Waste Management 59 (2017) 476–486

Contents lists available at ScienceDirect

Waste Management

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

Environmental and economic analysis of an in-vessel food waste composting system at Kean University in the U.S.

Dongyan Mu [a,*], Naomi Horowitz [a], Maeve Casey [b], Kimmera Jones [b]

[a] School of Environmental and Sustainability Science, Kean University, 1000 Morris Ave., Union 07083, NJ, United States
[b] Union County Vocational Technology High School, NJ 1776 Raritan Rd, Scotch Plains, NJ 07076, United States

ARTICLE INFO

Article history:
Received 9 May 2016
Revised 13 October 2016
Accepted 20 October 2016
Available online 2 November 2016

Keywords:
Food wastes recycle and reuse
In-vessel composting
Life cycle assessment
Cost-benefit analysis

ABSTRACT

A composting system provides many benefits towards achieving sustainability such as, replacing fertilizer use, increasing the quantity of produce sold, and diverting organic wastes from landfills. This study delves into the many benefits a composting system provided by utilizing an established composting system at Kean University (KU) in New Jersey, as a scale project to examine the composters' environmental and economic impacts. The results from the study showed that composting food wastes in an in-vessel composter when compared to typical disposal means by landfilling, had lower impacts in the categories of fossil fuel, GHG emissions, eutrophication, smog formation and respiratory effects; whereas, its had higher impacts in ozone depletion, acidification human health impacts, and ecotoxicity. The environmental impacts were mainly raised from the manufacturing of the composter and the electricity use for operation. Applying compost to the garden can replace fertilizers and also lock carbon and nutrients in soil, which reduced all of the environmental impact categories examined. In particular, the plant growth and use stage reduced up to 80% of respiratory effects in the life cycle of food waste composting. A cost-benefit analysis showed that the composting system could generate a profit of $13,200 a year by selling vegetables grown with compost to the student cafeteria at Kean and to local communities. When educational and environmental benefits were included in the analysis, the revenue increased to $23,550. The results suggest that in-vessel composting and the subsequent usage of a vegetable garden should be utilized by Universities or food markets that generate intensive food wastes across the U.S.

1. Introduction

According to the report by the Natural Resources Defense Council 2012 (Gunders, 2012), "getting food to our tables eats up 10 percent of the total U.S. energy budget, uses 50 percent of U.S. land, and swallows 80 percent of freshwater consumed in the United States. Yet, 40 percent of food in the United States today goes uneaten..." and more than 95 percent of food waste ends up in landfills (US EPA, 2014b). The egregious amount of food waste has raised concerns not only about the waste of energy and resources to produce the food, but also over the disposal of the food in landfills, because the food waste in landfills breakdowns and releases methane (CH_4), a much more potent greenhouse gas (GHG) than carbon dioxide (CO_2). Currently, landfills have become the third largest source of CH_4 emissions in the United States and have accounted for 18% of the total methane emissions there (US EPA, 2015).

Many researchers have proposed diverting food waste from landfills as a solution to reduce CH_4 emissions in the United States. Amongst all of the diverting technologies, composting is the method recommended the most, because it is able to reduce waste disposal in landfills, while simultaneously recycling organic materials by converting them into a beneficial product. In the composting process, organics decompose and stabilize in an aerobic condition. The final product, compost, can be used as a soil amendment that improves soil texture and fertility and thus reduces the use of synthetic fertilizers applied to the soil (US EPA, 2009). In addition to the usage of compost as a fertilizer, applying compost to the soil may increase the carbon storage capacity within the soil, which reduces GHG emissions into the atmosphere (Saer et al., 2013). Composting is also superior to other food waste recycling

Abbreviations: AASLAB, Agricultural Analytical Services Laboratory; CFC, chlorofluorocarbon; EPA, environmental protection agency; EU, eutrophication; FM, fresh matter; GHG, greenhouse gas; GWP, global warming potential; ISO, International Standard Organization; KU, Kean University; LCA, life cycle assessment; LCI, life cycle inventory; LCIA, life cycle impact analysis; PM, particulate matter.

* Corresponding author.
E-mail address: dmu@kean.edu (D. Mu).

http://dx.doi.org/10.1016/j.wasman.2016.10.026
0956-053X/Published by Elsevier Ltd.

technologies, such as anaerobic digestion and incineration, because it is easier to start and manage (US EPA, 2009), has better economic performance at a small scale (Murphy and Power, 2006), produces safer by-products, and releases less GHG emissions (Andersen et al., 2011).

Despite many benefits, the application of food waste composting remains low, i.e., only 8.3% of 36 million tons of food waste generated were recycled in 2011 (US EPA, 2014b). The concentrated food waste composting is even rare in the U.S. and is faced with many challenges, including (1) the food waste is created every day and easy to become putrid, which increases household's and waste management companies' workload on food wastes collection and sorting; (2) composting facilities find it difficult to discover end users to utilize the compost, and thus cannot make revenue by selling it to offset operating costs (Murphy and Power, 2006); (3) some composting technologies, such as Windrow, operate in open air, with feedstocks and operating conditions varying greatly in seasons and weather as a result the product quality is difficult to control; (4) the exhaust with its unpleasant odor can arouse objection in local communities.

In order to promote food waste recycling, Kean University (KU) initiated a composting project by establishing a composter at its Union campus (shown in Fig. 1). The composting project addressed current challenges in composting by making several significant improvements in the composting system design.

Firstly, instead of utilizing the popular windrow or tunneled composter, Kean University established an in-vessel composter where food waste decomposes in a rotary vessel with steel. As a result, the KU composter uses much less land and can accommodate a wide variety of organic wastes (US EPA, 2016). This in-vessel composter also allows a relatively flexible residence time, ranging from a few days to weeks, and well-controlled operating conditions (Cabaraban et al., 2008) even in extremely cold weather.

Secondly, the composter has the capacity to treat 1000 lbs of food scraps per day. The high treating capacity is larger than many existing in-vessel composters at other Universities. The expectation is that this large-scale application will treat more food scraps, and thus lower down operation costs per unit input and obtain more disposal cost offsets.

Lastly, an end user utilizes the compost product. The end user at KU is a 6-acre plant farm that provides vegetables and herbs to the student dining halls and a farm-to-table restaurant at KU. The farm, dining hall, restaurant, and composter, form a closed-loop life cycle in food production, consumption, and waste treatment, since no food waste is disposed of in landfills.

The KU composter also serves as an education center. Many students have visited the facility as part of a teaching lesson, or during the college's Open Day held once a year to welcome incoming freshmen. The university uses the composting project to demonstrate efforts in greening the university for both the students and the public. The composting system also provides internship/part-time job opportunities to students. Students are hired part-time to work in the composter and grow produce at the KU's Liberty Hall Farm during the growing season. This enables the students to collect real life experience in the field of sustainable technology and allows them to practice sills in facility operating.

Although many benefits have been identified for KU's composter, an analysis on environmental and economic performance has not been conducted so far. In particular, the benefits created from setting up a closed loop in food waste treatment had not been previously evaluated. The current knowledge gaps were mainly in three areas. First, the emissions from the in-vessel composting had not been tested; therefore, the full inventory of emissions could not be established. Second, analyses of the vegetable garden's yields have not been conducted, and thus incomes by applying compost could not be estimated. Third, there were indirect social and environmental benefits due to the food waste reduction on campus and diversion of organics from landfills, which were difficult to estimate.

This study aimed at filling in the knowledge gap for KU's composting system, and focused on conducting life cycle assessment and cost-benefits analysis to evaluate environmental and economic impacts. In order to determine the vegetable yields when compost is used, researchers conducted a vegetable growing

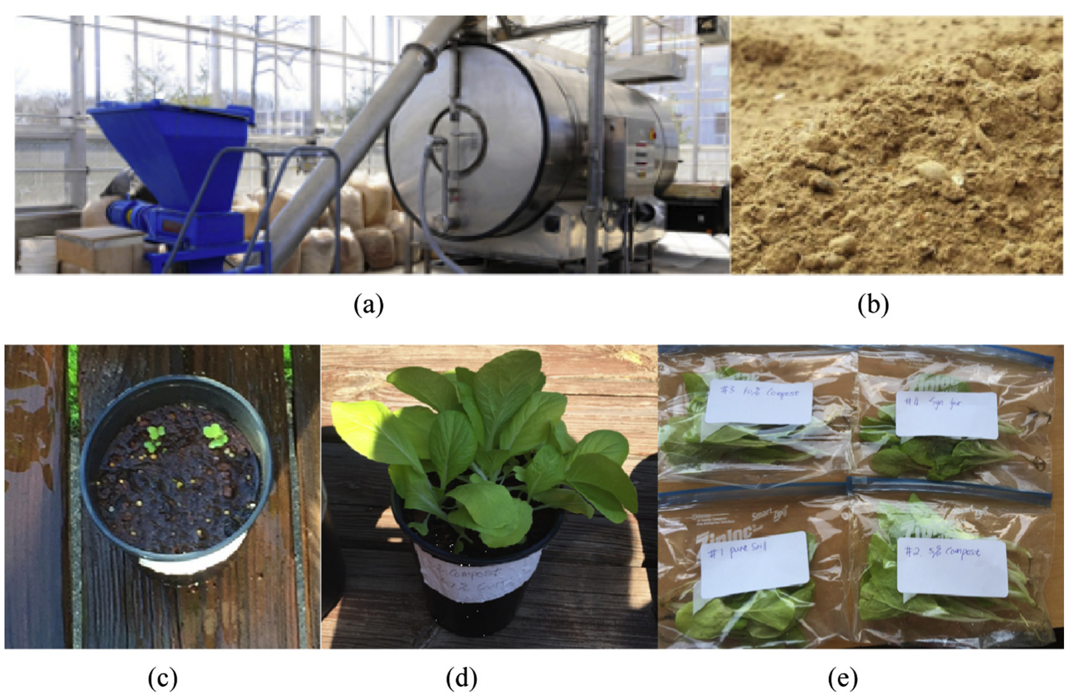

Fig. 1. KU composter and vegetable growing in soil with compost. (a) KU in-vessel composter. (b) Compost produced. (c) Sprouted seeds. (d) Harvest vegetables (30 days). (e) Vegetable samples sent to AASLAB.