



Contents lists available at ScienceDirect

Waste Management

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

Hydrothermal carbonization of food waste for nutrient recovery and reuse

Ifeolu Idowu^a, Liang Li^a, Joseph R.V. Flora^a, Perry J. Pellechia^b, Samuel A. Darko^c, Kyoung S. Ro^d, Nicole D. Berge^{a,*}

^a Department of Civil and Environmental Engineering, University of South Carolina, 300 Main Street, Columbia, SC 29208, United States

^b Department of Chemistry and Biochemistry, University of South Carolina, 631 Sumter Street, Columbia, SC 29208, United States

^c Department of Physics and Engineering, Benedict College, 1600 Harden Street, Columbia, SC 29204, United States

^d Coastal Plains Soil, Water, and Plant Research Center, Agricultural Research Service (ARS), United States Department of Agriculture (USDA), 2611 West Lucas Street, Florence, SC 29501, United States

ARTICLE INFO

Article history:

Received 8 June 2017

Revised 29 August 2017

Accepted 31 August 2017

Available online xxx

Keywords:

Food waste

Hydrothermal carbonization

Nutrient recovery

Fertilizer

ABSTRACT

Food waste represents a rather large and currently underutilized source of potentially available and reusable nutrients. Laboratory-scale experiments evaluating the hydrothermal carbonization of food wastes collected from restaurants were conducted to understand how changes in feedstock composition and carbonization process conditions influence primary and secondary nutrient fate. Results from this work indicate that at all evaluated reaction times and temperatures, the majority of nitrogen, calcium, and magnesium remain integrated within the solid-phase, while the majority of potassium and sodium reside in the liquid-phase. The fate of phosphorus is dependent on reaction times and temperatures, with solid-phase integration increasing with higher reaction temperature and longer time. A series of leaching experiments to determine potential solid-phase nutrient availability were also conducted and indicate that, at least in the short term, nitrogen release from the solids is small, while almost all of the phosphorus present in the solids produced from carbonizing at 225 and 250 °C is released. At a reaction temperature of 275 °C, smaller fractions of the solid-phase total phosphorus are released as reaction times increase, likely due to increased solids incorporation. Using these data, it is estimated that up to 0.96% and 2.30% of nitrogen and phosphorus-based fertilizers, respectively, in the US can be replaced by the nutrients integrated within hydrochar and liquid-phases generated from the carbonization of currently landfilled food wastes.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Concerns associated with anticipated future nutrient demands required to satisfy projected increases in food production due to the growing population are well documented (e.g., Cordell et al., 2009; Dawson and Hilton, 2011). Alexandratos and Bruinsma (2012) estimate worldwide fertilizer requirements will reach approximately 263 million tonnes in 2050. Challenges associated with achieving this level of fertilizer production stem from dwindling nutrient (particularly phosphorus) availability, inefficient nutrient use and/or recovery from residual materials, and/or high energy demands associated with fertilizer production (Cordell et al., 2009; Dawson and Hilton, 2011). Developing effective strate-

gies to overcome these challenges is critical for meeting future food demands.

One promising and potentially sustainable approach to alleviating some of these challenges is to recover nutrients from food waste using hydrothermal carbonization (HTC). Food waste represents a rather large and currently underutilized source of potentially available and reusable nutrients. In 2014, 38.4 million tonnes food waste were generated in the United States (US) (USEPA, 2016), which contain significant amounts of available nitrogen, phosphorus, and potassium. HTC is a thermal conversion process in which wet feedstocks are converted into value-added liquid, solid (also referred to as hydrochar), and gaseous products (Berge et al., 2011; Funke and Ziegler, 2010; Libra et al., 2011; Sevilla and Fuertes, 2009; Titirici and Antoniette, 2010) without the need for feedstock drying prior to conversion, at relatively low temperatures (<350 °C), and with relatively low input energy requirements (Berge et al., 2011, 2015; Funke and Ziegler, 2010;

* Corresponding author.

E-mail address: berge@engr.sc.edu (N.D. Berge).

Li et al., 2013; Libra et al., 2011). Managing food wastes using HTC has the potential to reclaim nutrients from these food wastes in a form that may be directly used as a fertilizer/soil amendment, potentially reducing the need for acquisition of virgin nutrients and thus reducing energy demands associated with fertilizer manufacturing.

The feasibility and environmental benefits associated with the HTC of different food wastes (e.g., corn, artichoke waste, onion, fish, mixed urban food waste) and food-related residues (e.g., corn-cob, grape seeds, rice hull, tomato peels) have been previously reported (e.g., Benavente et al., 2015; Cao et al., 2013; Li et al., 2013; Lu and Berge, 2014; Oliveira et al., 2013; Reza et al., 2013; Sabio et al., 2016). Understanding the fate of nutrients as a result of food waste carbonization is necessary to develop a nutrient recovery and recycling strategy. The fate of nitrogen, phosphorus, and/or potassium has been evaluated for a variety of feedstocks, including animal manures (e.g., cow, horse), bamboo, various digestates, straws, algae, and sewage sludge (e.g., Ekpo et al., 2016; Erdogan et al., 2015; Funke, 2015; Funke et al., 2013; Heilmann et al., 2014; Reza et al., 2016; Smith et al., 2016; Zhang et al., 2014). Nutrient fate reported in these studies varies significantly because of changes in feedstock composition/properties and process conditions, complicating the extension of such information to that of different feedstocks.

Relatively little information associated with the fate of primary (e.g., nitrogen, potassium, and phosphorus) and secondary (e.g., calcium, sodium, and magnesium) nutrients as a result of the carbonization of mixed restaurant-generated food wastes exists. Benavente et al. (2015) and Reza et al. (2013) evaluated the fate of nutrients of specific food wastes, reporting that between approximately non detectable levels to 50% and 5–55% of initially present phosphorus and potassium, respectively, ultimately reside in the hydrochar following the carbonization of olive mill, canned artichoke, and orange juice wastes and rice hull. The reported variability associated with nutrient fate in these studies suggests that information specific to the carbonization of restaurant-generated food waste is needed before an appropriate strategy for reclaiming nutrients from this waste stream can be developed.

The purpose of this work is to evaluate the fate of nutrients resulting from the carbonization of food waste collected from local restaurants and to ultimately use such information to determine the potential impact associated with offsetting the need for virgin nutrient acquisition and fertilizer production if using the generated solids as a fertilizer. The specific objectives of this work include to: (1) understand how changes in feedstock composition (e.g., food waste with and without packaging materials) and carbonization process conditions (e.g., reaction time and temperature) influence primary (e.g., nitrogen, phosphorus, and potassium) and secondary nutrient fate (e.g., calcium, magnesium, sodium), (2) determine the total leachable mass of primary nutrients from the solids, and (3) investigate the reduction of virgin primary nutrient requirements if food wastes were hydrothermally carbonized and nutrients subsequently recovered from the solid and liquid-phases.

2. Materials and methods

2.1. Food and packaging material acquisition and properties

Food waste was periodically collected from restaurants located near the University of South Carolina (Columbia, SC), following procedures outlined by Li et al. (2013). Briefly, this food waste consisted of a variety of different components, including seafood, meats, bread, pasta, potatoes, vegetables, and condiments. Immediately following collection, the waste was weighed and non-food materials (e.g., packaging) and food containing bones were removed. Packaging materials were subsequently separated into three categories: (1) paper, (2) cardboard, and (3) plastics. Food containing bones was not used in this study because of experimental constraints. The food waste was subsequently mixed and homogenized with a food-grade blender (Ninja Master Prep, Euro-Pro Operating LLC). All packaging materials (e.g. paper, plastic, cardboard) were shredded using a titanium paper shredder (25 by 4 mm strips). All food and packaging wastes were frozen until use.

The moisture, carbon, nitrogen, phosphorus, potassium, calcium, and magnesium contents of the collected food waste and packaging materials were measured (Table 1). The moisture content of the separated components was measured using a gravimetric technique. A mass of each component was dried in a laboratory oven at 80 °C for at least 48 h, or until the dried sample mass remained constant. Following drying, the carbon and nitrogen contents of the samples was measured using an elemental analyzer (Perkin Elmer 2400). Phosphorus, potassium, calcium, and magnesium contents of these materials were measured on aqueous filtrates of acid digested materials by inductively coupled plasma (ICP) by the Agricultural Service Laboratory at Clemson University. This acid digestion process involved first ashing the samples in a muffle furnace and subsequently dissolving the ash in 6 N HCl.

2.2. Batch HTC experiments

All batch carbonization experiments were conducted following procedures previously described (Berge et al., 2011; Li et al., 2013; Lu et al., 2012). Briefly, 40 g of room temperature food waste and/or packaging materials were placed in 160-mL stainless steel tubular reactors (2.54 cm i.d., 25.4 cm long, MSC, Inc.) fitted with gas-sampling valves (Swagelock, Inc.). All reactors were subsequently sealed and heated in a laboratory oven to the desired temperature. Reactors were sacrificially sampled over a period of 24 h. All experiments were conducted in triplicate. Based on results from Li et al. (2013), the sample masses of food and/or packaging materials used in this study are sufficient for obtaining reproducible results.

Three sets of carbonization experiments were conducted: (1) experiments in which separated food was carbonized at three different temperatures (225, 250, and 275 °C), (2) experiments containing food and packaging materials to evaluate the influence of packaging on food waste carbonization at 250 °C, and (3) experi-

Table 1
Collected food waste and packaging material properties.*

Waste component	Moisture content (% wet wt.)	C (% dry wt.)	N (% dry wt.)	P (% dry wt.)	K (% dry wt.)	Ca (% dry wt.)	Mg (% dry wt.)	Na (% dry wt.)
Food Waste	63.79 (0.71)	50.90 (0.57)	3.18 (0.15)	0.42 (0.01)	0.52 (0.01)	0.21 (0.01)	0.05 (0.001)	1.11 (0.04)
Paper	24.52 (6.42)	46.80 (1.12)	0.21 (0.15)	0.02 (0.003)	0.05 (0.006)	0.55 (0.43)	0.03 (0.01)	0.18 (0.06)
Cardboard	12.79 (4.59)	41.43 (1.75)	0.09 (0.02)	0.01 (0.005)	0.05 (0.04)	1.68 (0.31)	0.04 (0.02)	0.11 (0.01)
Plastic	4.10 (2.03)	80.54 (5.42)	0.22 (0.29)	0.01 (0.004)	0.03 (0.01)	0.12 (0.08)	0.01 (0.004)	0.05 (0.03)

* All values represent average values of at least 5 samples. Values in parentheses represent the standard deviations.

Download English Version:

<https://daneshyari.com/en/article/8870452>

Download Persian Version:

<https://daneshyari.com/article/8870452>

[Daneshyari.com](https://daneshyari.com)