Bioresource Technology 183 (2015) 61–69

Contents lists available at ScienceDirect

Bioresource Technology

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

Characterization of typical household food wastes from disposers: Fractionation of constituents and implications for resource recovery at wastewater treatment

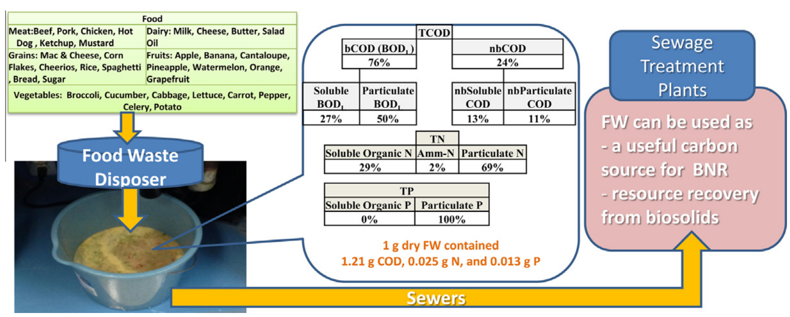
M. Kim [a], M.M.I. Chowdhury [b], G. Nakhla [a,b,*], M. Keleman [c]

[a] Chemical and Biochemical Engineering, The University of Western Ontario, London, ON N6A 5B9, Canada
[b] Civil and Environmental Engineering, The University of Western Ontario, London, ON N6A 5B9, Canada
[c] InSinkErator, Emerson Commercial & Residential Solutions, 4700 21st Street, Racine, WI 53406-5031, United States

HIGHLIGHTS

- Extensive detailed analysis of typical household FW with 33 different food types.
- COD and N were 3–5 folds higher in particulate form than in soluble form.
- COD/N ratios were higher in aqueous form (63:1) than particulates (42:1).
- FW can be an effective source of carbon for BNR and of N&P recovery from biosolids.
- The impact of FW on H_2S generation in sewers is negligible.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 November 2014
Received in revised form 4 February 2015
Accepted 7 February 2015
Available online 13 February 2015

Keywords:
Food wastes
Food waste disposer
Characterization
Municipal wastewater

ABSTRACT

Food wastes with typical US food composition were analyzed to characterize different constituents in both particulate and soluble phases i.e., solids, chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD), nitrogen (N), phosphorus (P). Relationships between various pollutants were also investigated using 50 samples. One gram of dry food waste generated 1.21 g COD, 0.58 g BOD_5, 0.36 g Total SS, 0.025 g Total N, and 0.013 g Total P. Distribution of constituents between particulate and aqueous phases indicated that 40% of COD and 30% of nitrogen were present in soluble form. Relative mass ratios of COD and nitrogen to solids were three to five times higher in particulates than in aqueous phase. However, COD/N ratios were higher in aqueous form than particulates at 63:1 versus 42:1. Detailed relationships between parameters showed that COD, nitrogen, and phosphorus in particulates are 200%, 3.6%, and 3.5% of the volatile suspended solids.

1. Introduction

With rapid urbanization and population growth, effective food wastes management becomes a pressing issue (Curry and Pillay, 2012). While landfill disposal have been traditionally used for food wastes, due to shortage of landfill sites and the negative effects of leachate on the environment, alternative ways to divert food wastes from landfills have been introduced i.e., composting, anaerobic digestion, use of food waste disposers (Curry and Pillay, 2012). Particularly, due to the high organic carbon content, extensive studies investigated the anaerobic digestion of food wastes to generate biogas (Curry and Pillay, 2012).

* Corresponding author at: Chemical and Biochemical Engineering, The University of Western Ontario, London, ON N6A 5B9, Canada. Tel.: +1 519 661 2111x85470; fax: +1 519 850 2921.
E-mail address: gnakhla@uwo.ca (G. Nakhla).

http://dx.doi.org/10.1016/j.biortech.2015.02.034
0960-8524/

Nomenclature

FW	food waste
FWD	food waste disposer
BOD	biochemical oxygen demand
BOD_5	5 day BOD
BOD_L	ultimate BOD
PBOD	particulate BOD
SBOD	soluble BOD
BNR	biological nutrient removal
C/N	carbon/nitrogen
COD	chemical oxygen demand
PCOD	particulate COD
SCOD	soluble COD
rbCOD	readily biodegradable COD
nbCOD	nonbiodegradable COD
DO	dissolved oxygen
N	nitrogen
TN	total N
PN	particulate N
SN	soluble N
SON	soluble organic N
rSON	recalcitrant SON
P	phosphorus
TP	total P
PP	particulate P
SP	soluble P
TS	total solids
TSS	total suspended solids
TDS	total dissolved solids
VSS	volatile suspended solids

Compared to extensive composting and digestion studies, scientific investigations on food waste discharge to sewers are relatively few. This approach is considered an effective food waste management; in fact, studies reported that 75% of the households food waste disposers (FWD) can contribute to the diversion of up to 43% of food wastes from landfills (Iacovidou et al., 2012). Currently, this technology is widely used in USA with the highest penetration of 50% (Iacovidou et al., 2012). However, concerns surrounding the use of FWD exist; particularly, some European countries restrict the installation of FWD due to concerns about potential adverse effects of food waste load on the sewage system, change of wastewater characteristics, and possible retrofit of treatment plants (Iacovidou et al., 2012).

Detailed food waste characterization is indispensable for food waste management. For instance, by analyzing the raw material compositions for anaerobic digestion, biogas content and energy generation can be estimated (Curry and Pillay, 2012). Similarly, carbon to nitrogen ratios, pH, and moisture content in food wastes are also essential to optimize composting performance (Adhikari et al., 2008). Different food waste characteristics in previous studies are summarized in Table 1 with Table 1A and B showing data from biofuel/composting studies, and food waste disposer studies, respectively. From Table 1A, the average moisture content of different food wastes including kitchen waste, mixed food wastes, and restaurant food was 84% with 16% solids content (Adhikari et al., 2008; Kiran et al., 2014; Li et al., 2008; Yasin et al., 2013). Biofuel/composting studies also analyzed chemical oxygen demand (COD), nitrogen, and carbon to estimate ratios of COD/TS, COD/nitrogen, and carbon/nitrogen with respective values of 1.4, 42, and 16. As presented in Table 1B, only a handful studies analyzed food wastes from disposers extensively with a definite paucity of information on soluble pollutants (Battistoni et al., 2007; Bolzonella et al., 2003; Metcalf and Eddy, 2003; Nilsson et al., 1990; Thomas, 2011). In addition, most of the studies in Table 1B provided theoretical values of food waste characteristics based on an increase in concentrations or per capita loading of pollutants as a result of the use of food waste disposers (Battistoni et al., 2007; Bolzonella et al., 2003; De Koning, 2004; Nilsson et al., 1990). For instance, Battistoni et al. (2007) who assessed the impact of food waste disposers on the wastewater treatment system in a small Italian town (Gagliole and 230 inhabitants) monitored influent wastewater characteristics changes during 454 days (275 days prior to the installation of FWD and 179 days after the use of FWD). The study estimated food waste TSS, COD, and TN concentrations to 72 mg/L, 298 mg/L, 15 mg/L, respectively, using less than 25 dry period samples. Compared to the theoretical studies, a study by Thomas (2011), one of a few experimental investigations of food wastes, analyzed food wastes collected from a total of 18 volunteers that were grinded using a FWD at a food waste mass ratio to water of 1:11.7 in order to project the effect of FW loading to wastewater treatment system. These investigations focused on the effects of grinded food wastes on municipal wastewater characteristics primarily COD/TSS, COD/TN, and COD/TP ratios of food wastes which were estimated at 2.7, 30.5, and 193, respectively.

While biofuel/composting food waste characterization studies showed extensive information on collected food waste characteristics, grinding food wastes in disposers impacts the particle size and hence solubilization of organics, nitrogen, and phosphorus. For example, scrutiny of the data in Table 1A reveals that the "collected" food waste has a COD/N ratio ranging between 31.9 and 62.9 with an average of 41.8 significantly greater than the 30.5 reported in Table 1B for FWD in the few studies available in the literature. Considering that wastewater treatment facilities consist of liquid and solid trains, it is essential to understand the fractionation of food wastes organics, nitrogen, and phosphorus in both particulate (including colloidal) and aqueous phases to facilitate thorough assessment of the potential impact of food wastes on municipal wastewater. Moreover, due to nature of food wastes, the characteristics are strongly influenced by cultural background, diet habits, and food types (Adhikari et al., 2008). Hence, characterization of a standard diet is also necessary to reflect local food waste conditions.

The primary objective of this study was to characterize the typical US standard diet after processing through food waste disposers and to investigate the relationships between various food waste pollutants. This study elucidates the detailed fractionation of food waste pollutants with respect to suspended, colloidal, and soluble parameters.

2. Methods

2.1. Food waste preparation and sample collection

Four different tests were conducted with 440 g of food waste with tap water as the dilution water. Food waste was prepared according to the typical US diet collected by the United States Department of Agriculture (US Census Bureau, 2008) (Table 2), using a grinding unit (Evolution Pro Essential®) provided by InSinkErator Canada. The weighed food wastes were ground with the addition of tap water as grinding fluid. Then the total amount of food waste slurry was transferred into the container where tap