In-Vessel Composting Of Food Waste – A Catering Waste Management Solution

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ABSTRACT

An economically viable system for converting catering food waste into a high quality compost has been developed. The scientific and technical requirements for composting, with food waste as the main feedstock, and fully compliant with EU regulations, to give a marketable product is described. Chemical and physical analyses of catering food waste show that it does not have the correct composition or consistent particle size for direct use as a composting feedstock. For food waste specifically there is also a requirement to achieve high temperatures in the composting process for long enough to destroy any pathogens present. The conversion of food waste to a high grade compost has been achieved in this work by a combination of macerating and dewatering to homogenize the feedstock and reduce the water content, with the addition of a carbon-rich bulking agent to achieve the correct C:N ratio and absorb any excess of water in a closed in-vessel composter. The composting process in a catering establishment trial was completed after 34 weeks without external heating giving a product that had been treated at sufficiently high temperatures to ensure pathogenic depletion to give a high quality product measured against BSI PAS 100 standards.

KEY WORDS

In-vessel composting, catering waste, food waste

1. INTRODUCTION

Biological treatment, under both aerobic and anaerobic conditions, is seen as a means of diverting biodegradable waste from landfill. In the European Union, for example, the Landfill Directive 1999 (European Parliament, 1999) sets targets for the reduction in disposal of biodegradable wastes to landfill and the Animal By-products Regulations 2002 (European Parliament, 2002) prevent the use of any food waste containing meat in animal feedstuffs. The Landfill Directive in particular seeks to limit the disposal of biodegradable waste to landfill and sets targets to achieve a reduction from 1995 levels to 75% of the 1995 level by 2006, 50% of the 1995 level by 2009 and 35% of the 1995 level by 2016.

Food waste represents a fraction of the biodegradable waste that historically has received less attention although it is the most likely waste stream to contaminate other waste fractions and has been the major contributor to methane production in landfill. Composting and other biological treatment technologies are not new but have not often been applied to the treatment of food waste because of health concerns relating to the spread of diseases and negative public perception (Gray 2006)

It is widely accepted that future treatments of food waste will have to include its segregation at source. Mason (2004) highlighted the importance of waste segregation for effective post-collection treatments and indicated that particle homogenization would probably have to be applied to the wastes prior to the biodegradation process. The success of any biological process using food waste as raw material also depends on the marketability of the product and The British Standard Institution's Publicly Available Specification for Composted Materials (BSI PAS 100) standard, launched in 2003 represents a suitable reference for good quality compost.

The recovery of commercially viable products from catering wastes is

important because it would lead to a major diversion of biodegradable material from final disposal processes such as landfill and incineration. The key issues in the production of compost, however, are related to the quality of the product rather than the content of the main feedstock. The economics of any composting product will therefore depend critically on the methodology used to convert the basic feedstock to a quality end-product.

We now report on the development of a closed-loop in-vessel composting methodology using catering food waste as the basic feedstock leading to a high quality product without the need for bacterial innoculation.

2 MATERIALS AND METHODS

2.1 Characterisation of food waste

Samples of macerated and dewatered food waste from two different catering sources were collected and characterized. Full analyses were carried out on samples from a university catering outlet (15 samples collected over a four month period, with an approximate weight of 20kg per sample before maceration and dewatering) to represent a typical food waste from a catering establishment. Sample analyses from the kitchens at HM Prison Morton Hall, where the composting trials were carried out, included only water content, dry matter content, carbon and nitrogen, mainly for determining the C:N ratio. Analysis of the product compost, from the trials does, however, reflect the nutrient and heavy metal contents of the food waste itself.

Pretreatment for characterisation involved passing the as-received samples through a macerator-dewaterer supplied by Imperial Machine Company Ltd (IMC), Wrexham, Wales) to separate liquids from the solid fractions. The macerator is designed to improve hygiene standards in handling kitchen waste, by treating food waste quickly avoiding odours and cross-contamination with food intended for human consumption. The average water consumption of the macerator is 2-2.7l/kg of food waste. The macerator is connected by a gravity feed to a dewaterer where the ground waste enters a system comprising a screening metal with orifices of 3mm diameter and a helicoidal bar which pushes the solid fraction through the orifices.

Water and dry matter contents were obtained by heating weighed samples at 105°C for 24 hours and determining weight loss.

Ash and volatile matter contents were obtained following the American Standard 2540E: Fixed and Volatile Solids ignited at 550°C method (APHA, 2006) by treating the dry matter at 550°C for 2 hours.

Carbon, nitrogen and phosphorus contents were analysed by NRM Laboratories Ltd using standard organic micro-analytical procedures on dried samples ground to pass a 1mm screen.

Nutrient and heavy metal element analyses were carried out on a digestate prepared following The British Standard ISO 11466:1995 method (BSI, 1995). The elemental contents of the digestate were determined by Inductively Coupled Plasma Emission Spectroscopy (ICP-ES) and Atomic Absorption Spectroscopy using a Perkin Elmer 2380 spectrometer.

The analytical data for the food waste samples are in Table 1.

2.2 Composting field trial at HMP Morton Hall

The composting trials were carried out at Her Majesty's Prison Morton Hall Swinderby, Lincoln, as an example of many institutions with similar food waste treatment problems including hospitals, care homes, schools, universities, motorway service areas, military bases, hotels, airports, medium and large corporate canteens, etc. The Morton Hall Facility serves 710 meals a day, and produces 1 tonne of food waste per week. The system used is shown schematically in Figure 1.

An in-vessel composter (*Big Hanna In-Vessel Composter Model T75*) was used in the trial to treat the dewatered and homogenized feedstock obtained from the catering waste. This composter, (length 2.90m, width 1.08m and height 1.55m), consists of a horizontally orientated rotating cylinder with fixed stationary rear and front ends, and an air circulation

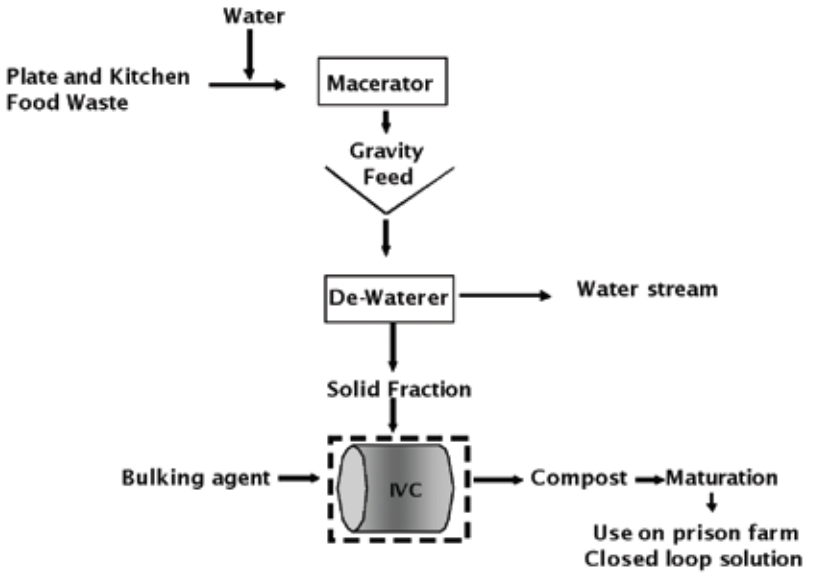

Figure 1: schematic of the in-vessel composting process of food waste

ventilation system. The cylinder with feedstock content is rotated and the material is turned over and ventilated periodically. Processed material is automatically emptied into a product vessel. The number of cylinder rotations, length of waiting time between sets of rotations, length of rotation periods, ventilation intensity, and feedstock level can be varied depending upon the amount and the composition of waste material. The composter can accept a maximum load of 325kg (depending on the filling level set) per week, and has an energy consumption of 1.4MJ per day.

Wood pellets, of length up to 4cm and 8mm diameter, were used as bulking agent in the production of the compost. The wood pellets displayed the following characteristics as specified by the supplier: C~50.1%; N~0.1%; with C:N ratio of ~500:1; dry matter content ~91.5 %; bulk density ~650kg/m^3; ash content <0.7 %.

After a residence time in the in-vessel composter of up to 8 weeks, the output compost was removed and placed in a pile in a greenhouse for maturation. In order to determine the optimum curing time of the compost and to characterise the compost according to BSI PAS100 standards, a new pile of output compost was set up each month, from which samples were taken for analysis.

2.3 Monitoring of composting process

The weights of input food waste and bulking agent and of output, compost, were monitored daily along with temperature, pH, oxygen and methane.

Temperature readings were taken once a day through the length of the composter (at five sampling points).

Methane formation and oxygen content were measured at the start-up stage (first 9 weeks) using a BW Gas Alert Micro Probe, with probe ranges for methane of 0-5% and for oxygen of 0-25%. These measurements were helpful to optimise the operating conditions of the process. After stabilisation of the process, further monitoring was not necessary.

Carbon dioxide and ammonia analyses were carried out on the compost samples using a *Solvita Compost Maturity Test Kit* to determine the rate of biodegradation. In the early stages of the trials, oxygen, methane and pH were monitored to identify any inefficiency of the composting process and to assess ventilation settings. Ammonia has a direct influence on the pH of the composting mix and because high pH inhibits biodegradation, the presence of ammonia in the gases may indicate a low C:N ratio or an excess of moisture. The test consists of gel paddles that change color depending on rates of emissions of carbon dioxide and ammonia, assigning carbon dioxide and ammonia indices. With those values, the sample is given an overall index of maturity. The index ranges from 1 to 8, with 1 and 2 being raw compost and 7 and 8 representing finished compost.

Solid samples from the composting mix were collected at five different points equidistant along the length of the composter and analysed to obtain the C:N ratio and water content. Samples were also collected periodically at the output of the composter to characterise the compost by similar methods to those used to characterise the food waste feedstock and to determine whether any pathogens remain in the final product. Pathogens were determined by methods consistent with the BSI PAS 100 specification for composted materials.

Monthly samples were taken from all maturation piles to assess and determine optimum curing time before the compost could be used.

3. RESULTS

3.1 Food waste characterisation

The results of the analysis of macerated food wastes in Table 1 should be typical of those from any catering establishment. The C:N ratios of the food wastes are too low to sustain aerobic digestion and for this reason a bulking agent must be added to increase the ratio. Any potassium, phosphorus, iron and magnesium contents of the food wastes will be beneficial to the composting process because they are essential nutrient elements. The heavy metal content of the food waste feedstock, which will be carried through to the final product, is low.

3.2 HMP Morton Hall trials

In a 34-week trial of composting of food waste at HMP Morton Hall, 4602kg of macerated and dewatered food waste was treated with 1080kg of bulking agent. Contrary to the composter guidelines, a 4:1 ratio of waste:bulking agent was found to be the optimum to enhance the C:N ratio in the grinder-dewaterer-composter system. The weight of the final compost obtained was 1900kg representing a reduction in mass from waste food to final product of over 60%.

The temperatures recorded daily at five points (A to E along the length of the composter with A near the input point and E near the output point) are shown in Figure 2.

The maturation of the output compost was followed on the basis of carbon dioxide and ammonia emissions that measure the continued effects of biological activity in the compost. The results showed that, after the 6-8 weeks in the in-vessel process, full maturation of the compost was achieved within a five month period.

Full analyses of the output compost are compared in Table 2 with the BSI PAS100 standard limits, and the results of pathogen analyses are in Table 3. The final compost falls well within the PAS 100 standard, and in particular, shows good plant germination and growth, lack of weed growth and absence of pathogens.

Constituent	Mean	Standard Deviation
Dry Matter (%)	23.3	2.3
Water (%)	76.7	2.3
Ash (%)	1.7	0.9
Volatile Matter (%)	98.3	0.9
Total Carbon	50.1	1.5
Total Nitrogen	4.4	1.2
Fe (mg kg^{-1} dry matter)	47	12
K (mg kg^{-1} dry matter)	5200	1700
P (mg kg^{-1} dry matter)	9.2	5.4
Mg (mg kg^{-1} dry matter)	620	270
Mn (mg kg^{-1} dry matter)	5.1	1.2
Ni (mg kg^{-1} dry matter)	2.8	1.7
Cd (mg kg^{-1} dry matter)	0.6	0.2
Pb (mg kg^{-1} dry matter)	2.8	1.5
Cr (mg kg^{-1} dry matter)	1.2	0.9
Cu (mg kg^{-1} dry matter)	5.4	1.1
Zn (mg kg^{-1} dry matter)	41	14
C:N Ratio	12:1	1

Table 1: analysis of typical food wastes

4. DISCUSSION OF RESULTS

The ideal feedstock composition for the manufacture of a high quality compost is (a) a C:N ratio of 25-30:1, which is required for optimum growth of the bacteria involved in the biochemical reactions involved and (b) a water content of about 60%. Catering food waste is not, in itself, a suitable feedstock for in-vessel composting partly because it is a heterogeneous mixture with a wide range of particle sizes but also because the C:N ratio in the waste at about 11:1 is far below the ideal ratio of 25-30:1 and the water content at 77% is also higher than the optimum. For food waste specifically there is also a requirement to achieve high temperatures in the composting process for long enough to destroy any pathogens present.

The conversion of food waste to a high grade compost has, however, been achieved in this work by a combination of grinding and dewatering to homogenize the feedstock and reduce the water content with the addition of a carbon-rich bulking agent to achieve the correct C:N ratio and absorb any excess of water in a closed in-vessel composter. The composting process was operated over a period of 34 weeks without external heating because the microbiological activity in the biodegradation generated sufficient heat to maintain the process. The temperatures in the composter took four weeks to breach the 60°C barrier, the maximum temperature achieved was over 70°C, and after the tenth week the average-temperature trend stabilised to permit the production of a consistent product. Temperature measurements along the length of the composter (Figure 2) show that the temperature exceeds the requirements for pathogen destruction maintaining 60°C for a period of two days. The composting trial was completed after 34 weeks giving a consistent product throughout, that had been treated at sufficiently high temperatures to ensure pathogenic depletion.

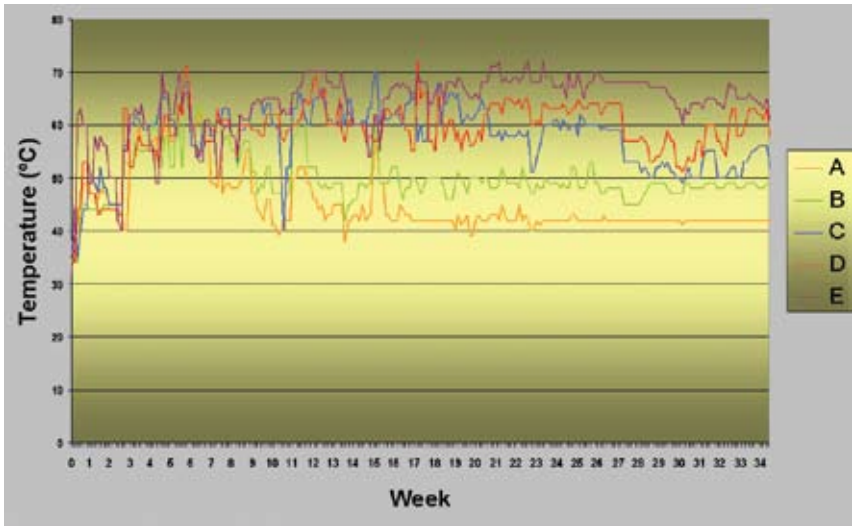

Figure 2: temperature profile recorded in the in-vessel composter during the 34-week-long trial

The analytical data for the resulting matured compost (Tables 2 and 3) show that the compost meets the highest quality standard set in the BSI PAS 100 (2005) standard. The pathogenic analysis in particular show consistency in the depletion of *E.coli* and *salmonella* as required by the standard and the heavy metal contents of the compost are significantly lower than the threshold limits specified in the standard.

The economic benefits of the in-vessel composting process arise from savings in (i) landfill costs (ii) zero food waste collection costs (iii) administration costs of food waste disposal (iv) the need to purchase compost for on-site horticultural operations and (v) vermin control charges. An economic evaluation of the composting system at HMP Morton Hall identified savings on previous practices of £12000 per annum

5 CONCLUSION

Diversion of food waste from landfill to composting would help to meet Government targets to reduce the amount of biodegradable waste sent to landfill as required by the

Constituent	Mean	BSI PAS 100 limit
Dry Matter (%)	59	2.3
Water (%)	41	2.3
Total Carbon	50.6	1.5
Total Nitrogen	1.51	1.2
Fe (mg kg^{-1} dry matter)	284	
K (mg kg^{-1} dry matter)	5780	1700
P (mg kg^{-1} dry matter)	2107	5.4
Mg (mg kg^{-1} dry matter)	592	270
Ca (mg kg^{-1} dry matter)	4705	1.2
Na (mg kg^{-1} dry matter)	5860	
Ni (mg kg^{-1} dry matter)	0.9	50
Cd (mg kg^{-1} dry matter)	0.1	1.5
Pb (mg kg^{-1} dry matter)	1.5	200
Cr (mg kg^{-1} dry matter)	0.32	100
Cu (mg kg^{-1} dry matter)	6.0	200
Zn (mg kg^{-1} dry matter)	139	400
Hg (mg kg^{-1} dry matter)	<0.05	1
C:N Ratio	33:1	1
CO_2 stability (mg g^{-1}) (Organic Matter per day)	5.3	16
Weeds growing (number)	0	0
Glass, metal and plastic contamination (% of air-dried sample<2mm)	0	0.5
Stones in mulch (% of air dried sample <4mm)	0	16
Stones in other than mulch (% of air dried sample)	0	8
Test plants germinated (% of control)	93.3	80
Test plant top growth (g as a % of control)	142.8	80

Table 2: full analysis of compost compared with BSI PAS 100 standard limits

Landfill Directive 1999 and would contribute to an effective reduction in greenhouse gas emissions. The composition of a typical food waste and particularly the C:N ratio and water content is not ideal for production of a high quality compost but the system described in this work shows how these problems can be overcome and with an appropriate temperature regime leads to a high quality compost. The composting process fulfils all of the operational requirements imposed by the Animal By-Products Regulations 2005, which ensures that the product compost does not pose any health risk, and the quality of the compost obtained conforms with the Standards for Composted Materials BSI:PAS100, which guarantees the marketability of the product.

The composting process developed in this study is readily transferable to all institutions and commercial operations with similar catering facilities and to source separated municipal wastes.

Pathogen	Measurement	BSI PAS 100 Limit
Salmonella	Negative	Absent in 25 g
E Coli (cfu g^{-1})	<10	1000

Table 3: pathogen analyses compared with BSI PAS100 Standard Limits

ACKNOWLEDGEMENT

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