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Benefits to decomposition rates when using digestate as compost co-feedstock: Part I – Focus on physicochemical parameters

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ABSTRACT

Anaerobic digestion (AD) has gained a significant role in municipal solid waste management, but managing a high volume of digestate is one of the challenges with AD technology. One option is to mix digestate with fresh and/or stabilized organic waste and then feed to the composting process. In this study, the effect of co-composting anaerobic digestate (in different quantities) on a composting process was investigated. The digestate was prepared in a pilot-scale 500 L high solids dry anaerobic digester and composting was completed in eight 25 L reactors with different ratios of digestate to fresh feedstock from the organic fraction of municipal solid waste (OFMSW). The digestate constituted 0, 10, 20, 30, 40, 50, 75, or 100% (wet mass) of the feedstock. The co-composting experiment was conducted in two phases: active aeration and curing. Monitored parameters included: process temperature, aeration rate, oxygen concentration of the outlet gas, mass changes, total solids, organic matter, pH, and electrical conductivity. In addition, respirometry, C:N ratio, ammonium to nitrate ratio, and Solvita® tests were used to quantify stability and maturity end points. The results showed that the addition of digestate to the OFMSW increased composting reaction rates in all cases, with peak performance occurring within the ratio of 20–40% of digestate addition on a wet weight basis. Reactor performance may have been influenced by the high total ammonia nitrogen (TAN) levels in the digestate. Composting rates increased as TAN levels increased up to 5000 TAN mg kg^{-1} DM; however, TAN may have become inhibitory at higher levels.

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1. Introduction

The organic fraction of municipal solid waste (OFMSW) is a significant portion of solid waste streams around the world. The interest in organic waste treatment has increased in recent years. Among the treatment technologies, anaerobic digestion (AD) has gained a significant role in municipal solid waste management due to its energy recovery benefits (Liu et al., 2012, De Baere, 2008). Digestate is the solid residues generated from the biodegradation of organic waste during the AD process. It is a valuable soil conditioner; however, this high moisture content by-product is not fully stabilized, and when applied to land as a fertilizer, there is an increased risk of odour complaints, potential for phyto-toxic responses, and some difficulties in handling the materials (Teglia et al., 2011). Therefore, management of a high volume of digestate is one of the challenges that AD plants currently face.

Composting or aerobic polishing are typically used to improve digestate quality (Wu et al., 2014; Lim et al., 2016). Post treatment of digestate in a composting process can assure the maturity and stability of this by-product (Askri et al., 2016; Camilleri-Rumbau et al., 2015; Zeng et al., 2016). The digestate from the AD process can also be co-composted with fresh and/or partially stabilized organic waste. Co-composting of digestate has not been significantly investigated in the literature and there is much to learn about the process (Zeng et al., 2016; Tambone et al., 2015).

There are several potential advantages of co-composting OFMSW and digestate associated with: improving the physico-chemical properties within the compost pile, e.g. moisture content, bulk density, and nutrient requirements, as well as, biological effects that may come from using the digestate as an inoculum (De Baere, 2008; Ryckeboer et al., 2003; Partanen et al., 2010). One aspect worth investigating is the quantity of inoculum (digestate) that should be added to obtain significant composting rate improvements. The quantity of inoculum introduced to the compost must be sufficient, otherwise the indigenous microorganisms in compost may not allow the inoculum microflora to develop and effectively influence the process (Fuchs, 2010; Golueke et al.,

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1954). Composting inoculation with digestate can also be more economically beneficial compared to direct microbial inoculation because, in this method, instead of purchasing or preparing the specific type of microbe, the waste is co-composted with another type of waste that already contains various microbial communities.

Considering all the possible advantages of co-composting of digestate and fresh organic waste, the objective of this study was to determine the impact of digest to fresh feedstock ratios on composting rates. The results of this study were divided into two parts. Part I reports on the effects of physicochemical parameters on stabilization rates and are discussed herein. Part II reports on the effects of biological characteristics and microbial population on stabilization rates and is discussed in Arab et al. (2017).

2. Materials and methods

To investigate the effects of adding digestate into the composting process, the experimental run was conducted in three steps. In the first step, digestate was prepared in a high solids anaerobic digestion (HSAD) process. In the second step, prepared digestate was mixed with the fresh compost feedstock with different mix ratios (%w/w) and aerated for 30 days. Finally, in the third step, the stabilized compost was cured for two months. The overall diagram of material flow and process used in this study is shown in Fig. 1.

2.1. Anaerobic digestion equipment

The digestate was prepared at Alberta Innovates – Technology Futures (AI-TF) laboratory using their high solids anaerobic digestion (HSAD) pilot-scale facility in Vegreville, Canada. The HSAD setup consists of two stainless steel dry digesters (primary digester and percolate digester) with working volumes of 500 L and 150 L, respectively. The digesters were automated with gas production, gas composition, pH, and temperature measurements.

2.2. Anaerobic digestion feedstock

Two consecutive HSAD batches were processed to prepare the digestate. The first batch generated digestate inoculum for the second HSAD feedstock batch. In the second batch, about 45% (wet mass) of the digestate inoculum prepared in the first batch was mixed with fresh feedstock.

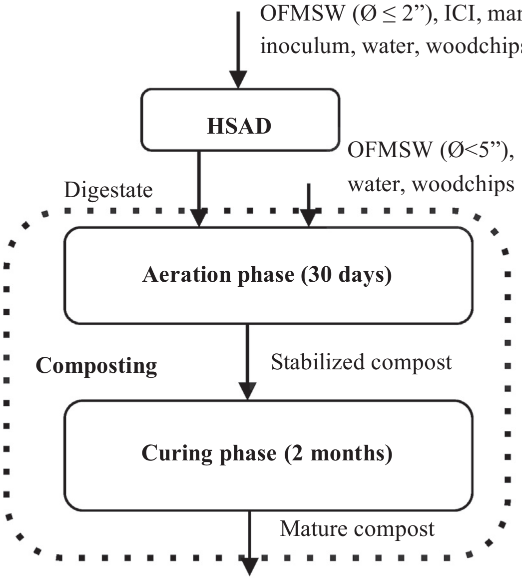

Fig. 1. Process and material flow used in research.

The anaerobic digester feedstock recipe was prepared to align with the expected full-scale feedstock to be used by the City of Edmonton (CoE). Feedstock consisted of three streams in both batches of the AD process: (1) organic fraction of municipal solid waste (OFMSW) with a particle size of <2″ collected from the Integrated Processing and Transfer Facility (IPTF) at the City of Edmonton (CofE); (2) source separated organics (SSO) collected from institutional, commercial and industrial (ICI) sectors; and (3) horse manure collected from one stable load (mixture of horse manure, urine, and sawdust). Inoculum was also added to batch 1 that was composed of a mixture of beef feedlot manure and wheat straw. In addition to these three streams, woodchips were also added to the feedstock as an amendment. The woodchips used in batch 1 were collected from the Construction and Demolition (C&D) waste pile at the CoE with a mixture of painted and white woodchips with the particle size of 6–8 in. For batch 2, the woodchips were collected from the green wood chips pile at the CoE and the particle size of 0.79 in. (20 mm) and smaller were screened out. Water was also added to adjust the total solids of the digester to the range of 30–35%.

The composition and amount of the materials used in the first and second batches of the dry digester are listed in Table 1.

2.3. Co-composting equipment & operation

The composting experiment was conducted in two phases to simulate the composting process in the full-scale operation. In the first, thermophilic phase, the materials were aerated in eight different reactors for 30 days. Each reactor was air tight with a working volume of 25 L. The schematic of an individual reactor is shown in Fig. 2. After 30 days of aeration, the materials were transferred to another type of reactor (not air tight) to simulate the post aeration and curing phases and were processed for another 70 days until all reactors reached the target stability criteria. The reactors used in the post aeration and curing phases were 20 L pails with perforated ends on the bottom and top to allow natural ventilation.

During thermophilic and latter phases, each reactor was insulated with 5 cm of thick pink fiberglass and an aluminium-reflecting blanket in order to minimize the heat loss. The insulated reactors were then placed in a temperature-controlled chamber. Each reactor was equipped with a thermocouple (HSTC-TT-K-24S-120-SMPW-CC). At start-up of the experiment, the temperature control chamber and reactors were at room temperature. During the thermophilic phase, the temperature of each reactor was recorded every 10 min. Each day the chamber temperature was adjusted to 5 °C below the temperature of the reactor with the lowest temperature to minimize the heat loss caused by temperature gradient between reactors and chamber. However, during

Table 1
Composition and amount of the materials in the anaerobic digestion batches.

Material	Batch 1	Batch 2	Batch 1	Batch 2
	% (wet weight basis)		kg (wet weight basis)	
OFMSW	32.6	22.9	105.8	100.9
ICI SSO waste	29.4	20.7	95.3	90.9
Horse manure	0.6	0.5	2.1	2.0
Inoculum[a]	5.6	45.4	18.1	200.0
Wood chips	3.5	2.6	11.4	11.3
Water	28.2	8.0	91.3	35.1

Note:
[a] Batch 1 consisted of beef feedlot manure and wheat straw and batch 2 consisted of digestate prepared in the first batch.

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