Enabling decentralized pre-composting of organic household waste with a novel high-rate bioreactor

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Introduction

In urban areas the collection and transport of organic household waste (fruit, vegetables, prepared dishes, meat and dairy waste) poses both economically and ecologically a burden due to its relative high volume and weight. A reduction in the volume of the waste implies a drastic diminution of the amount of trucks and energy needed to transport. As a result, the environmental impact of cities can be lowered and the quality of life can increase. The objective of this research is to develop a so-called "Urban pre-Composter", a compact bioreactor for decentralized treatment of kitchen waste to achieve a maximum volume reduction. The envisaged system is intended to be applied in the city of Antwerp (Flemish city of Belgium with 517.042 person equivalents (PE)) at collection points with serving capacity of 750 kg or the equivalent of the waste of 250 people over two weeks. Provided such system can be economically built, overall costs of composting are expected to be reduced due to the reduction of the need for transportation (traditionally contributing to 75% of the overall composting costs) and the shorter time required for the residual composting. Fig.1 illustrates the overall concept of the project. The key challenges to overcome for realizing the objective of volume and mass reduction are: (i) effective mixing; (ii) good substrate structure (increased porosity); (iii) sufficient aeration and (iv) minimal temperature as well as (v) moisture content fluctuations. A challenge that needs to be overcome on a social level is the elimination of potential odors so as to increase social acceptance.

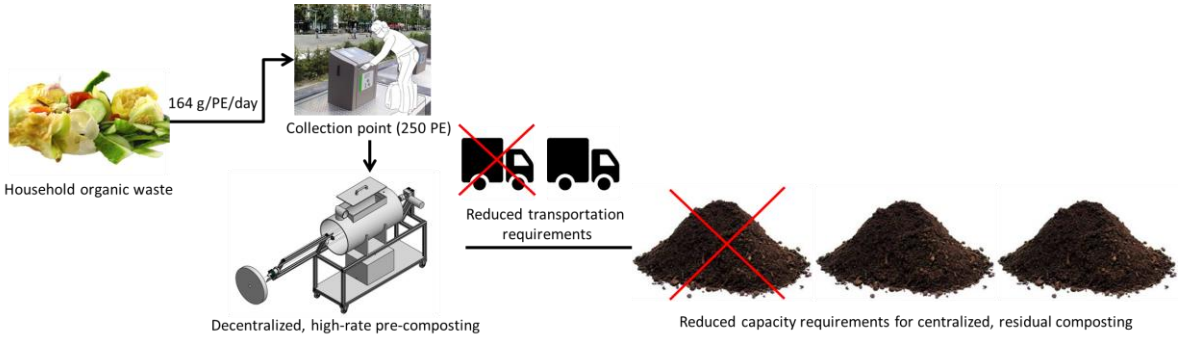

Fig. 1: Overall Urban pre-Composter concept (PE: person equivalent)

Methodology

The research consists of three phases. The first part concerns batch experiments to evaluate the potentials of the process. The second part focuses on the reactor design and the third on the reactor operation.

I. Two batch experiments were performed, representing the best (i) and worst (ii) case scenarios in terms of waste composition and experimental conditions. In the best case scenario, structure material in the form of straw and woodchips is added and composted at an initial temperature of 34°C. The worst case scenario represents the case where solely kitchen waste is used as substrate at 20°C. These preliminary results provided data concerning the process requirements and were further used for the optimization of the reactor design.

II. A prototype bioreactor of 200L (equivalent for serving 44 PE; 17.6% size of envisaged installation), was conceived, designed and constructed. The design of the drum composter focuses on tackling the typical problems of the composting process, such as the inhomogeneity of the substrate and operating conditions (e.g. temperature, moisture content) and the significant temperature fluctuations that cause variations in microbial activity. In addition, it is aimed to tackle problems derived from the composting of kitchen waste, such as leachate generation. The design addresses these problems through the use of: internal blades that are

enabling the agitation of the substrate, which therefore provide efficient mixing and hence reduce the need for structure material; air pumps that provide sufficient oxygen supply; innovative ways are followed to regulate moisture content.

III. The reactor will be operated in a fed-batch mode as this feeding regime represents the actual waste disposal behavior of the citizens. Furthermore, a part of the substrate will remain serving as inoculum for the next cycle, with each cycle lasting two weeks. The experiments aim at the optimization of the efficiency and rate of the process and will be performed using a formulated medium based on the average composition of waste disposed in the city of Antwerp. The tests will be performed under thermophilic temperatures to result in a higher decomposition rate. The reactor performance and compost quality will be monitored through a combination of online and offline measurements.

Results

A research within the Flemish Region revealed the following average composition of waste disposed in the collection points (in %w/w): bread (15%); vegetables (35%); fruit (35%); prepared dishes (6%); meat, fish and poultry (4%); dairy products (yogurt) (4%); sauces, herbs and spices (1%). Table 1 illustrates the characteristics of the organic waste, with the key feature being the notably high moisture content.

Table 1: Characteristics of the formulated waste medium. Percentages are presented in %w/w of total waste.

Parameter	Content	Disposal per collection point (250 PE)
Volatile Solids	29.8 ± 0.3 %	48.9 gVS/PE/d
Fixed Solids	1.08 ± 0.52 %	1.77 gFS/PE/d
Moisture content	69.1 ± 0.2 %	113 gH_2O/PE/d
Bulk density	17.2 ± 2.0 g/cm^3	-

As illustrated in Table 2, the best case scenario (i) showed a potential of 63.4% volume reduction and 35.5% mass reduction whilst the worst case scenario (ii) resulted in a volume reduction of 50.0% and a mass reduction of 16.0% after two weeks of experimental time. It should be noted that in both experiments no inoculation was performed, representing thus a low rate process since adapted microbes were not provided. The low value of maximum temperature during scenario (ii) indicates that the conditions were not favorable for the activation of the composting process, mainly attributed to the lack of porosity and the low initial temperature. On the other hand, the structure material used in scenario (i) increased the porosity of the substrate. Hence, air was more efficiently distributed resulting in higher decomposition. In addition, the experiments revealed the challenges derived from the composition of kitchen waste. More specifically, it was observed that scenario (i) resulted in percolate of 1.6L while in scenario (ii) the leachate generation was 4.1L. This leachate comprises an acidic wastewater with high organic load, which in conventional applications, has to separately be treated.

Table 2: Results obtained during preliminary batch experiments in a static pile

Scenario	Substrate composition*	Initial temperature (°C)	Aeration rate (L/kg_{waste}/min)	Pile turning	Volume reduction (%)	Mass reduction (%)	Max temperature (°C)	Leachate generation (L)
(i) Best case	60% FKW; 40% SWC	34	0.8	daily	63.4	35.5	50.2	1.6
(ii) Worse case	100% FKW	20	0.8	no	50.0	16.0	33.0	4.1

*FKW: formulated kitchen waste; SWC: straw and wood chips

The paper to be presented at the conference will detail the results of the prototype operation in terms of mass and volume reduction and end-products' quality. Preliminary batch results show that volume and mass reductions of 63% and 36%, respectively, should be achievable, whilst the first experiments performed using the prototype bioreactor resulted in ~60% volume and ~40% organic matter reduction. The novel reactor design aids in overcoming the bottleneck of the biomass oxygenation capacity and, after process optimization, can result in a further acceleration of the process.

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