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Short communication

Design and application of a pre-composting test step to determine the effect of high fat food wastes on an industrial scale in-vessel composting system

Ashoke David Maliki [1], Ka-Man Lai*

Healthy Infrastructure Research Centre, Department of Civil, Environmental and Geomatic Engineering, University College London, London WC1E 6BT, United Kingdom

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ABSTRACT

The high fat content in food wastes was suspected to inhibit an industrial in-vessel composting process from reaching the European Union Animal By-Product Regulation (composting temperature >70 °C for 1 h). The aim of this study was to design a test step to guide the mixing ratio of food waste to green waste to meet the regulation. A 15-compartment composting unit was designed to contain the compost mixes. Sausage and cheese wastes were mixed with green waste at 1:1; 1:2; 1:3 and 1:4 ratios by wet weight volume. Only the sausage waste mix ratio of 1:4 gave an average temperature of 70 °C for at least 1 h after 2 days of composting (fat content – 17%; C: N ratio – 8.6). All the cheese waste mixes did not reach 70 °C after 15 days of composting. This study demonstrated that using a simple pre-composting test step could reduce the chances of process failure during industrial composting. Although both sausage and cheese wastes are high in fat, they performed very differently in the composting process. Two linear equations were fitted to model the impact of these wastes on the maximum composting temperature.

1. Introduction

Large quantities of biodegradable municipal solid waste are generated everyday by households, consumers, industries and commerce (DEFRA, 2004; Sykes et al., 2007). In the UK, household waste produced per person increased by 15% between 1995/1996 and 2004/2005. According to the UK Composting Association report on composting activities, it was estimated that approximately 1 million tonnes of biodegradable waste materials are composted each year (The Composting Association, 2001). Waste composted in the UK has increased to 22% in 2004/2005 from 6% recorded in 1995/1996 (The Composting Association, 2006). It is foreseeable that composting will take an even more significant part in waste treatment in the future in order for the local councils and government to meet the European Union Landfill directive (European Union, 1999). Composting is the natural breakdown of organic materials under aerobic conditions to carbon dioxide and water, and generates heat. This heat creates an environment for thermophilic degradation of the waste, which speeds up the degradation process and stabilises the organic products and destroys plant and human pathogens and weed seeds. The optimal composting temperature is generally between 45 and 65 °C. Temperature, C:N ratio, oxygen and moisture content of the mixture are the commonly known factors which play a vital role in determining the success of composting (Pace et al., 1995). According to the European Union standards, for composting wastes of animal origins and wastes from catering premises, the composting industry has to follow the Animal By-Product Regulation 2005 (ABPR), in that composting temperature must reach 70 °C for at least 1 h with a maximum particle size of 12 mm (Office of Public Sector Information, 2005).

To meet the huge demand and quality requirements of composting, varieties of composting systems are in existence. In the UK, the open air windrow systems are main composting system and account for about 90% of the total composting carried out. In mainland Europe, large scale in-vessel and mechanical biological treatment plants are more popular because these indoor plants have the capability to maintain temperature and moisture during the composting process and can reduce odour and aerosol emission to the atmosphere (The Composting Association, 2006; Sykes et al., 2007). A large industrial vertical, continuous flow, in-vessel composting system called the Teg Silo Cage (TSC) is in operation in the UK by TEG Environmental Ltd. The TSC is a self-regulated (no mechanical aeration) system which retains heat at a high level and requires relatively less labour, land and operational support. Moreover, because of the

* Corresponding author. Tel.: +44 0 207 679 1368.
E-mail address: k.lai@ucl.ac.uk (K.-M. Lai).
[1] Current address: Federal Ministry of Works, Housing and Urban Development, Road Sector Development Team, No. 6 Niagara Close, Off Erie Crescent, Off Nile Street, Maitama, Abuja, Nigeria.

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in-vessel design, odour and other environmental nuisances can be controlled more effectively. This TSC system has been running since the facility was in operation and proved to be effective in treating various wastes following the ABPR. With the ever expanding opportunity for composting, a large quantity of industrial food wastes with high fat content was introduced to the waste stream. These high fat food wastes showed an inhibition of the composting temperature and thus re-composting was sometimes needed to meet the ABPR. Re-composting reduces the capacity for composting and increases the time and cost. As a result, it is the aim of this study to develop a simple experimental mock up of the composting system, and to identify and formulate the parameters which can help guide the mixing ratio of these high fat food wastes to green waste to meet the regulation.

2. Materials and methods

2.1. Composting materials

Sausage and cheese wastes came from two local food factories. The cheese waste was the main part of the pizza waste stream. This waste stream also contained half-baked dough bases and toppings including tomato, grated cheese, pepperoni and ham. The shredded green waste was collected from local councils. A representative sample of sausage, cheese and green wastes was taken and analysed by NationWide Laboratories, Lancashire, UK (Table 1). Total fat, total ash, dry matter, water extractable ammonium-N, dry organic matter, total nitrogen, organic carbon and nitrate-N were measured using acid hydrolysis, heating at 550 °C for 16 h, oven drying, Aqua 800, oven dry, Kjeldahl, potassium dichromate method and Aqua 800, respectively. Sausage and cheese wastes contained a significantly higher level of fats compared to the green waste. Moreover, these food wastes also contained a higher level of organic matter and total nitrogen. The C:N ratio of sausage, cheese and green wastes were 11, 4 and 8, respectively.

2.2. Composting mixtures and mock up of the in-vessel composting system

Food wastes and shredded green waste were mixed at 1:1; 1:2; 1:3; and 1:4 ratios by volume (wet weight) and shredded to reach the maximum 12 mm particle size limit. The bulk density of sausage, cheese and green wastes in the container (9.8 L) was in average about 0.87, 1.00 and 0.46 kg L^{-1}, respectively. Controls of only shredded green waste were also prepared. Each mix ratio experiment was carried out in triplicate; bringing the total experimental compost mixtures to 15. The calculated fat content, C:N ratio and bulk density of each mix ratio are showed in Table 2. The fat content in the food waste mixes increased significantly compared to the green waste controls, from 11 to 23 times higher in food waste mixes. The C:N ratio of sausage mixes were the highest compared to other mixes (up to 19% higher than the green waste controls), while cheese waste mixes had the lowest C:N ratio (up to 24% lower than the controls). With respect to the bulk density, both waste mixes had a higher bulk density than the controls, up to 59% and 46% higher than the controls in cheese and sausage mixes, respectively. Samples of the waste mixes and controls were taken for laboratory analysis as for the individual food and green wastes.

Table 2
Calculated fat content, C:N ratio and bulk density at each mix ratio.

Type of wastes	Mix ratio	Fat content (%)	C:N ratio	Bulk density (kg L^{-1})
Sausage	1:1	32	9.5	0.67
	1:2	24	9.0	0.60
	1:3	20	8.8	0.56
	1:4	17	8.6	0.54
Cheese	1:1	31	6.1	0.73
	1:2	24	6.8	0.64
	1:3	19	7.1	0.60
	1:4	16	7.3	0.57
Green waste only	1	1.4	8.0	0.46

The experiments were undertaken in a 15-compartment composting unit. The unit was designed and insulated to ensure similar internal conditions as a typical in-vessel composting system onsite. The unit was made from wooden crate and insulated with kingspan siteline. To further insulate the joints, sealants were used to seal up the joints. Each triplicate of the compost mixes was held in a 60 L weave bag and placed on the top of a bed of shredded green waste inside the composting compartment. This is to ensure that excess moisture due to condensation of heat generated during the composting process is absorbed to prevent possible leaching.

For temperature monitoring, two encased ibuttons (Maxim, UK) were placed in the middle of each triplicate of the waste mixes in the compartments. As a result, 6 temperature readings were obtained from each mix ratio, if all the ibutton worked properly. The ibutton is a computer chip, enclosed in a 16 mm thick stainless steel can. It was set to record temperature hourly. A handheld temperature probe was used to monitor the progress of the composting process daily. When the temperature reading from the handheld probe went back to below 30 °C, the ibuttons were removed from the compost and the experiment ended. The data from the ibuttons were downloaded to a computer via the one-wire viewer computer software application from the manufacturer (Maxim, UK). The weight reduction of the compost was also measured by comparing the final weight to the initial weight.

2.3. Data analysis

The temperature data recorded by the ibuttons were plotted over time and the pattern of the temperature profile was compared. In order to compare each mix, the data from the same food waste and mix ratio were combined to calculate the average and standard deviation of the maximum temperature reached and the time it took to reach that temperature. The correlation between the fat content of the food wastes and the maximum temperature reached during composting was analysed using a liner regression model.

Table 1
Properties of sausage, cheese and green wastes.

Waste types	Total fat g/100 g (w.wt[a])	Oven dry matter % (w.wt)	Total ash g/100 g (d.wt[b])	Organic matter % (w.wt)	Organic carbon %	Total nitrogen (Kjeldahl) % (d.wt)	Ammonium-N mg/kg (w.wt)	Nitrate-N mg kg^{-1} (w.wt)
Sausage	48	35	97	90	52	4.7	1250	2.8
Cheese	44	46	95	59	34	8.0	299	25
Green waste	1.4	44	50	22	13	1.6	808	17

[a] w.wt – wet weight.
[b] d.wt – dried weight.