Renewable Energy xxx (2017) 1–10

Contents lists available at ScienceDirect

Renewable Energy

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

In-vessel co-composting of biosolid: Focusing on mitigation of greenhouse gases emissions and nutrients conservation

Mukesh Kumar Awasthi [a, b], Quan Wang [a], Hongyu Chen [a], Meijing Wang [a], Sanjeev Kumar Awasthi [c], Xiuna Ren [a], Hanzhen Cai [a], Ronghua Li [a], 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] International Institute of Waste Management (IIWM), Bhopal, Madhya Pradesh, India

ARTICLE INFO

Article history:
Received 1 December 2016
Received in revised form
2 February 2017
Accepted 22 February 2017
Available online xxx

Keywords:
Dewatered fresh sewage sludge
Calcium-bentonite
Biochar
Greenhouse gas

ABSTRACT

In this paper study the feasibility of Calcium-bentonite (Ca-B) combined with biochar (B) as an effective amendment for the co-composting of dewatered fresh sewage sludge (DFSS) mixed with wheat straw (WS), focusing on mitigation of greenhouse gases (GHG) emission and nutrients loss. The 12%B mixed with three different concentration of Ca-B (2%, 4% and 10%) was supplemented into 1:1 ratio mixture of DFSS and WS (dry weight basis), while compared with a 12%B alone and control or without any amended treatments. This experiment lasted for 42 days in a 130-L reactor. The CH_4 and N_2O emission profiles were clearly indicated that 12%B alone and 12%B + Ca-B addition effectively buffered the composting mass and enhanced the rate of organic matter mineralization as compared to control treatment. Among the all treatments, minimum TOC (16.83%), TKN (0.38%) and dry matter (29.73%) losses were observed in 12%B+4%Ca-B applied treatment; and also improved compost quality compared to control. Furthermore, 12%B+4%Ca-B amendment was beneficial to the efficient organic matter degradation and low quantity of total GHG production from the feedstock without inhibition to composting compared with control treatment. Therefore, 12%B+4%Ca-B amendment is a promising ecofriendly solution for DFSS co-composting because it contributes to reduce the total GHG emission and produced matured compost with sound management of DFSS in China.

1. Introduction

Revalorization of present organic matter in the sewage sludge (SS) has leaded the path to new ecofriendly management strategies, which is fit with 3R's (Reduce, Reuse and Recycle) waste management philosophy since the organic matter (OM) processing technologies like anaerobic digestion and composting, and produced well stabilized end product that can be used as soil conditioner [1–3]. But, the recycling of high moisture contain SS mixed with agricultural organic waste as bulking agent through aerobic composting is one of best ecofriendly disposal methods for SS that convert into valuable end product and afterword allows their reuse as organic fertilizers in gardens for framings [3–7]. However, the anaerobic digestion has lead several advantages like energy conservation but required high level of investment and monitoring for commercial scale, and if the process not runs efficiently that can cause an odor nuisance and huge quantity of greenhouse gas (GHG) emissions [2].

On other hand, composting not only provides an effective and economic feasible method for biowaste disposal in developing countries like China, which tend to be identified the development and implementation this technology over the last many years by rapid increases in sludge production and abundant agricultural resources [4–12]. But an unfortunate occurrence during traditional composting is the loss of huge quantity of carbon and nitrogen through gaseous emission [9–6], which reduces the agronomic value of the end product and contributes to global warming potential, such as the climate change and formation of odor [13–16]. However, CO_2 and NH_3 emission are two important biogenic gases of composting due to the rapid bio-oxidation of OM but inefficient bio-degradation of OM also produced huge quantity of GHG such as CH_4 and N_2O gases. On the other hand, out of total gas emission from SS aerobic composting, 63% is CO_2, whereas 24% CH_4 and 3% N_2O alone produced, respectively [3,14–16]; but their global

* Corresponding author.
E-mail address: zhangzq58@126.com (Z. Zhang).

http://dx.doi.org/10.1016/j.renene.2017.02.068
0960-1481/

warming potential 30 and 210 times higher than CO_2 [16,17]. Consequently, SS usually has low C/N ratio, high water content and heavy metals, which are adversely affect the composting process and also indirectly contributed to GHG emission. Theoretically, the GHG emission was negligible observed; and CO_2 and NH_3 emission higher if the composting biomass C/N ratio is optimum ~25. Beside this, last few years many researchers have worked for the improvement of traditional composting by the amendment of different kinds of additives such as biochar, fly ash, wood ash, bottom ash, kaoline, zeolite, lime, phosphogypsum, medical stone, and struvite salt [18–26] and bulking agents like saw dust, agricultural wastes [11,27–29]; and the formulation of novel feedstock for the mitigation of CH_4 and N_2O emission.

With remark to control GHG emission during composting, no any previous literature available to reduce the emission of biogenic gases (CO_2 and NH_3) combined with other GHGs like CH_4 and N_2O; however, CO_2 emission is inevitable during composting when the OM mineralization, temperature and pH are high [3–6,28–32], and CH_4 and N_2O emission are significant. On the other hand, some previous studies have proved that more than 50% of total organic carbon, 75% of nitrogen is lost through gaseous emission during organic fraction of solid waste composting [24–26]. And most TOC is lost in the form of CO_2 emission, while 10–46% of TKN is lost in the form of NH_3 [3,24–26] and significantly very low (5–10%) is lost in the form of N_2O [29,30]. Furthermore, Sommer and Moller [29], has reported that about 0.01–0.03% of the initial TOC may be lost in the form of CH_4 emission, when anaerobic pockets formed inside of composting mass. Recently, agricultural biomass (wheat straw) recycling through biochar production and its utilization as bulking agent or amendment for SS composting is considered to be as cost effective technology [9,10]. Because this agricultural waste has a high potential as renewable resources and that can be turned into high-value by products like compost, and biochar addition in to composting mass has excellent ability to provide extra porosity to reduce the GHG and ammonia emission as well as increases the composting efficiency [13,18,19]. Recently, some studies reported that biochar addition has led to faster mineralization and reduced total GHG emission by 42.8% during the poultry manure composting [18,19,26], while some researchers reported that ~ 45–55% GHG emission reduction during pig feces and pig manure composting mixed with coffee husk biochar [8,29]. But most of previous studies have only focused on CH_4, N_2O and NH_3 reduction employing biochar as amendment for various types of organic waste materials composting [13,18,19,30–34], while CO_2 loss are another problematic issue. Looking this global warming impact, we hypothesized that Ca-bentonotie (Ca-B) combined with higher dosage of biochar addition into raw materials has various benefits during the SS composting. Because porous micro-structure of biochar has leads to provide optimum aeration for rapid biodegradation of OM that could not only reduce the GHG emission, but act as biofilter to decreased the CO_2 and NH_3 losses [8–10,18,19], consequently 12%B + Ca-B amendment alleviate the initial low pH during the thermophilic stage of composting. At present, from an extensive literature was searched and concluded that no previous studies reported carbon and nitrogen conservation combined with the mitigation of CH_4 and N_2O emission and its relation of microbial biomass of carbon and nitrogen during SS composting employing 12%B + Ca-B.

Table 1
Treatments and the dosage of different amendments used in each treatment on dry weight basis.

Treatments	Percentage of additive amendment (dry weight basis)	
	Calcium-bentonite (%)	Biochar (%)
DFSS + WS (Control)	0	0
DFSS + WS + 12%Biochar (12%B)	0	12
DFSS + WS + 12%B +2%Ca-B	2	12
DFSS + WS + 12%B + 4%Ca-B	4	12
DFSS + WS + 12%B +10%Ca-B	10	12

DFSS (Dewatered fresh sewage sludge), WS (Wheat straw), Ca-B (Calcium-bentonite).

Thus, a systematic research of SS composting is urgently needed to assess the fundamental technology parameters and promote the commercialization of this technology and organic farming. Finally, China is the second top most CO_2 producer country in all over the world and last few years facing high pressure in reducing GHG emissions, so the specific GHG reduction by ecofriendly organic waste management which can be achieved by aerobic composting of SS is gaining interesting and needs to be quantified. In this study, an in-vessel SS co-composting research is presented to elucidate the feasibility 12%B and Ca-B amendment as additive of developing composting technology in China as an effective disposal method for SS, focusing on mitigation of GHG production and nutrient loss during the SS composting (Table 1).

2. Materials and methods

2.1. Raw materials collection and processing

The dewatered fresh sewage sludge (DFSS) was obtained from a local municipal wastewater treatment plant (Yangling, Shaanxi Province, China) and wheat straw (WS) collected from the neighborhood agricultural farm research station of Northwest A&F University, Yangling, China. Chopped WS (2–5 cm) was used as a bulking agent to achieve the moisture content (~55%) and C/N ratio ~ 25, while DFSS and WS were mixed at 1:1 ratio (dry weight basis). Biochar was purchased from Yangling Yixin Energy Pvt. Ltd., Shaanxi Province, China, while Ca-B was obtained from Weifang Huawei Bentonite Group Co., Ltd., China. The biochar was prepared from WS biomass via slow and dry pyrolysis at a temperature of 500–600 °C at the atmospheric pressure for 24 h, which was initiated by start to pyrolysis of feedstock's from the bottom of the kiln. The basic properties of biochar is presented in Table 2, while

Table 2
Selected physicochemical properties of raw materials used in the present experiments (dry weight basis).

Parameters	DFSS	WS	Biochar	Ca-B	Mix
Moisture content (%)	81.24 ± 1.85	10.43 ± 0.20	2.42 ± 0.50	1.23 ± 0.08	56.23 ± 1.45
pH (solid:water = 1:5)	7.27 ± 0.04	4.93 ± 0.14	8.78 ± 0.10	8.52 ± 0.08	8.12 ± 0.05
EC (mS cm^{-1}) (solid:water = 1:5)	5.10 ± 0.16	0.71 ± 0.03	0.98 ± 0.03	0.14 ± 0.08	3.05 ± 0.03
Total organic matter (%)	79.28 ± 2.18	97.86 ± 2.74	96.23 ± 2.84	ND	93.63 ± 2.78
Total organic carbon (%)	41.38 ± 2.40	62.30 ± 2.41	67.75 ± 1.78	ND	44.89 ± 1.02
Total Kjeldahl nitrogen (%)	2.81 ± 0.15	0.80 ± 0.03	0.58 ± 0.02	ND	1.78 ± 0.05
C:N ratio	14.72 ± 0.05	77.90 ± 0.25	116.8 ± 1.4	ND	25.21 ± 0.12

ND (Not detected), DFSS (Dewatered fresh sewage sludge), WS (Wheat straw), Ca-B (Calcium-bentonite) and EC (Electrical conductivity). Results are the mean of three replicates ± standard deviation.

Please cite this article in press as: M.K. Awasthi, et al., In-vessel co-composting of biosolid: Focusing on mitigation of greenhouse gases emissions and nutrients conservation, Renewable Energy (2017), http://dx.doi.org/10.1016/j.renene.2017.02.068