Journal of Environmental Management xxx (2017) 1–12

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

# Optimization of food waste compost with the use of biochar

M. Waqas [a, b], A.S. Nizami [b, *], A.S. Aburiazaiza [a], M.A. Barakat [a, c], I.M.I. Ismail [b], M.I. Rashid [b, d]

[a] Department of Environmental Sciences, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia
[b] Center of Excellence in Environmental Studies (CEES), King Abdulaziz University, Jeddah, Saudi Arabia
[c] Central Metallurgical R & D Institute, Helwan, 11421, Cairo, Egypt
[d] Department of Environmental Sciences, COMSATS Institute of Information Technology, Vehari, 61100, Pakistan

ARTICLE INFO

*Article history:*
Received 20 March 2017
Received in revised form
8 May 2017
Accepted 7 June 2017
Available online xxx

*Keywords:*
Food waste
Compost
Biochar
Organic matter (OM)
Stable compost
Lawn waste

ABSTRACT

This paper aims to examine the influence of biochar produced from lawn waste in accelerating the degradation and mineralization rates of food waste compost. Biochar produced at two different temperatures (350 and 450 °C) was applied at the rates 10 and 15% (w/w) of the total waste to an in-vessel compost bioreactor for evaluating its effects on food waste compost. The quality of compost was assessed against stabilization indices such as moisture contents (MC), electrical conductivity (EC), organic matters (OM) degradation, change in total carbon (TC) and mineral nitrogen contents such as ammonium ($NH_4^+$) and nitrate ($NO_3^-$). The use of biochar significantly improved the composting process and physiochemical properties of the final compost. Results showed that in comparison to control trial, biochar amended compost mixtures rapidly achieved the thermophilic temperature, increased the OM degradation by 14.4–15.3%, concentration of $NH_4^+$ by 37.8–45.6% and $NO_3^-$ by 50–62%. The most prominent effects in term of achieving rapid thermophilic temperature and a higher concentration of $NH_4^+$ and $NO_3^-$ were observed at 15% (w/w) biochar. According to compost quality standard of United States (US), California, Germany, and Austria, the compost stability as a result of biochar addition was achieved in 50–60 days. Nonetheless, the biochar produced at 450 °C had similar effects as to biochar produced at 350 °C for most of the compost parameters. Therefore, it is recommended to produce biochar at 350 °C to reduce the energy requirements for resource recovery of biomass and should be added at a concentration of 15% (w/w) to the compost bioreactor for achieving a stable compost.



## 1. Introduction

In the Gulf countries, rapid growth in population, urbanization and living standards have resulted in a massive generation of municipal solid waste (MSW) (Anjum et al., 2016; Nizami et al., 2017). For instance, in the Kingdom of Saudi Arabia (KSA), the annual production of MSW has reached up to 15 million tons with an average rate of 1.4 kg per capita per day (Ouda et al., 2016). Food waste is the largest waste stream of MSW with a generation rate of around 8 million tons per year (Ouda et al., 2016). The collected MSW is disposed of untreated in the dumpsites or landfills with no material or resource recovery (Miandad et al., 2016). As a consequence, several environmental and public health issues such as greenhouse gas (GHG) emissions, waste leachate, waterborne pollutants and soil and groundwater contamination along with odors and vector-borne diseases are occurring in the vicinity of disposal sites (Rahmanian et al., 2015; Nizami et al., 2009, 2015). Therefore, a sustainable approach towards MSW management is becoming critical in the Gulf countries for the control of waste disposal problems (Khan et al., 2017a,b).

A sustainable approach requires the control, collection, transport, processing, and disposal of MSW with an objective to load reduction on landfills along with material recovery/recycling (Walker et al., 2009; Shahzad et al., 2017). There are several techniques in practice worldwide for waste processing into value-added products in the form of compost (organic fertilizer), biogas, animals feed and chemicals (Awasthi et al., 2016). Composting is an eco-friendly biochemical technique and a viable alternative for a sustainable MSW management (Jara-Samaniego et al., 2017). The life cycle assessment (LCA) studies proved that after anaerobic digestion, compost technology has better environmental and economic

* Corresponding author.
*E-mail addresses:* nizami_pk@yahoo.com, anizami@kau.edu.sa (A.S. Nizami).

http://dx.doi.org/10.1016/j.jenvman.2017.06.015
0301-4797/

values than other waste treating technologies like incineration (Korres and Nizami, 2013; Nizami et al., 2013, 2016a,b). It converts the organic waste into a stable humus-like material that can be used as an organic fertilizer, soil stabilizer, and promoter of crops growth (Shi et al., 2016).

In the natural process of composting, microorganisms including fungi and bacteria break down the complex organic matters (OM) into simpler products and finally into a mature compost (Sun et al., 2016; Sadef et al., 2016a,b). Although the process is completed in 4–8 months, but rapid composting techniques offer possibilities to lower down the processing period (Awasthi et al., 2016). Such process accelerating techniques include frequent turnings and shredding of feedstock, use of effective microorganisms (Sun et al., 2016), chemical nitrogen activators, worms and natural minerals and various additives and amendments (Chan et al., 2016). Among the additives, the use of biochar to optimize the overall composting process is getting significant attention in recent years due to its unique physiochemical characteristics (Czekała et al., 2016; Lopez-Cano et al., 2016).

Biochar is a carbon-rich material produced from pyrolysis of biomass (Dias et al., 2010; Lopez-Cano et al., 2016). The physiochemical characteristics of biochar mainly depend on the feedstock composition and pyrolysis temperature (Wu et al., 2012; Jindo et al., 2016). In the composting process, biochar is used as a bulking agent and plays a vital role in providing the aerobic conditions to compost materials (Zhang et al., 2014; Bass et al., 2016). Similarly, the presence of a wide range of functional groups on its surface adsorbs various essential cations and anions produced during the process (Bass et al., 2016). Moreover, its microporous structure absorbs common solvent such as moisture (Wei et al., 2014). However, the mechanism of degradation and mineralization of organic waste in the presence of biochar is rarely reported in the scientific literature (Bass et al., 2016), which is the focus of this study.

In KSA and other Gulf countries, a limited compost is produced from the food waste using the traditional methods of compost piles and trenches (Ouda et al., 2016). The quality of compost produced from these techniques is deteriorated with the presence of heavy metals and toxic materials and does not meet the international compost standards (Al-Turki et al., 2013). Moreover, an enormous amount of waste from date palm is generated in the Gulf countries that are either dumped in the landfills or burned. For instance, in KSA, more than 22 million date plants are present (Usman et al., 2015) and their waste after converting into biochar could provide an innovative way to optimize the food waste compost. Therefore, the primary objective of this study was to convert the food waste of KSA into a stable and nutrient-rich organic fertilizer by utilizing the biochar produced from lawn waste. Biochar was produced at two different temperatures of 350 °C and 450 °C and applied at a concentration of 10 and 15% (w/w) to an in-vessel compost bioreactor for examining its effects on compost quality.

## 2. Material and methods

### 2.1. Feedstock preparation

Food waste was collected from the main canteen of King Abdulaziz University (KAU), Jeddah, KSA, regularly for one week in order to get a homogenous mixture of feedstock. The collected food waste was considered as a representative sample of the waste produced at KAU canteen due to all types of food waste. The total number of individuals enter into canteen for breakfast is around 1500 per day, whereas during the lunch time the total number exceeds 3000 per day. The moisture content (MC) of the collected sample was 82.6%, and the use of such moisture rich waste mixture in the composting process can create waterlogged or anaerobic conditions (Brinton, 2000). Therefore, the sample was sun-dried for 24 h to achieve the desired MC (≤70%) for composting process, as per standard guidelines of Brinton (2000) and EPA (2014).

Fractional characterization of the food waste sample was carried out gravimetrically, and the percentage fraction of each material such as vegetables, fruit and meat, grain, rice and bakery products was estimated accordingly (EPA, 2014). The sample was well mixed and ground into small particles less than 5 cm, in order to accelerate the biodegradation rates of the composting process. The particle size of the sample was lowered to increase the surface area provided to the microbes for better degradation (Rawat et al., 2005). The chemical analysis of the collected food waste was carried out according to the standard methods (FCQAO, 1994), and their results are presented in Table 1.

### 2.2. Experimental setup

A laboratory scale in-vessel compost bioreactor made of plastic with a total working capacity of 10 kg was commissioned and used. Dimensions of the reactor were: height 63.5, diameter 68.6 cm and thickness 10 mm. The vessel was protected with aluminum foil and styrofoam to prevent heat losses. The schematic diagram of in-vessel compost bioreactor is shown in Fig. 1. The reactor was filled with mixed and ground feedstock up to 70%, whereas 30% of the area was kept as a head space. The volume and type of bioreactor used in this study were based on previously reported works on laboratory scale compost setups (Table 2). The thermometer was fixed in the middle of the compost bioreactor to monitor the temperature changes during the process. After loading the feedstock, the bioreactor lid was closed. Air ventilation was carried out through pores located at the lid of the bioreactor. Shredding of the compost mixture was carried out mechanically through an agitator for achieving uniform mixing and oxygen ($O_2$) supply throughout the experiment as recommended by An et al. (2012). The method of aerating the compost materials through turning and mixing was adopted according to the procedure explained by Singh and Kalamdhad (2014), Latifah et al. (2015) and Jindo et al. (2016).

### 2.3. Biochar preparation and characterization

For biochar production, lawn waste including date leaves, grass clippings, ornamental plant waste and coconut leaves was collected from KAU Campus (Waqas et al., 2017). In several studies, lawn waste has been used as a bulking agent in the process of composting (Elwell et al., 1994; Neugebauer and Sołowiej, 2017). In this study, lawn waste for producing biochar was used due to several advantages of biochar, including its bulking potential, rich nutrient composition that can improve the nutritive value of the compost, microporous structure, and presence of wide range of functional groups that provide sorptive sites for various essential ions produced during the composting process. The proportion of each

**Table 1**
Physiochemical characteristics of food waste.

| Parameters | Unit | Mean | Standard Deviation |
|---|---|---|---|
| Moisture content | % | 83.6 | 3.08 |
| Total solid | % | 18.1 | 4.23 |
| Organic matter (OM) | % | 92.1 | 0.50 |
| Ash content | % | 7.8 | 0.49 |
| Carbon | % | 51.3 | 0.28 |
| pH | | 6.4 | 1.10 |
| Electrical conductivity (EC) | mS $cm^{-1}$ | 1.7 | 0.02 |
| Ammonium ($NH_4^+$) | mg $kg^{-1}$ | 72.5 | 10.34 |
| Nitrate ($NO_3^-$) | mg $kg^{-1}$ | 22.8 | 8.91 |

Analysis was made on dry weight basis except for moisture, pH, and EC.