrogen mass balance of the products was also calculated at the end of the process.